Cognitive Structures of Kinesthetic Space
Reevaluating Rudolf Laban's Choreutics
In the Context of Spatial Cognition and Motor Control

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Volume One
Text

Contents

Volume One

Contents

Volume Two

List of Figures

Volume One

List of Tables

Volume One

List of Figures

Volume Two

List of Tables

Volume Two

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Declaration

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Abstract

The choreutic conception of the spatial aspect of body movements (originated by Rudolf Laban) was reevaluated according to cognitive and motor control research.

"Kinesthetic spatial cognition" (analogous to visual spatial cognition) was identified as the psychological realm of choreutic knowledge. Kinesthesia was identified as arising from sensory receptors throughout the body. Kinesthetic space was defined as spatial information derived from kinesthesia. Kinesthetic spatial cognition was defined as cognitive processes (eg. mental rehearsal) involving kinesthetic spatial knowledge. This concept of kinesthetic spatial cognition has not been heretofore explicitly developed in cognitive science.

Elements of the choreutic conception were psychologically validated since they are also well identified in cognitive and motor research. These include how spatial information is defined relative to a reference system; kinesthetic spatial knowledge is based on a mental code of elemental locations; higher-order networks of locations are collected into map-like spatial images; and many symmetrical operations can be performed. Close similarities were identified between choreutic polyhedral-shaped cognitive maps of the "kinesphere" and the "trajectory formation" model.

A choreutic prototype/deflection hypothesis posits that dimensions and diagonals serve as conceptual prototypes while actual body movement consists of deflections. Similar spatial prototypes were identified in visual spatial cognition, a kinesiological analysis supported the bodily tendency towards deflections, and this concurred with ergonomic measurements of the shape of the workspace. An experiment attempted to identify prototypes in kinesthetic spatial cognition.

Categories of kinesthetic spatial information are distinguished within choreutics and dance. These were reevaluated according to perceptual processes and kinesiology. Choreutic topological forms deflecting across various kinespheric nets are analogous to N. Bernstein's conception of the "co-ordinational net of the motor field . . . as oscillating like a cobweb in the wind". An experiment demonstrated that kinesthetic spatial information is organised into cognitive categories and that choreutic material and Labanotation symbols can be advantageously used in experimental research.

Key to Labanotation Direction Symbols

The Labanotation* direction symbols are used within this thesis. They refer to spatial directions as listed here. For further details see Hutchinson (1970), Hutchinson-Guest (1983), Knust (1979a; 1979b), Laban (1975b), and Preston-Dunlop (1969). The direction symbols are also discussed in Section IVA of this thesis.

- Centre
- Vertically upwards
- Vertically downwards
- Laterally leftwards
- Laterally rightwards
- Sagittally forwards
- Sagittally backwards

- Up-right-forwards
- Down-left-backwards
- Up-left-forwards
- Down-right-backwards
- Up-left-backwards
- Down-right-forwards
- Up-right-backwards
- Down-left-forwards

- Up-rightwards
- Down-leftwards
- Up-leftwards
- Down-rightwards
- Up-forwards
- Down-backwards
- Up-backwards
- Down-forwards
- Right-forwards
- Left-backwards
- Left-forwards
- Right-backwards

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* Laban originally named this system of movement notation "kinetography" (Knust, 1948a, p. 28), literally "movement-writing". Other systems of dance/movement notation or kinetography have also been developed (for a review see Hutchinson-Guest, 1989). In order to distinguish Laban's system it has been referred to as "Laban Kinetography" (Knust, 1948a, 1948b), "kinetography Laban" (Preston-Dunlop, 1969), "Laban Notation" (Laban, 1948, p. 6), or as either "kinetography Laban" or "Labanotation" (Hutchinson, 1970; Knust, 1979a; 1979b). There are some differences between European Kinetography-Laban and American Labanotation, but these are not critical to this thesis. The term "Labanotation" is used here to refer generally to the overall system of body-movement-notation originated by R. Laban and of which the direction symbols are still at the core.

I. INTRODUCTION

I.10 Brief Historical Review of the Work of Rudolf Laban

Rudolf Laban (1879-1958) was referred to in 1923 as "the greatest *Tanzformer* of the age" (ie. a dance law-giver and dance creator) and was considered by many to be "the supreme theoretician and organizer of the new dance world" which thrived in Europe from around 1900 until the second world war (Green, 1986, p. 108). In 1930 Laban had rose to the height of his career with an appointment as Director of Dance and Movement at Prussian State Theatres in Berlin. However, this ended in 1936 when his dance events in celebration of the Berlin Olympic Games, along with his books, movement notation, and name, were forbidden by the Nazis. Soon after, Laban moved to England where he began his work anew. Laban's life, especially during the German Weimar Republic and the Third Reich, has been reviewed by many authors (Green, 1986; Hodgson and Preston-Dunlop, 1990; Koegler, 1974; Preston-Dunlop, 1988) and his own reminiscences of early days dancing in Europe have also been published (Laban, 1975a).

Laban and his Students and Colleagues developed a mass of theoretical and practical knowledge about dance and movement. These theories and methods have been promoted over the years by the Laban Art of Movement Guild* and the Laban Centre for Movement and Dance# in the United Kingdom, the Laban / Bartenieff Institute of Movement Studies,§ and Motus Humanus† in the United States, and by the recently established European Association for Laban/Bartenieff Movement Studies (EuroLab)◊ in Europe. An overview of the development of Laban's work has also been presented by Maletic (1987).

I.20 The Need for a Reevaluation of Choreutics

I.21 Components of Laban's Study of Movement.

One of the principal components of Laban's theories of movement is a unique system for conceptualising and performing spatial forms created by bodily

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movements and positions. This system has become known as "choreutics" (Laban, 1966) or "space harmony" (Dell, 1972) and can be defined as "the study of harmonic spatial forms and the manner in which they materialise in movement" (Preston-Dunlop, 1984, p. viii).

Laban also devised system of movement notation, known as Labanotation or kinetography Laban, which has been well developed (Hutchinson, 1970; Hutchinson-Guest, 1983; Knust, 1979a, b; Laban, 1975b; Preston-Dunlop, 1969) and has been used for the notation of a vast number of dance works (many cataloged by the Laban Centre; London, and the Dance Notation Bureau, New York City). Another component of Laban's work focuses on bodily dynamics or "effort". This has also been well developed and applied in a variety of applications such as work efficiency in industry (Laban and Lawrence, 1947) the assessment of personality (North, 1972), decision-making style (Lamb, 1965; Lamb and Turner, 1969; Lamb and Watson, 1979; Moore, 1982), theatrical movement (Laban, 1980), and in social and cultural studies (Bartenieff and Lewis, 1980; Lomax et al., 1968). This is just a bare listing of the most prominent works and is no way representative of the vast amount of work done with Labanotation and effort theory (for a review see Maletic, 1987).

I.22 Choreutics as Underdeveloped.

Compared to the development and application of Labanotation and effort theory, choreutics has remained largely under-developed. In many cases the spatial forms identified by Laban are simply listed with brief instructions on their bodily performance (Dell, 1972; Preston-Dunlop, 1984) or presented as abstract spatial models without any explicit connection to human body movement (Laban, 1984). Occasionally the basic choreutic forms such as planes, diagonals, and figure-8s, or more complex choreutic forms, have been applied to dance technique by Bodmer (1979) and Loman (1987) and to ballet choreography by W. Forsythe (Sulcas, 1995) and to aerobics (eg. "kinespherics") by K. Lindahl (Brody, 1995). While some of the spatial forms identified in choreutics are used in these applications the underlying basis for the choreutic system, sometimes referred to as "choreutic laws" (Laban, 1966, p. 26) or the "binding laws of harmony" (Ullmann, 1971, p. 1) have not been systematically delineated or critically analysed. Therefore, the underlying validity of choreutics as a theory for comprehending the spatial aspect of human body movement has remained unevaluated. This is a gap in the current knowledge which this thesis addresses.

Part of the reason for this lack of a critical reevaluation of choreutics may be because it is lodged in a forever unanalyzable metaphysics. Choreutic writings typically contain a blending of scientific human movement study together with philosophical outlooks about the significance of human movement in human society and the universe. The use of crystalline (polyhedral) forms also promotes these metaphysical associations. This blending of the scientific and the magical began with Laban's own writings which may be expressively inspiring but their discussion is often obscure. Green (1986, p. 108) recounts how "There was a general agreement, even among his admirers, that he could not explain himself clearly". Indeed, the analyses of human movements in Choreutics are continually mixed with metaphysical musings (Laban, 1966, pp. 54, 91, 100, 114, 124).

This state of affairs can lead many students to regard choreutics with a sort of philosophical awe and consider it to be a historical oddity better suited for mystic or geometric study rather than being readily applicable to the practice of bodily movement (personal observation). Indeed, choreutics has been ridiculed on philosophical grounds (Langer, 1953, p. 186) while overlooking any serious scientific consideration of its relevance to kinesiology and the voluntary and reflexive control of human movement.

Nevertheless, it appears that it may be possible to critically reevaluate the basis for the choreutic conception of bodily movement "harmony" since considerable groundwork has been laid by a few previous researchers. Preston-Dunlop (1978) has asserted the irrelevance of cosmological theories to choreutics, separated choreutics from any stylistic convention, organised an abbreviation system for choreutic forms and identified their spontaneous occurrence in dance works. Preston-Dunlop (1981) continued this work by devising and applying a "choreutic-unit", "manner-of-materialization" analysis which distinguishes between different manners through which a choreutic form can be embodied (viz. spatial progression, body design, spatial tension, spatial projection). Preston-Dunlop (1984) then provided simple instructions on embodiment together with the largest listing of choreutic forms yet presented. Research by this author (Longstaff, 1986; 1987; 1989) has used geometric polyhedral analyses to comprehend symmetric transformations of choreutic forms which occur in dance and has identified certain underlying and consistent theories present in the array of choreutic writings by Laban and his Students/Colleagues. However, these foundations of choreutic knowledge are still dispersed and not concisely stated.

In order to obtain an objective understanding of choreutics the theories stated by Laban and his Students/Colleagues need to be systematically delineated, and these need to be reevaluated according to current scientific knowledge about human movement. This reevaluation is undertaken in this thesis.

I.30 Summary of the Research

I.31 The Realm of Choreutic Study.

An initial step in this research was to determine what fields of scientific knowledge consider the same subject matter as is addressed by choreutics. These other fields would then be used as a context in which to reevaluate the validity of the choreutic conception.

As mentioned above, the metaphysics of numerology, sacred forms, divine proportions and the seven components of colour, music, and organic growth have an intimate association with choreutics. These likely developed out of Laban's involvement with Rosicrucian Freemasonry during the early development of choreutics (Green, 1986, pp. 104-107). Many of these are embodied in the polyhedra used to conceptualise the space around the body and in the sequences of movements delineated within the polyhedra. Studies of Astrology have also been linked to the spatial organisation of choreutics (Auerbach, 1951). These cosmological theories can be a fascinating part of choreutic study, however Preston-Dunlop (1978) has asserted that they are not necessary for, and may even distract from, a purely practical study of the choreutic forms.

Choreutics can also be beneficially applied to many specialised fields such as dance education, the performing arts, movement therapy, and the analysis of movement in any context. This research considered choreutics primarily through the context of dance education. An initial overview of choreutic practice within dance education revealed three essential components. These can be referred to as conceptualisation, embodiment, and transformations.

The choreutic conceptualisation of space consists of imagining a framework of polyhedral networks which surround the body and serve as a map-like grid. Various spatial forms can then be conceptually identified according a series of nodes or points within the network.

The embodiment consists of physically performing an imagined spatial form with one's own body. Four types of embodiment or "materialisation" have been distinguished (Preston-Dunlop, 1981, pp. 54-60). In spatial progression the form is embodied by the pathway of a moving body-part or of the whole body. In body design the form is embodied by the sculptural mass of a body pose. In spatial tension the form is embodied by creating a perceptual illusion of a connection between two body parts across "empty" space. In spatial projection the form is embodied by creating a perceptual illusion of a line extending outwards into space beyond the body.

Transformations consist of mentally manipulating the conceptual image of a spatial form. A spatial form becomes disembodied, purely conceptual, and is not tied to a particular embodiment. Space is then treated as isotropic, ie. "democratic" (Preston-Dunlop, 1981, pp. 26, 37) in which all locations are treated as equally valid for use in any spatial form. A spatial form is then mentally transformed by any of several symmetry operations; rotation, reflection, translation, retrogradation, and sizing (enlarging / reducing). In addition, a form may be deflected or deviated so that its shape is actually changed or deformed.

These three choreutic processes of image conceptualisation, physical embodiment, and mental transformations were identified as having received considerable study within the field of psychology, in particular in studies of spatial perception (eg. McGee, 1979; Sedgwick, 1986) and motor skill learning (eg. Newell, 1991). Initial research confirmed this and revealed that many experimental tasks used in cognitive psychology and motor control studies are analogous to choreutic exercises. Thus, cognitive psychology and motor control studies were undertaken with the intent of identifying well established characteristics by which to reevaluate Laban's choreutic conception.

I.32 Gradual Refinement of the Focus of this Research.

During the course of this research the focus was gradually refined. The aim of the investigation from the original research proposal was to "discern problems, and to design and test techniques, of effective choreutic education" (Longstaff, 1990; Appendix I.10). This began with a review of spatial cognitive processes in order to identify educational issues about how humans perceive and remember the spatial aspect of body movements and positions. These studies in cognitive psychology and motor control revealed that the vast majority of research focused on visual spatial cognition and that the role of kinesthesia is often neglected. Since a large part of the choreutic system is based on kinesthetic spatial information it became evident that before educational techniques could be devised that the nature of kinesthetic spatial knowledge within choreutics must first be explored and defined.

Thus, in the "Application for Transfer of Registration from Master of Philosophy to Doctor of Philosophy" the focus of the research was explicitly refined to focus on identifying the nature of choreutic knowledge according to concepts of spatial cognition as developed in cognitive psychology and motor control research (Longstaff, 1992; Appendix I.20). An understanding of spatial cognition would then inform dance teachers and theorists about how kinesthetic spatial knowledge is mentally conceived and communicated. The findings of this research would be readily applicable to dance education, though this would not be the principal focus.

This refined focus was also accompanied by a new research title which proposed an "integration" of choreutic concepts together with spatial concepts from cognitive psychology and motor control. This notion of "integration" was questionable at the beginning since it would require that the experimental, analytical approach in cognitive psychology and motor control be brought together into a unity with the experiential, artistic, intuitive approach in dance. As the research neared its completion it was evident that, rather than an integration, the experimentally verified spatial cognitive processes identified in psychology and motor control studies had been used as a criteria and a context in which to reevaluate the system of choreutics as intuitively identified by Laban and his Students/Colleagues.

Thus, in this final thesis the notion of "reevaluating" choreutics in the context of spatial cognition and motor control has been used. The changing titles of this research has not been a shift in focus, but has been a refining of the essence of the research which gradually became evident as the research unfolded.

I.33 Summary of the Reevaluation.

In Section II. the concept of "kinesthetic spatial cognition" (analogous to the psychological concept of "visual spatial cognition"; eg. Phillips, 1983) was developed to define an overall realm in cognitive and motor control studies according to which the choreutic conception can be reevaluated.

In Section IIA. kinesthesia was identified as arising from sensory stimulations via receptors in muscles, tendons, joints, skin, vestibular apparatus, eyes, ears, and also from an interior knowledge of motor commands (efferent data). This assortment of stimulations from throughout the body are derived into perceptions of balance and equilibrium, self-motion, limb-motion, limb position, and force or exertion.

In Section IIB. "kinesthetic space" was defined as spatial information which is perceived and/or recalled through the kinesthetic perceptual-motor system. A multitude of types of environmental, bodily, and conceptual "spaces" were considered and concepts such as kinesthetic-motor space, work space, reach space, and movement space are seen as relatively synonymous with Laban's (1966) concept of the "kinesphere"; referring to the space within immediate reach of body movements.

In Section IIC. "kinesthetic spatial cognition" is defined as cognitive processes (eg. perception, imagery, mental manipulations) which are performed on kinesthetic spatial information. Support for this concept is built-up from psychological theory. A great deal of research has distinguished spatial cognition from verbal cognition as using separate cognitive resources (eg. Baddeley, 1986). Spatial information can arise from separate visual, audio, and kinesthetic perceptual-motor systems but is eventually represented in a unitary spatial memory system (eg. Baddeley and Lieberman, 1980; Solso and Raynis, 1979). Kinesthetic-motor knowledge is considered by many researchers to inherently require cognitive processing rather than consisting solely of sensory-motor responding. Kinesthetic-motor activity has long been identified as being at the basis of all spatial learning (eg. Piaget and Inhelder, 1967) and is hypothesised to function as a spatial rehearsal mechanism (eg. eye movements) (Baddeley, 1983). Body movements also appear to serve as a mechanism whereby spatial information arising from different receptors is compared and calibrated so that the various spatial sensations "read" the same. Many theorists also purport that kinesthetic-motor information is at the basis of all types of cognitive processes (including verbal). This concept of "kinesthetic spatial cognition" has not been heretofore explicitly developed in cognitive psychology and so constitutes new knowledge. This provides a cognitive and motor control context in which to reevaluate choreutics.

The choreutic conception can be reevaluated according to knowledge about kinesthetic spatial cognition. In Section III. four cognitive structures* used in choreutics were identified as having also been well developed in studies of spatial

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* A "cognitive structure" refers to the way in which knowledge is organised or structured during cognitive processes (eg. Thorndyke, 1977).

cognition and motor control. Briefly stated these are: 1) Spatial information is interpreted according to various systems of reference. 2) Mental representations of kinesthetic spatial knowledge are based on a code of elemental locations. 3) Individual locations are eventually collected into cognitive map-like spatial images of an entire environment. 4) Symmetrical transformations are often performed on spatial information. The explicit identification of these cognitive structures in spatial cognition research gives psychological validity to their fundamental role within the choreutic conception.

Section IIIA. considers how spatial information must be defined relative to a system of reference. Types of egocentric (body-relative) and exocentric (environment-relative) reference systems have been identified in cognitive studies. Reference systems distinguished in Labanotation and choreutics are validated by the identification of similar reference systems within spatial cognition research. This similarity has not been heretofore explicitly identified and so constitutes new knowledge. A great deal of differentiation is provided in the Labanotation and choreutic reference systems which could serve as tools in spatial cognition research.

In Section IIIB. a variety of research is considered which indicates that the mental representation of spatial information is based on individual locations. For example, the final location of a body movement can be recalled better than the distance moved and the location of one body-part can be recalled (virtually) just as well with a different body-part. These effects indicate that spatial locations are recalled rather than particular movements. (See IIIB.10.)

The mass-spring model for motor control provides a theoretical basis for a location code. The elemental unit of body-movement is thought to be a single motion toward a new "equilibrium point" where there is equal tension between agonist and antagonist muscles (Bizzi and Mussa-Ivaldi, 1989; Jordan and Rosenbaum, 1989). Each equilibrium point comprises one elemental location in the mental representation of a body movement. (See IIIB.20.)

A location code is also evident in studies of "trajectory formation" where measurements of the degree of path curvature and velocity of movement revealed that a path was divided into several "path segments" separated by "curvature peaks" (Abend et al., 1982; Morasso, 1983b). A model for the production of complex paths was developed in which the "primitive movements in the motor repertoire" consist of the path segments, identified as "strokes", and the curvature peaks identified as "guiding points" for the production of the trajectory. Angular transitions between strokes occur when they are performed in a discontinuous manner, whereas a partial time overlap between consecutive strokes causes one stroke to be blended or "superimposed" with the next stroke, creating a smoothly curving movement. This model of trajectory formation is identified as being similar to "spline functions" which generate curved lines from a series of straight vectors in computer graphics (Morasso, 1986, pp. 38-44). The "abstract representations" of a body movement are posited to be cognitively planned according to a series of locations in which "the desired shape is approximated by means of a polygon" (one location at each polygonal corner), and then "the sides of the polygon are generated and superimposed" in actual body movement (Morasso et al., 1983, pp. 86, 97). (See IIIB.30.)

Similar location-based models have been developed for handwriting production, motor control of speech, stimulus-response compatibility, spatial motor preprogramming, and in visual and verbal memory. (See IIIB:50, .70.) Coordinative structures are identified as the body-level counterpart to the spatial-level of the location code. A library of reflexive movements allow the entire body to automatically accommodate to the planned trajectory of an individual body-part. (See IIIB.60.)

These location-based models of motor control and spatial cognition give validity to the virtually identical conceptual structure used in choreutics where Laban (1966, pp. 27-28) identified the same movement attributes as the trajectory formation model and referred to them as "'peaks' within the trace-form" and "phases of its pathway". Kinespheric paths and poses are conceived as being polygonal-shaped. Curved or angular trajectories are produced depending on whether successive strokes are smoothly blended together or if the guiding points are abruptly accented. This choreutic conception is virtually identical to the trajectory formation model. (See IIIB.40.)

Section IIIC reviewed how sequences of locations which have been well learned will be conceptually joined together into map-like images which simultaneously represent an entire spatial environment. A great deal of "cognitive map" research has explored characteristics of these spatial images for environments ranging from small page-sized spaces accessible to eye and arm movements through to large country-sized spaces accessible by traveling. This provides psychological validity for Laban's use of geometric map-like images of the kinesphere (termed grids, networks, or scaffolding). Similar geometric kinespheric maps have been depicted by artists and architects (eg. Leonardo Da Vinci; Le Corbusier). In the choreutic conception bodily paths and poses are represented as groups of locations within polyhedral-shaped conceptual map-like images of the kinespheric network.

Section IIID reviewed the variety of symmetrical transformations (eg. mental rotation, reflection, imagined self-translation) which are used within spatial cognition tasks. Many motor control studies have also revealed that kinesthetic spatial information (eg. an arm movement) can easily be transformed (eg. reflected, rotated) or performed by different body parts. This ability to perform symmetrical operations is identified as being critical for effective everyday use of spatial knowledge (eg. when reading a map which is not in alignment with the actual physical environment). Five types of symmetrical transformations are identified within spatial cognition and motor control studies and referred to here as translation (including body transfer), reflection, rotation, size scaling, and retrogradation. These symmetries and their notation symbols can help clarify and make explicit the transformations in spatial cognitive tasks and dance practice. A large part of choreutic practice also consists of transforming spatial forms into new orientations and performing them with different body parts. Choreutic "scales" are composed of paths and poses with three-dimensional symmetry which are described identically to spatial patterns used while maintaining dynamic equilibrium in three dimensions. Because of this, the mental conception and physical execution of choreutic scales and rings can be considered to be cognitive and bodily practice in symmetrical transformations and varieties of dynamic equilibrium adjustments.

The four cognitive structures of kinesthetic space identified here (reference systems, location code, map-like images, symmetrical transformations) have been well developed within psychology and motor control research and so this provides a validation for their use in choreutics. These parallel spatial conceptions developed in choreutics and identified in spatial cognition and motor control research have not been heretofore identified and so constitute new knowledge about the psychological validity of the choreutic conception.

In Section IV. two components of choreutics were identified and reevaluated more closely. These include a prototype/deflection hypothesis for the mental conception and bodily action of kinespheric forms (IVA), and varieties of taxonomy-schemes for distinguishing between categories of kinespheric information (IVB). Perceptual/memory experiments were devised from previous psychological experimental methods for probing these choreutic components. Both experiments demonstrated the advantageous use of choreutic material and Labanotation symbols as stimuli in experimental research. This has not heretofore been explicitly identified and so constitutes new knowledge.

In Section IVA a choreutic prototype/deflection hypothesis was identified which posits that kinespheric dimensional and diagonal orientations serve as idealised conceptual prototypes of pure stability and pure mobility, while actual bodily movements occur as deflections ("inclinations") between nearby dimensional and diagonal directions. (See IVA.20,.40.)

Similar spatial prototypes are evident in the English language where dimensions are given the greatest conceptual specificity, diagonals (45°) are given less, and off-diagonal inclines are given the least specificity. Prototype effects are also demonstrated in spatial cognition research where (for example) dimensional orientations are perceived and responded to more readily than diagonal orientations ("oblique effect") and lines or angles are perceived/remembered to be more dimensional, or to be closer to 90°, than they actually are. (See IVA.30,.50.)

Anatomical constraints are identified as a principal source of deflections. Measurements of ranges of motion at single-joints did not support the deflection hypothesis but these are not ecologically valid measures of whole-body kinespheric structure. Kinesiological analyses of joint structures and muscular lines-of-pull both supported the hypothesis that body movements tend to move out of pure dimensionally-oriented Cartesian planes and into obliquely tilting paths. Therefore, oblique directions must be considered to be kinesiologically simpler than dimensional and Cartesian planar paths. (See IVA.70.)

Deflections are described in choreutics as arising from many sources including; rotary joint articulations which take the motion out of a pure Cartesian plane; effects arising from the physical forces generated during a movement (eg. momentum): and also from the desire by the mover to produce a particular expression or communication. The physical forces and expressive qualities of moving within Cartesian planes are flat, rigid, and contained, compared with the physics and expression of movement along inclined planes. Laban (1951, p. 11) made a similar observation that the inclinations are "most obvious in the expressions of emotional excitement" when the dynamism of inclinational slopes would be overtly exhibited. (See IVA.80.)

The hypothesised deflected inclinations create an icosahedral-shaped kinespheric structure with rectangular-shaped Cartesian planes. This is remarkably similar to ergonomic measurements of the shape of the workspace or "kinetosphere" (eg. Dempster et al., 1959; Squires, 1956). (See IVA.90.)

The choreutic conception can be considered to be a counter-part to the ballet conception. Ballet is based on a conception of dimensions which are implicitly deflected towards nearby diagonals during actual body movement. In contrast to this, choreutics is based on a conception of diagonals which are explicitly deflected towards nearby dimensions during actual body movement. Laban (1926, p. 64) summarises that ballet is "oriented in dimensional stability" while the "new dance" is "oriented in diagonal lability" and so Laban used the choreutic diagonal scale as the principal exercise in his dance technique classes (Bodmer and Huxley, 1982, p. 18). A few examples of ballet movements deflecting into inclinations are given here. The further development of a choreutic diagonally-based para-ballet movement technique is possible with an understanding of organic deflections into inclinational directions. This is a direction for future research. (See IVA.60,.80.)

An experiment was devised with the purpose of identifying cognitive prototypes in kinesthetic spatial cognition. Subjects made distance judgements between pairs of kinespheric directions (with Labanotation symbols used as stimuli) by drawing a symbol at an appropriate distance within a semi-circular grid (once with stimulus 1 fixed at the origin of a semi-circular grid, and once with stimulus 2 fixed at the origin of the grid). These were measured and scrutinised for the presence of asymmetrical distance judgements which are an indication of cognitive reference points (following Rosch, 1975a; Sadalla et al., 1980). Distance judgements were not significantly different regardless of which Labanotation symbol was fixed at the origin of the grid and so this did not support the hypothesis of reference points in cognitive maps of the kinesphere. However, it appeared that Subjects may have been estimating the static length of a line or the size of an angle rather than a distance along a particular direction *from* one location and *towards* another location. Alternative procedures for identifying reference points in kinespheric cognitive maps are suggested. (See IVA.110.)

In Section IVB hypothetical categories of kinesthetic spatial information are distinguished in dance and choreutics. These can possibly contribute to the need for defining a "class" of movement which has been identified as a fundamental problem in evaluating the schema theory for motor learning. Spatial perception research indicates that the primitive element of kinespheric poses is the straight body segment (eg. as in a "stick figure" representation of an animal's body) (Marr, 1980; Marr and Nishihara, 1978). Individual segments are organised into higher-order groupings (eg. ball-like, pentagon-shaped, "X"-shaped) according to the Gestalt principles of perceptual grouping. Motor control research indicates that the primitive element of kinespheric paths is the curved stroke between locations (eg. Morasso, 1986). Individual curved strokes can be organised into higher-order groupings (eg. straight paths, angles, loops, figure-8) according the possibilities afforded by kinesiological constraints. A method for developing a kinesiologically valid taxonomy of kinespheric forms is presented. Further refinements to an initial taxonomy developed here is a matter for future research. (See IVB.10-.30.)

Since visual and kinesthetic spatial forms can be easily recognised or produced regardless of metric variations, Bernstein (1984) asserts that they are mentally represented as "topological categories" (pp. 105, 108) which are embodied with slightly different metric variations on each successive physical execution yet the essential topological form is unchanged. Thus, Bernstein describes the "co-ordinational net of the motor field . . . as oscillating like a cobweb in the wind" (p. 109). This is virtually identical to the choreutic conception where kinespheric "natural sequences" are based on a contrast of "axial" versus "equatorial" shapes of motion, together with an intermediary "hybrid" (Laban, 1966, pp. 68-72) and these topological forms are conceived to deflect across various polyhedral-shaped cognitive map-like images of the kinespheric network. (See IVB.34.)

A movement memory experiment was devised with the purpose of identifying whether categories of kinesthetic spatial information are actually used in cognitive processes. Subjects learned sixteen discrete kinespheric-items and were allowed to recall these in any order over five learning and free recall trials. Measurements of "subjective organisation" indicated that kinespheric-items were organised into categories during learning and recall. An analysis of the categories led to a twofold hypothesis of category membership defined by the form (ie. movements with the same form were clustered together regardless of their orientation) and category prototypicality defined by the orientation (ie. movements oriented along a pure dimension or a Cartesian plane were recalled at the beginning of a cluster). Identifying kinesthetic spatial categories in this way has not been heretofore undertaken in psychological research and so constitutes additional new knowledge. (See IVB.50.)

In summary, new knowledge has been identified in this research relevant to dance education. There is a lack of verified knowledge about kinesthetic spatial cognitive structures by dance theorists and educators. This gap in the knowledge is addressed by this thesis which presents psychologically valid knowledge about cognitive structures of kinesthetic space written for dancers, movement educators, and others with no previous experience with cognitive theories.

New knowledge is also presented relative to the choreutic conception. A principal realm of the subject matter of choreutics was identified within the psychological concept of kinesthetic spatial cognition. Cognitive structures which are used in choreutics were psychologically validated by their well established identification in spatial cognition and motor control research. Choreutic conceptions of organic deflections and varieties of kinespheric categories were identified in this research and were supported with anatomical/kinesiological analysis and by psychological experiments.

In addition, new knowledge identified in this research is relevant to the fields of psychology and motor control. Whiting (1986) reviews the importance of human body movement within psychology and probes the question of why a subfield of psychology concerned with human movement has not been differentiated. It is pointed out that since virtually all behavioral and cognitive processes involve body movement that there is a "dualistic thinking implicit in trying to separate out movement from cognition" (p. 116). Whiting (1986) reasons that one factor leading to this neglect in studying body movements in psychology may be the methodological difficulties involved in trying to quantify their attributes. Even though body movement is familiar to everyone it is also elusive and its "vocabulary is difficult to codify"

(p. 124). Likewise, In Morasso's (1983b, p. 187) attempts to use verbal descriptions of three-dimensional arm/hand trajectories in motor control research, it is noted that "simple experiments of this kind reveal the dramatic inadequacy of natural language to express movements and spatial relations".

This problem has also been identified by Golani (1986) who asserts that movements must be considered in their entire three-dimensional plastic form rather than the incomplete planar analyses typically found in motor control studies. Another good example can be seen in the lexicon of "motor knowledge", or "motor language" presented by Cammurri and Colleagues (1986, pp. 104, 116-124) which consists of an assemblage of dance and movement terms without any consistent underlying analysis of their interrelationships. The necessity for a taxonomy of kinesthetic-motor knowledge has also been identified as essential for determining what constitutes a "class" of movements in studies of the schema theory for motor learning.

This problem of a lack of penetrating terminology for forms and orientations of body movements in psychology and motor control can be informed by the movement categories and terminology developed in choreutics and Labanotation. The first steps toward a more explicit taxonomy of motor knowledge is taken in this present research and directions for future inquiries are given. This research has also demonstrated the new knowledge that choreutic material and accompanying Labanotation symbols can be advantageously used as stimuli in psychological and motor control experiments.

This research has only been a beginning in defining the range of kinesthetic spatial knowledge. The foundation has been provided by firmly rooting choreutics within the context of spatial cognition and motor control. Future research can continue this process by continuing to clarify spatial cognitive structures within the study of dance and choreutics, and by utilising choreutic concepts and material within research into spatial cognition and motor control.

II. KINESTHETIC SPATIAL COGNITION: DEFINITIONS

The concept of "kinesthetic spatial cognition" (analogous to the psychological concept of "visual spatial cognition") is developed here to define an overall realm in cognitive and motor control studies according to which the choreutic conception can be reevaluated.

In Section IIA. kinesthesia is identified as arising from sensory stimulations via receptors in muscles, tendons, joints, skin, vestibular apparatus, eyes, ears, and also from an interior knowledge of motor commands (efferent data). This assortment of stimulations from throughout the body are derived into perceptions of balance and equilibrium, self-motion, limb-motion, limb position, and force or exertion.

In Section IIB. "kinesthetic space" is defined as spatial information which is perceived and/or recalled through the kinesthetic perceptual-motor system. A multitude of types of environmental, bodily, and conceptual "spaces" are considered and concepts such as kinesthetic-motor space, work space, reach space, and movement space are seen as relatively synonymous with Laban's (1966) concept of the "kinesphere"; referring to the space within immediate reach of body movements.

In Section IIC. "kinesthetic spatial cognition" is defined as cognitive processes (eg. perception, imagery, mental manipulations) which are performed on kinesthetic spatial information. Support for this concept is built-up from psychological theory. A great deal of research has distinguished spatial cognition from verbal cognition as using separate cognitive resources. Spatial information can arise from separate visual, audio, and kinesthetic perceptual-motor systems but is eventually represented in a unitary spatial memory system. Kinesthetic-motor knowledge is considered by many researchers to inherently require cognitive processing rather than consisting solely of sensory-motor responding. Kinesthetic-motor activity has long been identified as being at the basis of all spatial learning and is hypothesised to function as a spatial rehearsal mechanism (eg. eye movements). Many theorists also purport that kinesthetic-motor information is at the basis of all types of cognitive processes (including verbal). This concept of "kinesthetic spatial cognition" has not been heretofore explicitly developed in cognitive psychology and so constitutes new knowledge. This provides a cognitive and motor control context in which to reevaluate choreutics.

IIA. Kinesthesia

The terminology and functioning of the kinesthetic perceptual-motor system is briefly outlined here. For details, see Appendix II.

IIA.10 Variety of Terminology and Working Definitions

IIA.11 Variety of Terms.

A variety of terms, including kinesthesia, proprioception, somaesthesia, the haptic system, position sense, muscle sense, joint sense, and movement sense, have all been used in similar ways to describe aspects of the perception of bodily movements and positions.

The sense of movement and position of one's own body does not easily fit into Aristotle's classic five senses; seeing, hearing, smelling, tasting, and touching. Consequently Sir Charles Bell (1833) and others more recently (Fitt 1988, p. 266) use the notion of a "sixth sense". Dickinson (1974, p. 9) describes how this sixth sense conception is based on a "doctrine of 'specific nerve energies'" whereby a particular sense is thought to emerge from a particular sensory receptor. However, this has been shown to not hold true for vision and audition which both utilise sensory data from head/body movements in the perceptual process (Scharf and Houtsma, 1986; Sedgwick, 1986) and is especially true for kinesthesia which arises from receptors throughout the body. Thus, kinesthesia is not a new "sixth sense" but refers to perceptions which arise from many different sensory receptors located throughout the body.

Kinesthesia can be considered to be a generalised version of the sense of touch. Rock and Harris (1967, p. 96) use "touch in this broad definition" to refer to the sense of body movement and position. Similarly, the notion of the "haptic system" (from Greek *haptein*, to touch; Collins, 1986) is sometimes used very similar to kinesthesia with its "mode of attention" as "touching" and which the "hands and other body members" are considered to be the "organs of perception" (Gibson, 1966, pp. 50-53). Bastian (1888) originally proposed the term "kinesthesis" to replace both the terms "muscular sense" and "sense of force", and also noted that its "cerebral seat or area corresponds with the sense of touch" (p. 5).

Bastian (1888) included the perception of "position and movements of our limbs" and "different degrees of 'resistance' and 'weight'" within the heading of "kinesthesis". Some authors distinguish between kinesthesia as the sense of movement rather than the sense of static position since illusions can be experimentally induced in which these two "senses" do not correspond (Cross and McCloskey, 1973; McCloskey, 1973). However, in common usage "kinesthesia" refers to perceptions of movement, position, and force (American, 1982; Collins, 1986; Clark and Horch, 1986; English and English, 1974; Fitt, 1988; Rasch and Burke, 1978, p. 80).

Sherrington (1906) originated the term "proprioception" to refer to sensory receptors which are within "a cellular bulk more or less screened from the environment" (p. 316) and so "the stimuli to the receptors are given by the organism itself" (p. 130). In contrast "exteroceptors" refer to sensory cells which are "freely open to the numberless vicissitudes and agencies of the environment" (p. 317) and "interoceptors" refer to sensory cells on "surfaces" of the body but which have developed deep recessions so that "in this recess a fraction of the environment is more or less surrounded by the organism" (p. 317). Vestibular labyrinth receptors form a special case which are "derived from the extero-ceptive, but later recessed off from it" (p. 336) and which "co-operate together and form functionally one receptive system" with the proprioceptors (p. 341). Thus, the sensory receptors are distinguished as follows:

Proprioceptors found in:	muscles, joints, tendons, vestibular.
Exteroceptors found in:	eyes, ears, skin.
Interoceptors found in:	mouth, stomach, nose.

Sherrington's classifications of receptors have been followed closely by some authors (Dickinson, 1974, p. 10; Ellison, 1993, p. 75; Rock, 1968) but have been inaccurately represented by others (Wells and Luttgens, 1976, p. 58). The term "somaesthesia" is used similarly to proprioception to refer to stimulations arising from receptors in muscles, tendons, joints, and skin, but not vestibular (Bles, 1981; Lackner and Dizio, 1984; Taub et al., 1973; 1975).

IIA.12 Discussion.

The proprioceptive/exteroceptive distinction between internal stimuli from the body versus external stimuli from the environment has been found to be invalid. In many cases external stimuli such as visual-field motion or audio-field motion (see below) can induce perceptions of self-motion even in the absence of joint, muscle, tendon and vestibular stimulations (eg. G. J. Anderson, 1986) and are vital for the sense of balance or equilibrium (eg. Lee and Aronson, 1974). Thus, the notions of "visual proprioception" (Gibson, 1966, pp. 36-37; Lee and Aronson, 1974; Lee and Lishman, 1975), "visual kinesthesis" (Lishman and Lee, 1973; Rieger, 1983; Warren et al., 1988, p. 646), "visuopostural feedback" (Souder, 1972, p. 15), or even "exproprioception" (literally, perceiving the inside from the outside) (Fitch et al., 1982, pp. 275-276; Lee, 1978) have been used. Receptors in skin must also be classified as both exteroceptors and proprioceptors since they can receive stimulation from the environment or from the body. Because of this invalid internal / external distinction, the term "proprioception" will not be used here.

The terms "kinesthesia" and "proprioception" are also not consistently defined. Sometimes they are considered to be synonymous (Clark and Horch, 1986; Moberg, 1983, p. 1; Schmidt, 1982, p. 202). In the narrowest view stimulations arising from receptors in muscles, tendons, and joints (not labyrinth or skin) are included as proprioceptors (Fitt, 1988, p. 266) or as kinesthetic (Laszlo and Bairstow, 1971). Many other combinations are also used, sometimes including labyrinth, or skin, or both (see Appendix II). In the broadest conception, visual, audio, skin and labyrinth receptors are included together with receptors in muscles, tendons and joints as all contributing to kinesthesia or proprioception (Gibson, 1966, pp. 36-37; Rasch and Burke, 1978, pp. 80-81; Schmidt, 1982, chapter 6).

Kinesthesia is sometimes used to refer to conscious perceptions since the Greek root *aesthesia* means "to perceive", while proprioception is not necessarily conscious but may be considered as functioning to elicit unconscious automatic reflex reactions (Ellison, 1993, p. 75; Paillard and Brouchon, 1974, p. 275). McCloskey (1978, p. 764) discusses how Sherrington (1906) used proprioception in this reflexive sense which may not necessarily be conscious. Accordingly, "visual kinesthesia" is used to refer to conscious perceptions of motion (Lishman and Lee, 1973) while "visual proprioception" is used for reflexive reactions to maintain balance (Lee and Lishman, 1975).

Research has also focused on whether muscle spindle receptors have any direct access to conscious perception (Browne et al., 1954; Goodwin et al., 1972a; 1972b; 1972c; Moberg, 1983; Oscarsson and Rosen, 1963; Phillips et al., 1971; Provins, 1958). This is referred to as the "problem of 'conscious proprioception'" (Gelfan and Carter, 1967). In McCloskey's (1978) exhaustive review of "kinesthetic sensibility", and in particular the question of "Are muscles sentient?", it is stressed that kinesthesia arises as a phenomenological experience contributed to from a multitude of receptors, rather than conscious perceptions from individual receptors. Dickinson (1974, p. 10) reiterates this position that stimulations from individual receptors must be correlated at an unconscious level before a unified kinesthetic or proprioceptive perception rises to consciousness. Therefore unconscious and conscious levels are both part of the perceptual process. Whether these are referred to as kinesthetic or proprioceptive is arbitrary.

IIA.13 Working definitions.

Because of the invalidity of the internal/external distinction, the term "proprioception" will not be used here (following Clark and Horch, 1986, p. 13.2). In light of the other terms available the notion of proprioception is not necessary.

Kinesthesia will be used in its broadest sense to refer to the sensations arising from muscle, tendon, joint, skin, labyrinth, visual, and audio receptors. In addition an interior knowledge of motor commands or "efferent data" (see below) is another source of kinesthetic information. Other "senses" can be classified as kinesthetic sub-systems. These include limb position sense, limb movement sense, sense of linear or rotary self-motion, sense of balance or equilibrium, and the sense of force.

"Somatic" will be used in its typical definition of referring to perceptions arising from receptors in muscles, tendons, joints, and skin. These receptors comprise a complete grouping in themselves within the larger group of kinesthetic receptors.

IIA.20 Types of Kinesthetic Raw Data

A variety of sensory receptors and an internal knowledge of motor commands all contribute data which is derived into kinesthetic perceptions.

IIA.21 Muscle Receptors.

Large muscle fibres which produce the muscle's force of contraction are referred to as extrafusal fibres. Muscle sensory spindle organs are composed of modified muscle fibres referred to as intrafusal fibres and are arranged in parallel to the extrafusal fibres. Within the spindle organ are primary spindle endings, which are sensitive to small quick changes of muscle length and velocity of muscle change-of-length, and secondary spindle endings, which provide data about the overall muscle length (Clark and Horch, 1986; Rothwell, 1987, pp. 76-87).

IIA.22 Tendon Receptors.

Golgi tendon organs are located at muscle-tendon junctions and are attached end-to-end with muscle fibres and tendon filaments. This arrangement allows them to respond to muscle-tendon tension, regardless of muscle length (Clark and Horch, 1986; Rothwell, 1987, pp. 74-104).

Paciniform corpuscles are found near the Golgi tendon organs and are sensitive to vibrations. Free nerve endings are found throughout the muscles and tendons and are sensitive to mechanical pressure and pain.

IIA.23 Joint Receptors.

Golgi sensory receptors are found in ligaments which form the outer layer of joint capsules. Ruffini receptors and paciniform corpuscles are found in the tendon material of the joint capsule. Free nerve endings are found throughout the joint connective tissue (McCloskey, 1978, pp. 766-767). The functioning of these joint receptors is debated (for reviews see Clark and Horch, 1986; McCloskey, 1978; Rothwell, 1987, pp. 74-104). Some researchers have posited that joint receptors respond to particular joint angles (Skoglund, 1956) but this conclusion has been refuted by others (Burgess and Clark, 1969; Grigg, 1975). These researchers have also found a response of joint receptors to pressure within the joint capsule (Clark, 1975; Clark and Burgess, 1975).

IIA.24 Skin Receptors.

A variety of receptors are found in skin (Clark and Horch, 1986; Rothwell, 1987, pp. 74-104). Free nerve endings are close to hair follicles and stimulated by movements of bodily hairs. Merkel disks respond to slow changes in skin pressure. Meissner corpuscles respond to quick changes in skin pressure. Ruffini sensory endings respond to skin stretching in one particular direction but not others. Pacinian corpuscles respond to rapid vibrations.

IIA.25 Vestibular Receptors.

The vestibular system is the non-auditory part of the inner ear and is composed of the otolith organs and the semi-circular canals (Howard, 1986). The otolith organs respond to linear accelerations and also give a constant response to the pull of gravity. The semi-circular canals respond to angular accelerations (ie. rotation). Once a constant velocity is reached the vestibular system stops responding.

IIA.26 Visual Receptors.

The eyes can be dissected into several components including the cornea which gathers light rays, the adjustable opening of the pupil, the oval shaped lens and the retina consisting of photo-sensitive sensory receptor cells (Hood and Finkelstein, 1986; Westheimer, 1986). Eye movements such as monocular focus and binocular focus provide further information for visual perception (Hallett, 1986). Visual field motion refers to the visual stimulations moving across the retina and is associated with perceptions of self-motion (Andersen, 1986; Gibson, 1966). This is accompanied by visual nystagmus (Hallett, 1986). The vision of one's own body moving is also an important visual kinesthetic stimulation (Adams et al., 1977; Klein and Posner, 1974; Reeve et al., 1986).

IIA.27 Audio Receptors.

Audio receptors consist of the outer ear which collects sound waves into the auditory canal and to the tympanic membrane (ear drum). The middle ear transfers and amplifies these vibrations to the spiral-shaped cochlea of the inner ear where they stimulate sensory endings (Scharf and Buus, 1986; Scharf and Houtsma, 1986). Audio field motion consists of the movement of environmental sounds relative to the body as a result of the body traveling through space. Audition of the body is also an important kinesthetic cue in which body movements can be heard internally, and the effects of movements in the environment can also be heard (Gibson, 1966, p. 37).

IIA.28 Efferent Data.

A mechanism is also hypothesized whereby we have an internal knowledge of motor commands which have been initiated (Clark and Horch, 1986, p. 13.57). This is referred to here as "efferent data" and can be considered to be "central feedback" (as opposed to peripheral feedback from sensory receptors) (Kelso, 1977b; Larish et al., 1979).

IIA.30 Deriving Kinesthetic Perceptions

Kinesthetic perceptions are rarely derived from a single sensory organ located in one part of the body. Instead, the sensory data from many types of receptors is integrated into a single kinesthetic perception.

IIA.31 Sense of Balance or Equilibrium.

The sense of balance or equilibrium is closely related to the gravitational vertical which is sensed by the vestibular otolith organs and also by the pressure-sensitive receptors in joints and skin. The sense of balance also relies on visual field motion since this will induce reflexes designed to maintain balance (Lee and Aronson, 1974; Lee and Lishman, 1975; Lishman and Lee, 1973).

IIA.32 Self-motion and Limb-motion.

"Self-motion" s used here to refer to motion which either 1) translates the entire body through space to a new location (linear self-motion), 2) turns the entire body around an axis (rotary self-motion), or 3) a combination of translation and rotation (circular self-motion). In contrast, "limb-motion" is used here to refer to the motion of body-parts relative to other body-parts. Similar distinctions have been referred to as "locomotion" versus "contour motion" in movement memory studies (Lasher, 1981, p. 394) and "locomotor" versus "axial" movements in dance technique (Chellis, 1941, pp. 305-308; Gates, 1968, pp. 103-104):

> [Axial movement consists of] Movement around an axis, such as arm movements around the individual body as an axis.... Swinging, turning, and beating movements are illustrations of axial movement....
>
> [Locomotion consists of] Movement which progresses in space or from place to place ... Running, skipping, and leaping are examples of locomotor movement. (Love, 1953, pp. 8-9, 54)

According to this definition in dance technique, turning in place would be categorised as an axial movement. However, according to the definition used here both turning and locomotion are categorised as types of self-motion. This follows the use of "self-motion" (Andersen, 1986, Brandt et al., 1975; Wong and Frost, 1978), or "ego-motion" (Brandt et al., 1977) in psychological studies of motion perception. Turning and locomotion are both categorised as types of self-motion because these are kinesthetically perceived in similar ways (see below).

IIA.32a Sense of self-motion.

Somatic and vestibular stimulations might seem to provide the basis for perceptions of self-motion but these are actually dominated by data from visual field motion and audio field motion which can easily induce illusions of self-motion. For example when a large truck next to one's car begins to move it may be momentarily perceived as one's own car moving. These illusions are also easily produced in the experimental setting (Andersen, 1986; Bles, 1981). The illusion of self-motion from visual field motion is so robust that Subjects' knowledge about the illusionary set-up does not decrease the strength of the illusion (Lishman and Lee, 1973, p. 292) and it will occur even when accompanied by conflicting vestibular and somatic sensations (Berthoz et al., 1975; Bles, 1981; Johansson, 1977). However, when visual field motion and vestibular data are both available the perception of self-motion is quickest and speed estimates are most accurate (Melcher and Henn, 1981). The role of vestibular receptors is indicated since the characteristics of the self-motion illusion are tied to the vestibular characteristic of responding to acceleration but not steady speed (Brandt et al., 1973; Dichgans et al., 1972; Dizio and Lackner, 1986; Held et al., 1975; Reason et al., 1982; Wong and Frost, 1978).

IIA.32b Sense of limb-motion.

Limb movement sense is tied to the perception of limb position since a new position can only be reached by a movement, and every limb movement leads to a new position. However, in experimental settings limb position sense can be separated from limb movement sense (Horch et al., 1975; McCloskey, 1973). Just as with limb position sense, vision of the body can dominate limb movement sense (Klein and Posner, 1974; Laszlo and Baker, 1972). In natural settings, limb movement sense appears to arise from the same sources as limb position sense.

IIA.33 Limb Position Sense.

Limb position sense is dominated by data from the vision of one's own body and greatly looses accuracy if this source of stimulation is not available (Adams et al., 1977; Posner, 1967). A great deal of research has been devoted to discerning the non-visual mechanisms of position sense (for reviews see McCloskey, 1978; Clark and Horch, 1986). Early research led to the interpretation that joint receptors are responsible for limb position sense (Adams et al., 1977, p. 13; Andrew and Dodt, 1953; Gibson, 1966; Roland, 1979; Skoglund, 1956) although this has been overwhelmingly shown to be erroneous (Burgess and Clark, 1969; Clark, 1975; Clark and Burgess, 1975; Clark et al., 1979; Cross and McCloskey, 1973; Grigg, 1975; Kelso et al., 1980; McCloskey, 1978, pp. 766-767) it is sometimes still adhered to (Ellison, 1993, p. 75; Fitt, 1988, p. 266). Other research has indicated the role of muscle spindle receptors in limb position sense (Craske, 1977; Goodwin et al., 1972a; 1972b; 1972c; McCloskey, 1973). Skin receptors have also been shown to play a vital role for limb position sense in areas of high density of skin receptors (hands and face) (Moberg, 1983).

IIA.34 Sense of Force and Exertion.

The sense of force or sense of exertion can be derived from pressure sensations in skin and joint receptors and tension sensations from tendon receptors. The weight of an object is perceived to be heavier when the muscles lifting it are fatigued (McCloskey et al., 1974), therefore the perception of force appears to be related to efferent data about the amount of exertion being expended. When a reflexive contraction of the muscle is induced (by a physiotherapy vibrator) then Subjects can distinguish between the force encountered by the muscle and the exertion ordered by the motor commands (Ibid). This indicates that the sense of force may be derived from somatic receptors while the sense of exertion is derived from efferent data.

IIA.40 Conclusions: Kinesthesia.

Kinesthesia was identified as arising from sensory stimulations via receptors in muscles, tendons, joints, skin, vestibular apparatus, eyes, ears, and also from an interior knowledge of motor commands (efferent data). This assortment of stimulations from throughout the body are derived into perceptions of balance and equilibrium, self-motion, limb-motion, limb position, and force or exertion.

IIB Kinesthetic Space

The concept of "kinesthetic space" is placed within the larger category of "perceptual-motor space". Kinesthetic space refers to spatial information gained through kinesthesia and is fundamental to the subject matter of choreutics.

Designations of various "spaces" often run rampant in motor control and cognitive literature. For example, Paillard (1987) refers to a plethora of twenty-one varieties of space.* For clear discussions about spatial cognition the various types of "space" need definition.

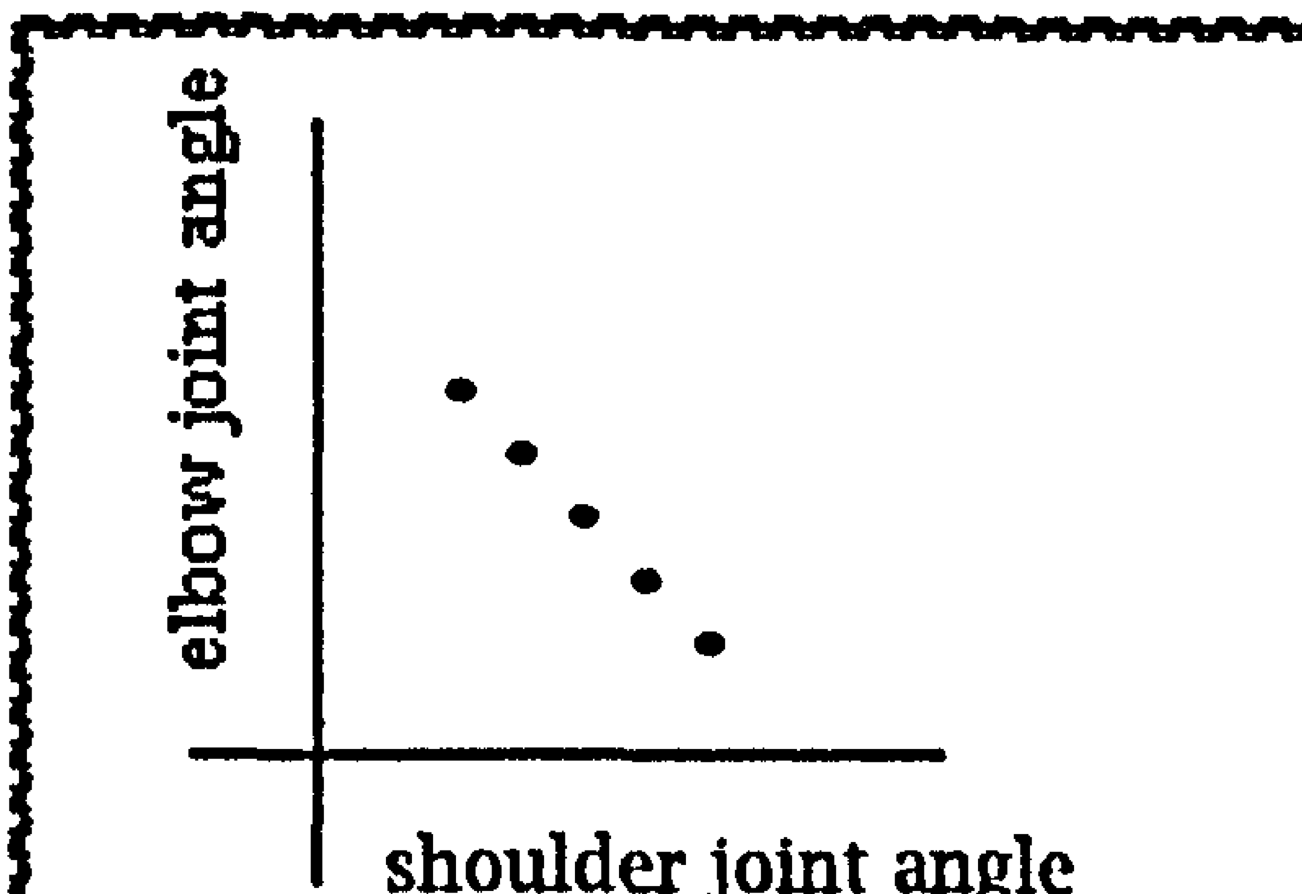

Figure IIB-1. "Joint space" as a graph of the joint angles (modified from Pew and Rosenbaum, 1988, p. 477).

IIB.10 Factor Spaces

The idea of a "space" will not be used in this study to refer to "factor spaces" which are statistical devices for spatially representing correlations among any number of different types of data (English and English, 1974). For example, "cognitive-space" or "representational space" are sometimes used to refer to how a concept can be mentally represented as the intersection of a set of any number of "dimensions" (eg. shape, size, colour, location) (Saltz, 1988). The "joint space" (Hollerbach et al., 1987, p. 197; Pew and Rosenbaum, 1988, pp. 476-477), or the "'intrinsic' space of the joints" (Morasso, 1986, p. 21) are also used in this analytical way to refer to the "space" of a graph which plots the relationship (for example) between the changing elbow and shoulder joint angles during a movement (Fig. IIB-1). "Space" will also not

* Paillard (1987) uses the terms "physical space", "extracorporeal space", "extracorporeal physical space", "environmental space", "astronomic space", "atom's space", "sensorimotor space", "sensorilocomotor space", "visuo-locomotor space", "locomotor space", "visuo-motor space", "visuo-motor subspaces", "retinocentric space", "visuo-oculomotor-space", "visuo-cephalo-motor space", "proprioceptivo-motor space", "tactilo-motor space", "postural space", "body space", "reach space", and "hand space".

be used here to refer to cognitive "space" (Baddeley and Hitch, 1974, p. 76) or the type of "workspace" (Morris, 1987, p. 406) used to refer to the amount of cognitive resources available for information processing.

IIB.20 Physical, Environmental, Objective, Euclidean Spaces

Many types of space refer to the physical environment which is objective and exactly measurable.

IIB.21 Physical Space, Environmental Space, External Space.

The terms "physical space", "environmental space" (Paillard, 1987, pp. 47-48), "'extrinsic' space" (Morasso, 1986, p. 21), "external space" (Souder, 1972), "objective space" (Huttenlocher et al., 1991, p. 355), or "objective external space" (Bernstein, 1984, p. 108) are generally used synonymously to refer to the actual physical spatial environment of the real world which is exactly measurable. This is as opposed to what a person might subjectively perceive about the environment.

IIB.22 Extracorporeal, Extrapersonal Space.

"Extrapersonal space" (Grüsser, 1983; Jeannerod, 1983) and "extracorporeal space" (Paillard, 1987, p. 43) are sometimes used synonymously as referring to the space which is outside of the physical body. Paillard (1987) combines this with "physical space" (see above) to produce "extracorporeal physical space" (p. 45), presumably the physical environment outside of the physical body.

Grüsser's (1983) conception of the extrapersonal space includes all the space outside of the physical body. Since much of this space can be easily moved into it might be more accurately described as perceptual-motor space (see below). These include Grüsser's "grasping space", "instrumental grasping space", "near-distant action space", and "far distant action space". Beyond these spaces available for body actions is the more remote visual space called the "visual background".

IIB.23 General Space.

"General space" is sometimes used to refer to the space in the environment which is outside of the physical body and also beyond the immediate reach of the limbs (Laban, 1966, p. 10; Salter, 1977, p. 129).

IIB.24 Euclidean Space.

The term "Euclidean space" (or Euclidean distance etc.) is in reference to Euclid (365-275 B. C.) who produced The Elements, a compilation of Greek geometry which is still the basis for geometrical study today. The concept of Euclidean space is sometimes used in cognitive studies to refer to the straight line directions and distances (ie. "as the crow flies") as opposed to distances and directions along a route which the subjects have actually experienced (McNamara et al., 1984, 1989).

IIB.25 Cartesian Space.

The notion of "Cartesian space" is in reference to René Descartes (1596-1650) who devised the "Cartesian coordinate system" according to which the location of any point can be specified with a set of coordinates. Cartesian space is sometimes referred to in cognitive and motor control research as generally synonymous with an objective environmental space (Hollerbach and Flash, 1982, p. 68).

IIB.30 Perceptual-Motor Spaces

The perception of space and motor actions within that space are intimately tied together. Perceptions of space guide motor actions along the routes to particular locations. In turn, motor actions transport the body to new locations from which further perceptions of space can be obtained. For example, visual spatial perception utilises eye rotations and head/neck movements to perceive stimuli from slightly different viewpoints. In the same way, head and postural movements add to audio spatial perception by providing more stimuli samples. Thus, the terms "visual space" and "audio space" both imply the participation of the motor system and are sometimes more fully referred to as "visual-motor space" and "audio-motor space". The same can be said for kinesthetic space which might be referred to as kinesthetic-motor space. Likewise, the concept of a "motor space" also implies the participation of kinesthesia since this occurs together with motor actions.

IIB.31 Sensory/Perceptual-motor Space: Spatial Fields.

The terms "perceptual-motor space" and "sensorimotor space" (Paillard 1987, p. 58; Sauvy and Sauvy, 1974, p. 21) can be used to refer to space perceived through any of the perceptual-motor systems. Within any perceptual-motor space are individual spatial "fields", variously referred to as "sensory fields", (English and English, 1974; Grüsser, 1983, p. 328), "receptive fields" (Grüsser, 1983, p. 329), or "sensorimotor fields" (Paillard and Brouchon, 1968, p. 38), and which refer to the range of spatial stimulation reaching a particular perceptual system at any one moment (eg. the "visual field"; Collins, 1986; Sedgwick, 1986).

Occasionally the terms "perceptual field" (English and English, 1974) or "perceptual space" (Johansson, 1958; Paillard and Brouchon, 1968, p. 37) are used in a slightly different way to refer to the remembered aspects of the environment rather than those currently available to the receptors. This definition is identical with "conceptual space" (see below).

IIB.32 Visual Space.

The concept of "visual space" (visuospace, visual-motor space) refers to the space available through the visual perceptual-motor system. This is the most common conception of a perceptual-motor space and has received the most attention in cognitive studies. Studies of visual space and visual images have led to the theory of "visuo-spatial working memory" and the "visuo-spatial scratch-pad" which is a proposed mechanism responsible for mentally rehearsing, storing, and manipulating spatial information (Baddeley, 1983; 1986; 1990; Farmer et al., 1986; Logie, 1986; Logie and Baddeley, 1990).

IIB.33 Audio Space.

The "auditory space" (English and English, 1974) or the "audiospatial" field (Ruff, 1985) refers to the spatial information available through the auditory perceptual-motor system. For example, the direction and distance of sound sources can be localised and the shape of a path followed by moving sound sources can be perceived.

IIB.34 Proprioceptive Space.

The concept of "proprioceptive space" (Paillard and Brouchon, 1968, p. 38) or "proprioceptivo-motor space" (Paillard, 1987, pp. 46-47) is occasionally used to refer to the spatial information available through proprioceptive sensations. Paillard (ibid) appears to consider this as synonymous with "body-space" (see below) and "postural space".

IIB.35 Tactile Space.

"Tactile space" (Hall, 1966, pp. 57-59; Paillard and Brouchon, 1968, p. 38), "tactilo-motor space" (Paillard, 1987, p. 46), or "tactual-kinaesthetic space" (McFarland et al., 1962) are occasionally used to refer to the spatial information available through the sense of touch; for example, the perception of shapes and textures of nearby objects which can be touched . Within the broad definition of kinesthesia (see IIA) tactile space can be conceived as a sub-space within kinesthetic space.

IIB.36 Thermal Space.

Hall (1966, pp. 52-57) refers to "thermal space" and "thermal spheres" in which aspects of the spatial environment can be perceived through thermal receptors in the skin. This might be conceived as a sub-space within tactile space.

IIB.37 Kinesthetic Space.

The notion of kinesthetic space is the logical progression from visual space, audio space, and tactual space, referring to the space perceivable via kinesthesia. In studies of "proximics" the sociologist Edward Hall (1966, pp. 51-52) uses "kinesthetic space" to refer to the perception of office spaces and hotel rooms according to how the arrangements of desks, furniture, etc., either permit or restrict body movements. Smyth and Pendleton (1990) experimented with memory for "configured movement" (ie. body poses) and suggested that they may be remembered within a "kinaesthetic-spatial system" (p. 304). When touch and movement are combined, it can be said to produce a perception of "tactual-kinaesthetic space" (McFarland et al., 1962).

IIB.38 Kinesphere (Kinetosphere, Strophosphere, Ergosphere).

The term "kinesphere" was coined by Laban (1966, p. 10) to refer to "the sphere around the body whose periphery can be reached by easily extended limbs". Salter (1977, p. 54) refers to the kinesphere with the terms "gestural space" and the "zone of reach". This concept has been well developed in dance studies, applied to the analysis of any type of movement event, and is used in assessments of motivation and decision making style, particularly in managers and manager teams.* The notion of a "kine-sphere" indicates a conceptual spherical-shape of kinesthetic space. However, this is a simplification of actual body movement. The size and shape of a person's visual and audio space depends on features in the environment (eg. buildings, trees) which determine the visual and audio stimulations that can reach the sensory organs. Similarly, kinesthetic space is generally conceived as spheric-shaped but in actuality the shape of the kinesphere is modified somewhat according to constraints within the human anatomy. The actual shape of the kinesphere is considered within the discussion of the prototype/deflection hypothesis (see IVA.70).

The similar term "kinetosphere" was introduced by Dempster and Colleagues (1959, p. 291) to refer to "the total range of translational movement of the end member of a series of links". This is a "space-shape which encloses a specific class of hand

* "Kinesphere" has been discussed in dance studies by Dell (1970, p. 69; 1972, p. 5), Hutchinson-Guest (1983, pp. 54-55), Laban (1963, p. 85; 1966, p. 10; 1980, p. 35), Preston-Dunlop (1978, pp. 3, 12-13; 1979a, p. 133; 1980, p. 22; 1981, p. 27), Salter (1977, p. 54), and Ullmann (1971, p. 6); within the broader analysis of any type of movement event by Bartenieff and Lewis (1980, p. 25) and Moore and Yamamoto (1988, p. 193); and in assessment of motivation and decision making style by Lamb (1965, p. 52), Lamb and Watson (1979, p. 51), Lamb and Turner (1969, p. 56) and Moore (1982, p. 68).

motion" according to "a rigidly imposed set of conditions, which limit the hand to purely translatory types of motion". That is, a kinetosphere refers to the range of space available to hand and arm motion while the hand is held in a fixed orientation throughout. For example the hand can be maintained in an orientation with the palm facing forward while the arm moves through its range of motion. This restriction of the hand to a single orientation also results in restrictions of the range of the hand/arm motion.

Dempster and Colleagues (1959, pp. 291-292) coined other related terms. A "strophosphere" refers to the combined space from several different kinetospheres (different hand orientations). An "ergosphere" is used in the broadest sense to refer to the range of movement with "wholly unrestricted movement for any and all hand and forearm orientations". Thus, Dempster and Colleagues' kinetosphere is defined by rigidly imposed restraints, whereas their ergosphere is identical to the choreutic concept of the kinesphere. They also specify that "kinetosphere" is not another term for "workspace" (see below), however the two terms are sometimes considered as synonymous within the field of ergonomics (Damon et al., 1966, p. 317; Pheasant, 1986, p. 139).

Sometimes the kinesphere is also referred to as the "personal space" (Laban, 1966, p. 10; Salter, 1977, p. 129). However, "personal space" often has emotional and social connotations (see below) which are not part of a purely kinesthetic-motor conception of the kinesphere.

IIB.40 Motor Spaces

Space can be defined according to the motor actions and the type of body movement (limb-motion, self-motion) which themselves define the extent and shape of the space. The role of kinesthesia is implied within motor spaces since any voluntary movement will generate efferent data and elicit sensory feedback but here the stress is on the motor actions rather than the perceptual response.

IIB.41 Motor Space.

The terms "motor space" (Paillard and Brouchon, 1968, p. 38; Viviani and Stucchi, 1992, p. 232), "motor field", or "physiological motor field" (Bernstein, 1984, pp. 102, 108) are occasionally used to refer to the space which is available to the body's motor system and is identified as being "analogous with the concept of the visual field" (Ibid., p. 108). The similar notion of an "activity space" (Hall and Cobey,

1974) refers to the spatial patterns created by the activity of an organism or an object (eg. a ball). The notion of a motor-space is also always implied, and sometimes explicitly included, in references to perceptual-motor spaces (see above).

IIB.42 Work Space, Reach Space.

The concept of the "work space" or "reach space" has been well developed in the field of "ergonomics" (also called "human factors engineering") (Pheasant, 1986, p. 3) and is virtually synonymous with motor space. Whereas "static reach" refers to the distance which a limb can extend away from the body, the "dynamic reach" refers to the volume of space which is within the range of the limb's movement. Thus, "dynamic anthropometry" refers to the measurement of the range of motion of the body's limbs (Dempster, 1955; Dempster et al., 1959, p. 289). This volume of space is variously referred to with the terms work-reach-space-envelope* and is virtually identical with the choreutic concept of the kinesphere (see above). The terms "workspace" (eg. Bizzi and Mussa-Ivaldi, 1989, p. 772; Hollerbach et al., 1987) and "reachspace" (Paillard, 1987, p. 46) have been adopted by motor control researchers.

The work space is described in many ways. It is the "space within reach", consisting of the "space-geometry of hand motions" or the "range of hand motion". This is "bounded by an intangible surface" which represents the "extreme range of motion" of the hand and can be considered as "the region of potential position of the hand point" producible from arm and upperbody articulations (Dempster et al., 1959, pp. 289-291, 303, 308). The workspace can be defined as "a three-dimensional region surrounding the worker, defined by the outermost points touched by the various parts of the body" (Damon et al., 1966, p. 317).

Dempster (1955) describes how the "maximum range" of movement for a body segment can be plotted on a sphere with the articulating joint at the centre. The "circumscribed area" on the surface of the sphere which marks out the joint's range of movement can be called the "bounding surface", "excursion cone", "joint sinus", or the "joint range" (pp. 568-569) and can be illustrated as "globographic representations

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* Variously referred to as the"working area" (Barnes, 1963, p. 259; International, 1978, p. 157), "workspace", "work envelope", "space envelope" (Damon et al., 1966, pp. 134-135; Dempster, 1955, p. 559), "shape envelope" (Dempster, 1955, p. 580), "region or space envelope", "hand reach" (Dempster et al., 1959, pp. 290, 308), "workspace envelope", "reach envelopes" (Pheasant, 1986, pp. 138-140), "working space" (Barnes, 1963, p. 261; Critchlow, 1969, pp. 86-89),"working planes", or as an "anthropometric and ergonomic space unit" (Critchlow, 1969, pp. 86-89).

of the joint ranges" (ie. a sphere at each joint with the joint range marked out within that sphere) (p. 566). When the range of a multi-joint linkage is considered (rather than motion at a single joint) this can be referred to as the "cumulative range of the end member" (p. 570) or the "cumulative space range" (p. 580). These can be considered to be maps of the "potential space" or "potential range" (p. 575), that is, the "space available for potential activity" (p. 577) for the particular body-parts.

Pheasant (1986, pp. 141-142 ; also Damon et al., 1966, p. 317) describes that within the reachspace or workspace envelope are various "zones of convenient reach" which refer to "a zone or space in which an object may be reached conveniently - that is without undue exertion". The shape of a reachspace zone depends on the constraints of human anatomy. Different degrees of extension outward from the body are also identified as a "maximum working area" resulting from maximum extension of the limbs, and the "normal working area" which is the size of space "described by a comfortable sweeping movement" of the limb.

The notion of different workspace zones for different body-parts is identical to Laban's (1966, pp. 18-26) identification of the zones for each of the limbs as a basis to identifying the fundamental body movement possibilities (see IVB.33). The distance that the limbs extend outward away from the body are also described in choreutics as "degrees of extensions" which are "restricted or augmented" and so create a "smaller kinesphere" or a "larger kinesphere" (Ibid, p. 41) and as "distance from center" in Labanotation (Hutchinson, 1970, p. 158).

IIB.43 Movement Space.

The term "movement space" is also sometimes used, generally synonymous with workspace (Bizzi and Mussa-Ivaldi, 1989, p. 772).

IIB.44 Grasping Space.

Grüsser (1983, pp. 327-329) uses "grasping space" to refer to the "immediate surround of our body" which is the "manual grasping range". This is generally identical to the workspace or the kinesphere. Grüsser also describes the "instrumental grasping space" in which the grasping space is extended when the subject uses "instruments" or tools to extend the length of the limbs.

IIB.45 Locomotor Space.

"Locomotor space" and also "sensorilocomotor space" (Paillard, 1987, p. 48) can be used to refer to the space perceived when the entire body locomotes.

IIB.46 Action Space.

Grüsser's (1983, p. 330) concepts of "near-distant action space" and "far-distant action space" are identical with types of locomotor spaces. This type of "action space" is considered to be outside of the reach of the limbs and its size is dependent on a subject's body size and walking speed. The near-distant action space is as large as "the distance at which the [Subject's] uncertainty appears when walking or running blindfolded", approximately seven meters.

IIB.47 Body Space.

Grüsser (1983, p. 327) uses "body space" to refer to the space occupied by the physical mass of the body. This is distinguished from the space available to limb movement (which Grüsser terms the "grasping space"; see above).

Apparently "body space" is used by Pheasant (1986) in a very general way to refer to static and dynamic anthropometry and ergonomics since it is used for a book's title but only briefly mentioned in the introduction and never explicitly referred to in the text. In reference to body space, Pheasant describes that its "form and dimensions should be derived from those of the human body, from the characteristics of the human senses and from the verifiable data of human experience" (p. 1). Likewise, Paillard (1987, pp. 46-47) considers "body-space" to be a type of "proprioceptivo-motor space" (see above) containing the physical body itself and also movements from one bodily position to another.

IIB.48 Body Space Hierarchy.

A hierarchy of body spaces can be envisaged ranging from the space available to the movement of a single body segment, to the space available to a multi-joint linkage. Paillard (1987) gives examples for the visual motor system of an anatomical hierarchy referred to as the "plurality of visuomotor space-structures" (p. 46). When the space is perceived by the eyes (retinal space) and eye movements, this "visuo-motor space" is more specifically a "visuo-oculomotor-space" (oculomotor; for six extrinsic muscles of each eye). When head movements are also included this becomes a superordinate "visuo-cephalo-motor space" ("cephalo" from Greek referring to the head) (p. 45). This process of designating larger superordinate spaces can continue by adding additional body segments to the moving linkage. When the entire body begins to transport itself through space it can be termed a "visuo-locomotor space" (p. 46).

Paillard (1987, p. 58) also conceives of this type of hierarchy for kinesthetic space or somatic space. For example, a "local sensorimotor space" might be the space "involved in pointing with the hand, using the wrist articulation only". This might be referred to as the hand space or the wrist space. A hierarchical arrangement is suggested, consisting of "different sub-spaces (wrist, elbow, shoulder)".

A similar body space hierarchy can be identified within Labanotation. When the notation is used for limb positions, it specifies the direction of the distal end of a limb (eg. hand, foot) relative to the limb's proximal joint (shoulder, hip) (Hutchinson, 1970, pp. 32, 229). That is, the proximal joint is thought of as the centre of the body-limb space. Sub-spaces can be specified by indicating the body-segment to be moving, for example the direction of the hand relative to the wrist might be considered to be a hand space* with the centre at the wrist (the most proximal joint of the linkage). Higher-order spaces can be indicated by an "inclusion of the body in an arm movement [which] means that the upper section of the torso participates in the direction of the arm movement" (Ibid, pp. 253-254). The resultant movement is equivalent with conceiving of a whole-body space with the centre at (or near to) the body's centre of gravity. This body-space hierarchy is identical to considering various body-points (eg. joints) as the origin of egocentric reference systems (see IIIA.26).

IIB.50 Mentally Represented Space

Types of "space" can also be distinguished which refer to memories of space and/or emotional feelings and attitudes about space.

IIB.51 Imaginal Space, Conceptual Space, Represented Space .

A space can be imagined which is not directly perceived from the real world but is a memory representation of a space previously perceived or a conceptual creation of a space one imagines might exist. This "imaginal space" (Byrne, 1974, pp. 57-59), "conceptual space" (English and English, 1974), "representational space" (Piaget and Inhelder, 1967; Sauvy and Sauvy, 1974, p. 21), or "represented space" (Huttenlocher et al., 1991, p. 355) refers to the conceptual memory representation or mental image of a space (as opposed to the immediate direct perception of space). The spatial image

* "Hand space" (Dempster et al., 1959, pp. 292, 313; Hollerbach et al., 1987, p. 197; Pew and Rosenbaum, 1988, pp. 476-477), the "'extrinsic' space of the hand" (Morasso, 1986, p. 21), or the "Cartesian space of the hand" (Hollerbach and Flash, 1982, p. 68) are often used to refer to the space available for hand motion as a result of movements of the entire arm . According to the body space hierarchy developed here this would be referred to as a hand/forearm/upperarm space, or as a whole arm-space.

may accurately depict real physical space but will also typically be biased by one's own personal perceptual experiences and subjective attitudes (eg. a bias toward spatial prototypes; see IVA.50).

IIB.52 Personal Space.

The concept of "personal space" often refers to subjective feelings of territoriality or ownership of space. Sommer (1969) states that "personal space refers to an area with invisible boundaries surrounding a person's body into which intruders may not come" (p. 26). Sometimes this is also referred to as a "portable territory" (p. 27) or a "body territory" (pp. 43-44).

Similarly, Hall (1966) discusses "personal distance" which "might be thought of as a small protective sphere or bubble that an organism maintains between itself and others" (p. 12). The far reach of personal distance extends to the furthermost reach of the limbs and so is the same size as the kinesphere. Other sizes of spacings between people include "intimate distance", "social distance", and "public distance" (pp. 110-120). In all cases perceptual-motor attributes are used to define the size and boundaries of the space but the focus is on the personal and social significance of human interaction at each distance. In this sociological context Hall states that a person's space does not refer to "the actual amount of air displaced by the body", but that the personal "space envelopes" consist of "a series of invisible bubbles" which are the "extensions of his personality" (p. 121) (as opposed to extensions of the limbs). Rather than being based on anatomy the personal space is based on social norms and these vary from culture to culture.

Grüsser (1983, p. 327) follows a more philosophical view derived from Kant that the "personal space" contains the "space of the self" or the "ego space", and which "remains within the limits of body space in an awake and attentive subject, but it is, within these limits, vague and ill defined".

In studies of choreutics the personal space is sometimes discussed as being virtually synonymous with "kinesphere" (see above) (Laban, 1966, p. 10; Moore and Yamamoto, 1988, p. 193; Salter, 1977, p. 129). Certain social and emotional affects have also been ascribed to the kinesphere such as "the space surrounding each person which belongs to him" (Preston-Dunlop, 1984, p. viii), "the space I sense as mine" which can expand or shrink depending on one's mood (Hackney, 1990), the space which is "psychologically their personal 'property'" (Hutchinson-Guest, 1983,

p. 310), or as the "psychological kinesphere" which relates to "how far one projects one's effort life into space" (Schick, 1990).

There is an undeniable intrinsic relationship between the emotional/social significance of space and the perceptual-motor actions within space, however these can also be distinguished:

> [The kinesphere] is *related* to the concept of 'personal space' referred to in interpersonal communication studies, and to 'body image boundary' referred to in body image studies, and to 'territory' referred to in sociological studies of communication. [But] The kinesphere *differs* from [these] other conceptions of the space surrounding the body by the fact that any organisation of that space is undertaken with reference to the movements that the body makes within it. (Preston-Dunlop, 1981, p. 27 ; similar statement in 1978, p. 13 [italics mine])

Occasionally "personal space" (Ruff, 1985, p. 901) or "intrapersonal space" (Roland, 1979, p. 79) are used synonymously to refer to an egocentric system of reference whereby movements of a body-part are identified according to their relationship with other body parts (see IIIA.10).

IIB.53 Extrapersonal Space.

The term "extrapersonal space" is sometimes used to refer to anything outside of the personal space. Since the concept of personal space is defined in terms of social and emotional territories, then the extrapersonal space will be outside of the personal territories.

In a more restricted sense, the extrapersonal space refers to any space which is outside of the physical mass of the body (Grüsser, 1983; Jeannerod, 1983, p. 1) and in this sense it includes the kinesphere or workspace.

Extrapersonal space is also sometimes used to refer to an exocentric system of reference according to which locations of body-parts or other objects are identified according to their relationship to locations in the environment (Roland, 1979; Ruff, 1985, p. 901) (see IIIA.10). These might be more properly referred to as "personal and extrapersonal frames of reference" (Ruff et al., 1981, p. 435).

IIB.60 Conclusion: Kinesthetic Space

The term "kinesthetic space" is adopted in this study since it follows the analogous concepts of visual space, audio space, and tactile space used in cognitive studies. "Kinesthetic space" was defined as spatial information which is perceived and/or recalled through the kinesthetic perceptual-motor system. A multitude of types of environmental, bodily, and conceptual "spaces" were considered and the concepts of the workspace, motor space, action space, movement space, and reach space are relatively synonymous with kinesthetic space and with Laban's (1966) concept of the "kinesphere"; referring to the space within immediate reach of body movements.

Since the sensory perceptions of space and the motor actions in space go hand-in-hand the conceptions of visual-motor space or audio-motor space are more accurate than simply visual space or audio space. The notion of a "kinesthetic-motor space" is cumbersome and "kinemotor" (ie. movement-motor) seems redundant. The terminology is inadequate. Even the term "kinesthetic" is inadequate since it specifies movement (*kine*) though it is generally agreed that perceptions of body positions and force will also be included under its heading (see IIA). Nonetheless, "kinesthetic space" and the "kinesphere" will be used in this study since they appear to be the best available terms in current usage. The "motor" will always be implied as part of kinesthetic space whenever the movements are voluntarily produced (and thus generating efferent data; see IIA.28).

IIC. Kinesthetic Spatial Cognition

"Kinesthetic spatial cognition" can be defined as referring to the perception, memory, and recall of spatial information via the kinesthetic perceptual-motor system.

IIC.10 Spatial Cognition versus Verbal Cognition

A great deal of research has demonstrated that spatial cognitive processes and verbal cognitive processes use separate cognitive resources. This has formed the basis of multi-channel models of information processing according to which cognitive attention can be allocated simultaneously to separate verbal and spatial tasks (eg. Allport et al., 1972; McLeod, 1977). This has been developed into the model of "working memory" which includes the "visuo-spatial scratch pad" for spatial rehearsal and processing and the "articulatory loop" for verbal rehearsal and processing (eg. Baddeley, 1986). Demonstrations of separate verbal and spatial cognitive processes are briefly reviewed here (for details, see Appendix III).

Much of the research probing multi-channels of information processing comes from "dual-task interference" studies in which a subject undertakes two separate tasks simultaneously, or a second task is undertaken while information from the first task is held in memory for later recall. The typical result is that two concurrent verbal tasks will interfere with each other, and two concurrent spatial tasks will interfere with each other, however a spatial task and a verbal task can often be performed as well simultaneously as either task can be performed individually. This result is interpreted as indicating separate spatial versus verbal cognitive resources (Allport et al., 1972; Baddeley et al., 1975; Baddeley and Liberman, 1980; Brooks, 1967; 1968; 1970; Farmer et al., 1986; Logie, 1986; Phillips and Christie, 1977b; McLeod, 1977; Morris, 1987; Pritchard and Hendrickson, 1985; Salthouse, 1974; 1975).

Other evidence for multi-channel models comes from studies of patients with neurological disease or injury. Often the ability to solve one type of cognitive task has been damaged while ability for other types of tasks remains normal. This is also interpreted as indicating the use of separate cognitive resources devoted to the different types of tasks. Much of this work has also contributed to the general notion of specialisation of the right cerebral hemisphere for spatial tasks and the left cerebral hemisphere for verbal tasks (De Renzi and Nichelli, 1975; De Renzi et al., 1977; Fried et al., 1982; Hanley et al., 1991; Kosslyn, 1987; Paivio and te Linde, 1982; Paivio and Ernest, 1971).

The right-brain spatial, left-brain verbal specialisation is not a fixed relationship but appears to be based on more fundamental differences in processing styles of the two cerebral hemispheres such as sequential processes of the left hemisphere versus holistic processes of the right hemisphere (Bradshaw and Nettleton, 1981; Luria, 1970; Trevarthen, 1978). There are also considerable differences between subjects (Ojemann, 1979; Gur and Reivich, 1980). In many cases the hemispheric superiority is minimal (ie. both hemispheres perform verbal or spatial tasks equally well), or is even reversed. For example, Levy and Reid (1976) found a correlation in which right-handed normal writers and left-handed inverted writers exhibited the normal right-hemisphere spatial, left-hemisphere verbal superiority. In contrast, right-handed inverted writers and left-handed normal writers had reversed hemispheric superiority.

Separate modes of spatial versus verbal cognitive processing are also posited by the "dual-coding hypothesis" which proposes that the spatial imagery system and the verbal system comprise two distinct symbolic systems which are involved in cognition (Paivio, 1978; 1979, p. 233). When both a verbal and a spatial code are learned for the same item then it is said to be dual-coded and can usually be remembered better. Dual-coding can also facilitate the recall of body movements when a verbal label is learned together with a motor action (Ho and Shea, 1978; Shea, 1977; Winter and Thomas, 1981)

In addition, a kinesthetic-motor code ("enactment") can be identified which also facilitates verbal memory when it is dual-coded together with a verbal phrase (Cohen, 1981; 1983; Cohen et al., 1987; Engelkamp, 1986; 1988a; 1988b; Engelkamp and Zimmer, 1984; 1990; Nilsson and Cohen, 1988; Saltz, 1988; Saltz and Donnenwerth-Nolan, 1981). It appears that the motor enactment learning strategy leads to such good verbal recall performance that other factors have no further beneficial effects. Thus, enactment learning is believed to provide an "optimal encoding" (Nilsson and Cohen, 1988, p. 427) or an "inherent richness" (Cohen et al., 1987, p. 110).

Similar types of dual-coding have a long history of use in various strategies for improving memory from the ancient Greeks through to modern times. Many of these mnemonic strategies utilise a large group of imagined spatial locations (eg. rooms in a building). An image of each item-to-be-remembered is visualised as being at each of the locations. During recall subjects imagine a walk through the building and recall the image present at each of the locations. A variety of these memory strategies have been reviewed by Bower (1970a), Yates (1966), and Paivio (1979, pp. 153-175).

Ho and Shea (1978) point out that the superior memory performance from dual-coding can be explained according to the "levels of processing" model of memory (Craik and Lockhart, 1972). The dual-code increases the "depth" of processing by encouraging both both elaboration and distinctiveness of the item-to-be-remembered which are both necessary to improve memory performance (Craik, 1983; Eysenck, 1979; Hunt and Einstein, 1981; Hunt and Seta, 1984).

However, in some cases when verbal labels are attached to stimuli the memory for those stimuli does not necessarily improve. Rather, information in the verbal labels appears to be relied upon and the actual details of the stimuli may be forgotten (Carmichael et al., 1932; Daniel, 1972; Goldstein and Chance, 1970; Hall, 1977; Hirtle and Jonides, 1985; Hirtle and Mascolo, 1986; Klatzky et al., 1982; Nagae, 1980; Pezdek and Evans, 1979; Price, 1968; Ranken, 1963; Schooler and Engster-Schooler, 1990).

IIC.20 Spatial Information Processing

Spatial information can be perceived through visual, audio, and kinesthetic perceptual-motor systems which may exhibit separate perceptual, retention, and retrieval characteristics (Connolly and Jones, 1970; Jones and Connolly, 1970; Diewert and Stelmach, 1977; Newell et al., 1979; Posner, 1967; Reeve et al., 1986; For details see Appendix IV). It is also well documented that visual spatial information tends to dominate auditory or kinesthetic spatial information (Adams et al., 1977; Klein and Posner, 1974; Laszlo and Baker, 1972; Pick et al., 1969; Posner et al., 1976; Reeve et al., 1986; Willott, 1973).

In other cases information from all the perceptual systems appears to be integrated into a single unified spatial representation. Accordingly, what was initially conceived of as "visual memory" (eg. Baddeley et al., 1975; Phillips and Christie, 1977a) was later refined into a unified concept of "spatial memory" which is devoted to spatial information from any perceptual system (Baddeley and Lieberman, 1980). In many cases spatial perception and performance is identical regardless of which perceptual system is used (Bairstow and Laszlo, 1978a; Solso and Raynis, 1979), and spatial "images" are not necessarily visual (Kerr, 1983; Millar, 1990).

Two fundamental types of spatial information can be distinguished. Location spatial information refers to loci or targets which are independent of the body movements which might be used to perceive or recall these. Whereas configuration spatial information refers to figures which are specific to particular body parts (Smyth et al., 1988; Smyth and Pendleton, 1989; 1990). Location versus configuration types of spatial information are analogous to "space" versus "shape" as identified in "Laban Movement Analysis" (Dell, 1970; Hackney, 1989; Maletic, 1987) or to "spatial progression" versus "body design" as developed in "choreological studies" (Preston-Dunlop, 1980, pp. 87-93; 1981, pp. 54-60; 1984, p. x).

IIC.30 Kinesthetic Spatial Cognition

IIC.31 Spatial Cognition.

"Cognition" is defined as "a generic term for any process whereby an organism becomes aware or obtains knowledge . . . It includes perceiving, recognizing, conceiving, judging, reasoning" (English and English, 1974), or as "the activity of knowing: the acquisition, organization and use of knowledge" (Neisser, 1976, p. 1). In common usage cognition might be considered to be different than perception but research has revealed that perception involves cognitive processes of interpreting sensory data relative to past experiences and current knowledge. That is, perception is interpretation (for a review see Eysenck and Keane, 1990, pp. 84-95).

The concept of "visual cognition" is used in psychology and includes the perception, memory, and retrieval of visual shapes and their locations (eg. Pinker, 1984). In a similar way the notion of "vestibular memory" is sometimes used to refer to task performance based on spatial information arising from vestibular sensations (Israel and Berthoz, 1992, p. 197). The concept of "spatial cognition" is also widely used (eg. Brésard, 1988; Thinus-Blanc, 1988; Sadalla et al., 1980) to refer to the cognitive processing of any type of spatial task.

The notion of "kinesthetic spatial cognition" developed here is analogous to "visuo-spatial cognition" (Phillips, 1983) and refers to perception, memory, and retrieval of spatial information which has risen from kinesthetic stimulations. This includes "kinesthetic memory" (eg. Keele, 1968) and "motor memory" (eg. Housner and Hoffman, 1979) as used in motor control and cognitive research.

IIC.32 Body Movement as Cognitive.

The conception of kinesthetic-motor cognition is supported by many researchers who consider motor actions to inherently involve high-order cognitive processes rather than being controlled solely by lower-order sensory-motor processes. Paillard (1987, pp. 60-63) summarises the difference between "two classes of information processing by the nervous system". Whereas the sensorimotor mode is primarily automatic, unconscious, and driven directly by sensory data, the cognitive mode is evidenced by conscious attention (though this may also be automatic) and is driven by internal computations and memorial cues:

> The sensorimotor processing mode directly relates, via external loops, sensory information (gathered by sense organs from the physical world) to motor activities directly driven by this information . . .
>
> The cognitive processing mode concerns the internal dialogue between the cognitive apparatus and stored mental representations of the physical environment, under the supervision of a conscious evaluator and the monitoring of attentional and intentional processes. (Paillard, 1987, p. 63)

Paillard (1987) confronts the dispute over whether spatial information is processed by sensorimotor responses to the immediate environment (eg. automatic reflexes), or by cognitive operations. This is described as a debate of "trenchant opposition between behaviourist and cognitivist theories" (p. 43). Paillard reviews a variety of fundamental spatial tasks and skills such as maintaining the perceived stability of visual space despite eye and body movements, visually fixating a stable target despite eye and body movements, smooth pursuit visual tracking of a moving target, quick programmed eye movements to fixate on a newly appearing target, bodily pointing at a visual target, and processes of adaptation to the displacement of the visual field as a result of looking through prisms. In each of these spatial skills Paillard describes how they can be accomplished by sensorimotor functions (perceptual responding based on automatic reflexes) and cognitive operations (conscious responding based on mental representations). It is clear from the discussion that both sensorimotor and cognitive modes of responding are active for all types of spatial processes.

Likewise, in their studies of locomotor patterns, Baratto and Colleagues (1986) develop a "motor cognitive model" (p. 79) which considers "movement as a cognitive process" (p. 81) in which high-order motor cognitive processes control lower-order motor subsystems. They reevaluate several pathological movement behaviors according to this model. For example, patients with central nervous system lesions have difficulty in motor learning whereas patients with peripheral impairments (eg. insufficient muscular force, limited joint motion) still have a large capacity for motor learning, "expressing a high degree of 'motor intelligence'" (p. 80).

Other researchers also refer to high-order "motor knowledge" (Camurri et al., 1986, p. 88) which is processed at the "motor cognitive level, ie. at a level of motor or visuo-motor reasoning" (Morasso et al., 1983, p. 84). These "higher, cognitive levels" of the motor system can be considered to include "motor programming, organization, planning, and anticipation" (Thomassen, 1992, p. 250). Accordingly, researchers refer to "the perception and processing of kinesthetic spatial information" (Bairstow and Laszlo, 1980, p. 1), simply "kinesthetic information" (Keele and Ells, 1972) or "efferent information" and "proprioceptive information" in which the movement plan is considered to be "knowledge" represented as an "image or template of the motor commands" (Kelso, 1977b, pp. 42, 44). This leads to common hypotheses of "motor engrams", a "motor image of a movement", a "motor image of space" (Bernstein, 1984, pp. 99-102, 109) or simply as a "motor image" (Housner and Hoffman, 1979; Marteniuk, 1973; Posner, 1967).

One type of evidence for cognitive processes in kinesthetic-motor learning and memory come from studies is which Subjects imagine that they are moving. In these cases the motor image will interfere with other cognitive tasks just as if the body movements had actually been performed (Johnson, 1982; Marteniuk, 1986). Thus, movements, and movement images, appear to play a role in higher-order cognitive processes:

> Viewed like this, movement learning has information processes held in common with a large number of cognitive problem solving tasks. Thus, . . . at least early in movement acquisition, there are cognitive information processes that underlie movement learning. (Marteniuk, 1986, p. 74)

Gardner (1983; 1990) distinguishes similar notions in terms of six types of "intelligence". "Linguistic intelligence" includes semantics (verbal meanings), syntax (word order), pragmatics (word functions), and phonology (word sounds). "Musical intelligence" includes knowledge of pitch, rhythm, melody, harmony, timbre, and orchestration. "Logical-Mathematical intelligence" includes knowledge of number, quantity, sets, and operations. "Spatial intelligence" includes knowledge of form, transformations, structure, and kinesthetic and visual manipulation of real-world objects. "Bodily intelligence" includes knowledge of bodily movement capabilities. "Personal intelligence" includes knowledge of emotional, psychological, and social capabilities.

Aylwin (1988) also distinguished between visual, verbal, and motor "cognitive styles" (also called "representational styles" or "modes of thought"). Subjects' visual, verbal, or motor cognitive styles could be determined by analysing their free associations to various stimuli. These cognitive styles were then positively correlated with Subjects' performance measures on several different personality and aptitude tests.

Laban (1952) made a similar distinction between "action memory" which includes "the mastery of movement" as opposed to "verbal memory" which includes a knowledge of intellectual facts. He stresses that even though bodily movement actions can never be separated from cognitive thinking, that knowledge about the "logic of action" has not been well developed compared to knowledge about "verbal logic". This "logic of action" cannot be learned from verbal descriptions only but must be experienced through actual bodily movement.

In another perspective, Jordan and Rosenbaum (1989) discuss how the motor system serves to move the sensory receptors to new places, thus allowing more information to be gathered by the perceptual systems. This information is then cognitively assessed in order to determine where, when, and how to move next. Because of this fundamental interrelationship between sensory perception and motor action they assert that "cognitive science, insofar as it regards perception as one of its core problems, cannot afford to ignore action" (p. 727).

Whiting (1986) also reviews the importance of human body movement within psychology and probes the question of why a subfield of psychology concerned with human movement has not been differentiated. It is pointed out that since virtually all behavioral and cognitive processes involve body movement that there is a "dualistic thinking implicit in trying to separate out movement from cognition" (p. 116). The practical, doing, "knowing how", procedural knowledge has been separated from the conceptual, thinking, "knowing that", propositional knowledge. Whiting questions this distinction and also the devaluation which is given to the non-verbal processes. He argues that cognitive abstract thought is essential for the learning of body movements and for their successful application in appropriate contexts (pp. 121-125).

Aspin (1977) considers "Knowing how", as traditionally referring to procedural knowledge such as a knack or skill in games requiring bodily training and having a benefit of therapy or relief but which also lacks cognitive content. Whereas "knowing that" is traditionally considered to refer to propositional knowledge such as serious intellectual education and the rigor of academic disciplines which brings cognitive understanding. The distinction between these types of knowledge can be traced back to the ancient Greeks and was made explicit in modern times by Ryle (1949). However, Aspin (1977) disputes the basis of this distinction as a fallacy of the philosophical perspective of "'essentialism'" which assumes that concepts (in this case "knowledge") can be reduced to one or more essences. It is argued that language cannot be divorced from context and so a multitude of different types of "knowledge" (not only knowing-how and knowing-that) can be identified according to the particular context in which they occur (pp. 28-29). Furthermore, the traditional conception of knowing-that versus knowing-how cannot be sharply distinguished since one will always be based on the other. Knowing-that (propositional knowledge) will always be based on knowing-how to justify and support the knowledge and knowing-how to use a symbol system to express it. Conversely, Know-how (procedural knowledge) will always be based on knowing-that certain criteria constitutes success and that certain aspects of the overall context must be considered for successful performance. Therefore, there is a "fundamental connectedness" and interdependence between these types of knowledge, not a sharp distinction (pp. 23-28).

Psychologists have been traditionally most interested in studying propositional verbal processes, and more recently spatial processes have received attention, but body movement processes have been neglected. This is true in spite of their most basic role in all forms of cognition (eg. subvocal articulation movements as the basis for verbal perception and rehearsal; Baddeley, 1990, pp. 71-81; Baddeley et al., 1981; Hintzman, 1965; 1967; Levy, 1971).

Whiting (1986) begins to integrate body movement into psychological study. A hierarchy of body movements is conceived, including "movement elements" (single action of a group of motor effectors), "modular units" (a series of movement elements), and "movement actions" (an "orchestrated" group of modular units) (p. 131). As learning proceeds the control of movement is thought to shift to higher levels in the hierarchy and so becomes more and more subject to cognitive input. Thus, a "cognitive motor system" (p. 133) is proposed:

> . . . it is wished to postulate a cognitive-motor representation system as part of a more general cognitive representation system responsible for upper-level control of human physical actions. The general conception therefore of a cognitive motor system is in terms of a hierarchical organization, the various levels of which reflect a shift from representations of, at the lowest level, specific movement elements, to, at the highest level, motor plans or cognitions of more general operations. (Whiting, 1986, p. 133).

Also, in studies of motor-enactment (see IIC.10) the typical finding is that acting-out the content a verbal sentence greatly increases the likelihood that that sentence can later be verbally recalled. Saltz (1988) also found that covert motor enactment (ie. very small, not noticeable, movements used to act-out the sentence) resulted in as good verbal sentence recall as overt motor enactment. Since motor processing (ie. "M-processing") results in automatic deep learning of verbal phrases, it can be seen as a separable memory subsystem (Engelkamp, 1988a; Engelkamp and Zimmer, 1984; Saltz and Donnenwerth-Nolan, 1981):

> At a theoretical level, the existence of covert M-processing would support the writer's assumption that motoric factors can be conceptualized as an aspect of cognitive representational systems. (Saltz, 1988, p. 412)

The exception to the predominance of psychological research into propositional knowledge is research in motor skill learning, but here the laboratory experiments use minor actions which are separated from cognitive requirements of a surrounding environmental context and so have little (if any) ecologic validity. When body movement is observed in its natural setting, and when movement actions occur in complex situations, then cognitive knowledge of the surrounding situation is critical for successful selection and implementation of bodily movements.

Whiting (1986) reasons that one factor leading to this neglect in studying body movements may be the methodological difficulties involved in trying to quantify their attributes. Even though body movement is familiar to everyone it is also elusive and its "vocabulary is difficult to codify" (p. 124). Likewise, In Morasso's (1983b, p. 187) attempts to use verbal descriptions of three-dimensional arm/hand trajectories it is noted that "simple experiments of this kind reveal the dramatic inadequacy of natural language to express movements and spatial relations".

A good example of this problem can be seen in the lexicon of "motor knowledge", or "motor language" presented by Cammurri and Colleagues (1986, pp. 104, 116-124) which consists of an assemblage of dance and movement terms without any consistent underlying analysis of their interrelationships. This problem can be informed by the movement categories and terminology developed in choreutics. The first steps toward a more explicit taxonomy of motor knowledge is taken in this present research.

IIC.33 Kinesthetic Basis for Spatial Knowledge.

The varied nature of what can be considered to be "spatial knowledge" can be grasped by reviewing the wide variety of what is considered to be "spatial" stimuli and tasks. This review reveals that the kinesthetic perceptual-motor system is fundamental for the learning and recall of spatial knowledge. This notion that kinesthetic-motor activity is a principle method for gathering perceptual information about space can be traced back to the 1800s (Viviani and Stucchi, 1992, p. 230). A variety of "spatial" stimuli have been used in experimental research. Many of these overtly utilise the kinesthetic-motor activity, for example spatial positioning, abstract and skilled body movements, spatial localization, Corsi blocks, and many cases where figures are physically traced or drawn (for details see Appendix V). In some cases the sense of "touch" is used which is itself a type of kinesthesia since touching requires body movements and arises from the same receptors as does kinesthesia (see IIA.11). When learning about large-scale environments "Actual locomotion in space appears to be an almost essential condition for the construction of spatial representations" (Siegel and White, 1975, p. 26).

Covert kinesthetic-motor processes can also be identified within "visual" spatial tasks (eg. seeing various figures, arrays, or matrices). The only purely "visual" space would be the array of stimuli reaching the retina of an unmoving eye. However, in natural visual perception the eyes rarely remain still. Eye movements appear to be essential to visual spatial perception. Efferent data about motor commands sent to the six extrinsic muscles of each eye and kinesthetic stimulation arising from those muscles provides information about eye movements and eye positions. These play a critical role in spatial perception.

When the eyes move then the visual stimulation moves across the retina. A classic question in psychology concerns how a perceiver is able to distinguish whether the environment is moving or whether one's own eyes are moving. This perceptual problem is generally believed to be resolved by an efferent copy of the motor commands sent to the extrinsic eye muscles. This data is provided to visual perceptual processes which determine whether the visual motion across the retina is attributable to environmental motion, body motion, or a combination of both (eg. Grüsser, 1986b). In Helmholtz' early conception of efferent data it was conceived as knowledge of the "'effort of will'" (Matin, 1972, p. 368). Grüsser (1986a) reviews the history of similar ideas of "interaction theories of visual perception" from pre-Socratic philosophers to to its development as the "reafference principle" by Von Holst and Mittelstaedt (eg. Jeannerod et al., 1979; Von Holst, 1954).

Kinesthesia and the "oculomotor system" (extrinsic eye muscles) are generally thought of as two separate systems (eg. Craske and Crawshaw, 1974a, p. 106). Eye movements must be correlated with retinal vision during the process of visual perception. Other, more typically "kinesthetic" receptions often must also function closely with vision. For example, if the visual array is moving across the retina as a result of hip/knee/ankle articulations (eg. walking), while the extrinsic eye muscles hold the eyes still, then kinesthetic stimulations (including efferent data) provide information which leads to a perception of a moving body within a stable environment (rather than vice versa). Kinesthesia (including efferent data) relative to any body movements (including eye movements) plays an essential role in "visual" spatial perception.

Kinesthesia and efferent data about eye and body movements within visual perception are sometimes referred to as the "oculomotor" aspects (Israel and Berthoz, 1992, p. 196), the "extraretinal signal" (Jeannerod, 1983, p. 4; Skavenski et al., 1972), or as "extraretinal information" (Paillard, 1987). Matin (1972) notes that "The terms extraretinal source, signal or influence are intended to refer to any channel in which information is not derived from stimulation of the retina by light" (p. 332), that is, information about movements of the eyes or other body-parts. Likewise, when head/neck movements are included together with eye moves it can be termed the "eye-head motor system" (Bizzi, 1974, p. 106).

Support for the role of efferent data within visual perception can be found in experimental effects. When the eye is moved with an exterior apparatus by the Experimenter then Subjects are unaware of their eye having moved and so exterior objects, rather than the eye, are perceived to have moved. A similar experience can be obtained by pulling on the skin around one's own eye causing it to move and resulting in a visual impression of the surrounding environment in motion. Conversely, if a Subject executes motor commands for eye movements, but the eye is restrained by an exterior apparatus, then Subjects still perceive (erroneously) that their eyes have moved and so exterior objects (which are actually stationary) are also perceived to move (Brindley and Merton, 1960; Irvine and Ludvigh, 1936). In another type of task, when viewing a visual picture the movements of the eyes are critical for selectively focusing on various aspects of the picture during learning. Recognition memory performance for pictures has been shown to positively correlate with the number of visual fixations each picture received during learning, regardless of the overall amount of time spent looking at the picture (Loftus, 1972).

These effects indicate that the role of efferent data (central feedback, or "outflow") appears to be more important than sensory information (peripheral feedback, or "inflow") (Matin, 1972, p. 368; Skavenski et al., 1972). However the response of muscle spindle receptors is minimal when movements are imposed externally rather than produced voluntarily (see APX. II.43). Thus, in normal conditions it may be that efferent data and muscle spindle response work together. Matin (1972, pp. 371-373) discusses the possibility of this "hybrid mechanism" which includes both afferent and efferent information within visual-kinesthetic spatial perception.

IIC.34 Kinesthetic-motor Mechanism for Spatial Calibration.

The kinesthetic mechanism for spatial perception is also evident in the phenomenon of "adaptation to displaced vision" (for details see Appendix VI). When a discrepancy is introduced between perceptual systems (eg. by wearing prisim-glasses which displace or reverse the visual image) then the interpretation of kinesthetic stimulations will adapt so that the different perceptual systems "read" the same (Gibson, 1966, p. 122; Moulden, 1971; Rock and Harris, 1967). This ability to adapt is referred to as "perceptual-motor plasticity" and is necessary to develop a calibration among the spatial stimulations arising from different perceptual systems (Held, 1968; Held and Freedman, 1963) and also to calibrate spatial information arising from different body-parts (Kenny and Craske, 1981; Lackner, 1973; Putterman et al., 1969; Rock and Harris, 1967, p. 101). A kinesthetic-motor mechanism is evident in this perceptual spatial calibration since active voluntary movement (rather than passive) produces the greatest and fastest adaptation (Held and Freedman, 1963; Held and Gottlieb, 1958; Held and Hein, 1958). Voluntary movement is not always necessary for adaptation (Howard et al., 1965; Mather and Lackner, 1975) but it may be that the increased kinesthetic and efferent data arising from voluntary movements elicits the greatest adaptation (Lackner, 1977a). These adaptation effects indicate that kinesthetic information (including efferent data) is at the basis for calibrating the different perceptual systems so that a unitary spatial perception is derived.

IIC.35 Kinesthetic-motor Mechanism for Spatial Rehearsal and Memory.

Since kinesthetic-motor activity is associated with spatial perception it is a logical extension to suggest that it is also associated with the mental rehearsal (eg. imagination) of spatial information. It is well known that rapid eye movements accompany dreaming while asleep. These usually occur together with other body movements and they are believed to be involved in the visual imagery accompanying dreaming (Aserinsky and Kleitman, 1953; 1955). Likewise, Deckert (1964) found that the eye movements which occurred when Subjects visualised a swinging pendulum (with eyes closed) were virtually identical to eye movements occurring when actually watching a pendulum. This kind of evidence leads investigators to believe that eye movements and other bodily orientation movements serve as a mechanism for spatial imagination (eg. Berlyne, 1965).

Incidental observations of movements during spatial cognitive processes have also been noted. Byrne (1974) observed that when Subjects were imagining a spatial matrix that "some Subjects made noticeable finger or head and eye movements that traced out the matrix" (p. 57) and noted twice how subjects made statements about needing to use eye movements to scan the spatial images (pp. 56, 58). Thus, a kinesthetic-motor mechanism underlying the use spatial imagination is suggested (p. 59). Brooks (1967) also observed that Subjects frequently glanced away from the answer sheet when recalling an imagined matrix and that "Subjects explained the glancing away as 'getting the pattern back'" (p. 294).

Idizikowski and Colleagues (1983) tested a hypothesis that extraneous eye movements might disrupt spatial imagination. Reflexive rotational nystagmus eye movements had no effect on the simultaneous performance of Brooks' matrix (for description of Brooks' matrix see Appendix V). However, they suggested that the spatial "rehearsal-controlling process may not be the eye movements themselves but rather the central system involved in their voluntary control" (p. 231). Voluntary visual tracking, with or without corresponding visual field motion across the retina, did result in a decrement to Brooks' spatial matrix recall, but not to Brooks' verbal material. Voluntary stationary eye fixation had no effect on performance. These results indicate that voluntary eye movement disrupts the spatial imaging process.

Quinn and Ralston (1986) built a large matrix (0.4 m^2) wherein Subjects could move their hand through the squares while learning and imagining the Brooks' matrix material. Moving the Subjects' hands either actively (Subject voluntarily moves) or passively (Experimenter manipulates Subject's relaxed arm) into the wrong squares resulted in a decrement to the matrix recall, while moving into the correct squares or tapping in place did not result in any change to recall performance. This indicates that incompatible movements disrupt the spatial imagining process.

IIC.36 Kinesthetic-motor Basis for Cognition in General.

Many theorists go even further and purport that kinesthetic and motor activity plays a fundamental role in all types of cognition. McGuigan (1978) offers an extensive review of research which has reported consistent patterns of muscular activity throughout the body during various cognitive tasks. McGuigan proposes that skeletal muscular activity related to cognition generates "nonlinguistic coding . . . a more primitive kind of symbolism than that needed for language" (p. 88). When certain stimuli arouse certain muscular activities the kinesthetic information from the muscular activities becomes part of the mental representation of the stimuli. When perceiving the same stimuli again, or simply thinking about, imagining, or dreaming about the stimuli, the muscular activity is repeated.

Weimer (1977, p. 302) distinguishes the "motor theory" from the "muscle theory". According to the muscle theory, activity of the muscles are utilised within cognitive processes (eg. McGuigan, 1978; see above). However, the motor theory is about central nervous system activity rather than the peripheral muscles. Viviani and Stucchi (1992) describe how according to the motor theory "motór processes enter into the genesis of percepts" (p. 230). The motor actions used to explore the environment and gather sensory data will be included with the perceptions of that environment, but the motor theory is "not contingent upon actual execution of motor actions" (p. 231) but is based on the cognitive "activation of stored motor routines" (Jordan and Rosenbaum, 1989, p. 727):

> A motor theory of memory need not necessarily involve actual movements. Visual or auditory input might be converted to motor commands that control muscle movements, and the motor commands may be remembered whether or not the movement is actually initiated. (Keele, 1968, p. 387)

Watson (1924, pp. 264-265) was an early advocate of body movements being at the basis of thought and verbal processes and points out that movements are intelligently organised in the infant long before words, and that motor actions are constantly forming without words throughout life. Words are thought to gradually develop in order to name the underlying motor processes and eventually the verbal organisation becomes dominate. Motor processes are thought to make up the Freudian "unconscious" and the emotional processes which are conceived to be more basic to thought than words. Laban also expresses a similar conception of motor actions as the basis for cognition:

> The words of language, giving names to objects and thoughts, conceivably sprang into being in remote times from movement impulses which were made audible. Thinking is certainly a kineto-dynamic process, and its trace-forms [ie. movement pathways] (presumably complicated shadow-forms [ie. covert pathways], noticeable in free space lines) will one day be discovered. (Laban, 1966, p. 124)

Coren (1986) reviews the history of motor theories of perception ("efferent theories") and identifies their fundamental conception that the primary function of the brain is to produce motor actions:

> This postulate is that the brain, viewed objectively, is primarily a mechanism for governing motor activity. Its *raison d'être* is the transformation of sensory patterns into patterns of motor coordination. This viewpoint is, of course, quite out of keeping with the generally accepted notion that the major functions of the brain are the manufacture of ideas, feelings, the storage of memory, and the interpretation of sensations into a conscious representation of the external environment. Such subjective phenomena . . . may simply be epiphenomena - the byproduct of brain activity - rather than its targeted functional result. . . . When reduced to its essence, the fundamental interpretive task of the brain . . . is to transform the sensory inputs into motor programs that allow the organism to interact with the external environment. (Coren, 1986, p. 394)

The traditional view of motor actions as interpreting the mind can be contrasted with this integrated view of motor actions as constructing the mind:

> From the time of Aristotle it has been taught that the motor system is the chattel of the sensory system. Nourished by the senses the motor system obediently expresses in automation and relatively uninteresting fashion the cleverly contrived ideas of the higher mental processes, themselves offshoots of the sensory mechanisms. In this view, action is interpretive of the sensory mind . . . [As an alternative to this] a constructive theory of mind [is advocated] in which it is argued that higher mental processes in addition to perception are skilled acts that reflect the operating principles of the motor system. In short, experience is constructed in a fashion intimately related to the construction of coordinated patterns of movement. (Turvey, 1977, pp. 211-212)

Similar to this is the "principle of somatotopy" (Trevarthen, 1978, pp. 110-113) according to which kinesthetic-motor activity plays a critical role in all areas of brain development. Therefore, the actual structure of the brain can be described as "body-shaped maps" and "mechanisms of the brain [are believed] to be laid down anatomically in close correspondence of motor function".

Gyr and Colleagues (1979) reason that the kinesthetic-motor mechanism in adaptation to displaced vision (see IIC.34) supports the notion that there is "an active involvement of areas of the motor cortex and motor-sensory feedback systems in the perceptual process" and so "neurological processing of sensory input is dependent on the organization of motor activity" (p. 59). Since both sensory and motor aspects are involved, they refer to these as "sensorimotor theories" of perception.

The influence of motor commands on perception is well known in studies of visual perception. Motor commands which produce eye movement (ie. extraretinal information) appear to play a vital part in the visual perception of whether the exterior environment is perceived to be moving or whether the body is perceived to be moving (see IIC.33). Coren (1986) has also demonstrated that efferent motor commands operate to produce varieties of visual illusions in configurations of line segments (eg. Mueller-Lyer illusion).

In specific, the motor theory of speech perception posits that the perception of spoken language is not based on auditory recognition of sounds which are translated into meaningful words, but that language is perceived from a recognition of the physical movements which would have to be made in order to make those sounds (Viviani and Stucchi, 1992, p. 230). This may consist of a "decoder" which perceives audio phonemes according to neoromotor commands of the muscles which would be used to produce the sounds (Liberman et al., 1967). That is, speech perception requires "the hearer to utilise the same central neural machinery that would be involved in speaking" (Weimer, 1977, p. 283). The motor commands which would be necessary to make the speech sound are used to interpret the phonic stimuli, but these motor actions are known internally rather than having to be fully enacted (Ibid, p. 282). Likewise, Sperling (1967) developed a model in which the visual image of a letter is stored in memory and rehearsed as a "'program of motor-instructions'" (p. 291). This is sometimes conceived in terms of subvocal articulatory movements which appear to form the basis of verbal rehearsal rather than the auditory sounds of the words (Baddeley, 1990, pp. 71-81; Baddeley et al, 1981; Hintzman, 1965; 1967; Levy, 1971).

The motor theory of speech perception can be extended to the perception of other types of stimuli. The perceptual systems are seen by Weimer (1977) as "motor skills production systems" since the act of perceiving is seen as an act of constructing motor actions which correspond with the stimulus (p. 283). This process of constructing motor actions during perception is equally applicable to the processes of imagination and hallucination (p. 289).

The motor theory of perception is most readily applicable to spatial perception because of the critical role of body movements during spatial learning. According to the motor theory, knowing the location of an object in space means knowing the motor commands and movements necessary to reach the object (Viviani and Stucchi, 1992, p. 232). This agrees with Piaget's view that "in order to know objects, the subject must act upon them" and so "knowledge is constantly linked with actions or operations" (Piaget, 1970, p. 104). The development of abstract spatial representations through motor actions has been explored in detail in the classic work on childrens' spatial learning by Piaget and Inhelder (1967). Accordingly, in sociological studies Hall (1966, p. 108) points out that "perception of space is dynamic because it is related to action - what can be done in a given space - rather than what is seen by passive viewing".

Shapes of objects are originally learned by correlating visual appearance of seeing the shape with the kinesthetic experience of touching the shape. When later seeing the same shape the kinesthetic-motor actions of touching such a shape are recalled (without actually touching the shape or doing the movements again). Festinger and Colleagues (1967) found support for this theory by training Subjects to associate a visually straight line with a curving body movement by having Subjects touch curved objects while looking through prisms which made the objects appear straight. This visual/motor relationship led to perceptions of curved body movements as indicating a straight line in visual space. They conclude that visual perception is based on "preprogrammed efferent [motor] instructions that are activated by the visual input" (p. 34).

This interior knowledge of motor processes which serves as the basis of motor theories of perception is referred to by Viviani and Stucchi (1992) as "implicit motor competencies". That is, an implicit understanding of biomechanical "motor regularities and constraints" which limit the variety of body movement characteristics (p. 235). The influence of implicit motor competencies on perception has been shown is a variety of studies.

When a sequence of similar stimuli are presented in slightly different spatial locations the Observer will frequently perceive this as a single stimuli which is moving through the space. This is known as "apparent motion" (Johansson, 1975; Kolers and Pomerantz, 1971). A common example is the perceived movement of lights on a theatre sign resulting from a sequence of lights turning on and off in sequence. The typical effect is that apparent motion will be perceived along the shortest possible path from the first stimuli to the next (eg. Shepard, 1984). This same type of apparent motion will be perceived when viewing a sequence of human body poses. However, in this case the pathway of the illusory movement will conform to anatomic constraints even if this is not the shortest distance between the position of a limb in one photo to the next photo (Shiffrar and Freyd, 1990). This indicates an implicit understanding of biomechanical constraints which exerts an automatic influence on perception.

When lights are attached to the major joints of a human body (eg. knees, hips, etc.) and these are observed in darkness (ie. the lights can be seen but the actual physical body cannot be seen) Subjects will instantly recognise movements of the lights as being a human body (Johansson, 1973; 1977). These findings indicate an implicit knowledge of human movement constraints. What is more significant for the motor theory of perception is that Subjects would have had the greatest amount of visual experience seeing their friends' gaits, and the least amount of visual experience seeing their own gait, yet when viewing the gaits on a video recording (showing only a group of twelve lights, one at each of the major skeletal joints, and thus unable to see the actual physical body) Subjects recognised their own gait better than they recognised their friends' gaits (Beardsworth and Bukner, 1981). This supports the idea that Subjects recognised their own gaits best because of their implicit knowledge of their own personal motor processes.

Viviani and Stucchi (1992) review a biomechanical constraint which specifies a "functional relation" between the velocity of the hand (in a multi-joint movement) and the degree of curvature of the hand's pathway. This relation is precisely specified in a ratio known as the "two-thirds power law" (p. 236). In general terms the hand's velocity will decrease in regions of high curvature and will increase where the curvature is more flat (p. 239). They characterise this constraint as a "biological signature" and review evidence that perception will implicitly conform to this signature.

Viviani and Stucchi (1991) showed Subjects a spot of light moving in an ellipse or random curved patterns. When the velocity of the moving light was actually constant Subjects perceived that its velocity was changing. Subjects attempted to adjust the velocity of the light until it appeared to be moving at a constant speed throughout the pathway (the velocity was automatically allowed to be variable from one part of the path to another, unbeknownst to Subjects). When the light appeared to Subjects to be moving at a constant speed, in actuality the velocity modulations and the degree of pathway curvature were conforming with the two-thirds power law. Thus it appears that the motion of the light was perceived according to implicit knowledge of motor constraints.

Subjects were also shown recordings of movements of lights attached to the major joints of a human body and asked to adjust the velocities of the lights until the body movement looked as "natural" as possible. In this case they also adjusted the velocities to conform with the two-thirds power law (Viviani and Stucchi, 1992, pp. 240-242).

IIC.40 Conclusions: Kinesthetic Spatial Cognition

"Kinesthetic spatial cognition" is defined as cognitive processes (eg. imagery, mental manipulations) which are performed on kinesthetic spatial information. Support for this concept is built-up from psychological theory. A great deal of research has distinguished spatial cognition from verbal cognition as using separate cognitive resources. Spatial information can arise from separate visual, audio, and kinesthetic perceptual-motor systems but is eventually represented in a unitary spatial memory system. Kinesthetic-motor knowledge is considered by many researchers to inherently require cognitive processing rather than consisting solely of sensory-motor responding. Kinesthetic-motor activity has long been identified as being at the basis of all spatial learning and is hypothesised to function as a spatial rehearsal mechanism (eg. eye movements). Body movements also appear to serve as a mechanism whereby spatial information arising from different receptors is compared and calibrated so that the various spatial sensations "read" the same. Many theorists also purport that kinesthetic-motor information is at the basis of all types of cognitive processes (including verbal). This concept of "kinesthetic spatial cognition" has not been heretofore explicitly developed in cognitive psychology and so constitutes new knowledge. This provides a cognitive and motor control context in which to reevaluate choreutics.

III. COGNITIVE STRUCTURES OF KINESTHETIC SPACE

The concept of kinesthetic spatial cognition defines an overall realm within which the choreutic conception can be reevaluated. Four principal components of choreutics are identified here as also having been well developed in in psychological and motor control research, briefly; A) Systems of reference; B) Location code; C) Map-like spatial images, and; D) Symmetrical transformations. This provides psychological validity for their use in the choreutic system.

Section IIIA considers how spatial information must be defined relative to a system of reference. Types of egocentric (body-relative) and exocentric (environment-relative) reference systems have been identified in cognitive studies. Further differentiated reference systems have been distinguished in choreutics and Labanotation which could provide tools for cognitive studies.

In section IIIB a variety of research is considered which indicates that the mental representation of kinesthetic spatial information is based on individual locations. These positions of agonist/antagonist equilibrium are evident as curvature peaks between individual strokes in the trajectory formation model. Curved versus angular paths are created by the amount of overlap between successive strokes. A virtually identical structure is used in choreutics where paths are identified according to observable locations of "peaks". Coordinative structures are identified as the body-level counterpart to the spatial-level of the location code. A library of reflexive movements or "coordinative structures" allow the body to automatically accommodate to the planned trajectory of a body-part.

Section IIIC considers how individual locations are conceptually joined together into map-like images (cognitive maps) which simultaneously represent the entire spatial environment. Choreutics uses polyhedral-shaped cognitive maps of the kinesphere (variously termed, grids, nets, scaffolding, etc.).

Varieties of kinesthetic-motor symmetrical transformations are identified in section IIID, these include body-transfer, translation, sizing, reflection, rotation, and retrogradation. The ability to perform symmetrical transformations is identified as essential to spatial cognitive ability. Choreutic "scales" are identified as being bodily and cognitive practice in executing and conceptualising symmetrical transformations and bodily adjustments to maintain dynamic equilibrium.

IIIA. Systems of Reference

Spatial information (eg. directions) must be known relative to some system of reference, otherwise its meaning will not be clear. For example, the direction "forward" might be considered relative to the anterior surface of the body, or it might be considered relative to the front of a room (eg. "come forward", that is, come to the front of the room). The use of systems of reference in spatial cognition research has been generally distinguished into egocentric (relative to the subject's body) or exocentric (relative to the exterior environment) systems of reference. Several other more detailed systems of reference have been distinguished within choreutics and Labanotation.

IIIA.10 Egocentric versus Exocentric Reference Systems in Psychology

Spatial cognition research has generally distinguished between the egocentric reference system in which directions are conceived as relative to the body, versus the exocentric reference system in which directions are conceived as relative to the surrounding environment.

IIIA.11 General Distinctions.

The egocentric and exocentric reference systems are referred to in many ways. These include the "personal and extrapersonal frames of reference" (Ruff, 1985; Ruff et al., 1981), as "viewer centred" versus "object centred" (Frisby, 1986, p. 171), as "body-related reference" verses "allocentric", as the "spatial reference system" or "environment-related reference" (Larish and Stelmach, 1982), as "viewer-centred frame of reference" versus "frames of reference that are embedded in external objects" (Hinton and Parsons, 1981), as a "body-based reference system" versus an "objective gravity-based reference system" or an "environmental frame of reference" (Riesser and Pick, 1976), or as the "coordinates of body space" versus the "coordinates of external space" (Souder, 1972, p. 14).

The egocentric reference can be described as a "direct dialogue" with the perception of the world, producing a "body-centered mapping" of the space, while the exocentric reference consists of "mental representations" which can "step back from the immediate sensory input" about the world and to compute a more abstract "allocentric space-coordinate system" (Paillard, 1987, p. 43). In an egocentric, "subject-relative" bodily coordinate system the retina, head, torso, or pelvis etc. serve as the frame of reference, while in an exocentric, "object-relative" external coordinate system objects in the visual field serve as the frame of reference (Mack, 1986). Roland (1979) asserts that the egocentric "intrapersonal space" and the exocentric "extrapersonal space" present different types of cognitive tasks, producing different cortical activation patterns.

For visually perceived figures, pictures, etc., the egocentric orientation can be referred to as the "retinal orientation" (ie. in the same orientation relative the the subject's eye regardless of the orientation relative to gravity). The exocentric orientation might consist of a gravitational orientation (ie. the orientation relative to gravity regardless of the retinal orientation) or as a particular orientation relative to a visual reference "frame", or other visual features which surround the object (Rock, 1973, p. 11).

The distinction between egocentric and exocentric reference systems is important in the theory for the visual recognition of objects which has been developed for computer programs. Egocentric representations are conceived as consisting of a single viewpoint of a visual object while exocentric representations consist of "viewpoint-independent representations" of an object so that it can be recognised from any angle. Exocentric representations are centred in the object rather than being centred in the retinal image of the observer. The directions (eg. vertical, lateral, sagittal) of an exocentric representation can be based on the dominate axes which are inherent in the physical structure of the object. These salient axes then become the basis for describing the length, width, etc. of the object in an exocentric fashion. When there are no obvious axes within the shape then the gravitational vertical is used as the basis of the exocentric reference system. Successive viewer-centred images are used to derive an updated object-centred (viewpoint independent) representation of an object (Frisby, 1986; Humphreys, 1983; Hinton and Parsons, 1981; Marr, 1980; Marr and Nishihara, 1978).

In the memory and recall of spatially directed body movements an egocentric reference system can be conceived as recalling a particular bodily "response" while an exocentric reference system can be conceived as recalling an exterior spatial "place" (regardless of the bodily movement involved) (Bremner and Bryant, 1977). That is, the egocentric representation relies on a kinesthetic sensory code, while the exocentric representation relies on an abstract spatial code.

However, Millar (1981) distinguishes between two types of "egocentric" spatial code. Egocentric "movement coding" consists of knowing a spatial location according to a particular body movements required to get there, whereas egocentric "self-referent coding" consists of knowing a spatial location according to its relationship to one's own body (eg. that the location lies on the body's median plane, or is directly in front of the right shoulder, etc.). For example, an egocentric self-referent code can be recalled with different body movements such as reaching to a body-relative location with either arm.

IIIA.12 Developmental Progression.

A developmental progression is identified in which infants tend to base their knowledge of spatial locations on an egocentric representation in which locations of objects are recalled by reproducing the same movements which were used to experience the locations originally. However, older children and adults have learned to use an exocentric representation in which locations of objects can be recalled independent of the particular movements or the body's orientation relative to the space (Acredolo, 1977; Bremner and Bryant, 1977; Hardwick et al., 1976; Piaget and Inhelder, 1967).

IIIA.13 Egocentric and Exocentric Representations in Spatial Cognition.

Depending on task requirements and the intention of the Subject, spatial information is sometimes egocentrically represented and sometimes exocentrically represented.

In the typical "oblique effect" (see IVA.52) adult humans can identify lines or rectangles faster if they are oriented vertically or horizontally than if they are oriented diagonally (45°). The system of reference operating in this oblique effect can be isolated by tilting Subjects (45°) so that gravitational vertical and horizontal lines (exocentric) are oriented diagonally relative to the retina (egocentric) (and vice versa, gravitational diagonal orientation is equivalent with retinal vertical and horizontal orientation). In this condition Attneave and Olson (1967) found that the oblique effect corresponds to the (exocentric) gravitational orientation rather than the (egocentric) retinal orientation.

Likewise, Rock (1973) experimented with a variety of visual stimuli and found that the time to recognise a visual figure is typically based on its (exocentric) gravitational orientation rather than its (egocentric) retinal orientation. For example, if a visual figure is tilted away from its usual gravitational orientation it will take longer to recognise, but tilting a Subject so that an object is not in its usual retinal orientation (but retaining its usual gravitational orientation) has no effect on recognition time.

Similarly, Rieser and Pick (1976) probed the reference system used in kinesthetic perception. In "haptic" perception Subjects grasped a bar (oriented vertically, horizontally, or diagonally) with their hand, and in "tactual" perception the bar (in a particular orientation) was pressed against Subjects' forehead or abdomen. Subjects' bodies were then tilted and they attempted to recognise the particular bar orientations from this new bodily orientation. The "tactual" learners tended to recognise the stimuli according to the egocentric body reference system and the "haptic" learners tended to recognise the stimuli according to the exocentric gravitational reference system. It was concluded that haptic sensations (grasping the bar) are learned according to a gravitational reference system since joint and muscle movements are closely integrated with vestibular information within the kinesthetic perceptual motor system (eg. reflexive motor actions can be induced by changes in body orientation). However, purely tactual sensations (the bar pressed against the skin) are not tied to vestibular information about gravity but are typically used to identify the egocentric location of a skin irritation (eg. an itch).

However, Rieser and Pick (1976, p. 118) noted that Subjects asked questions (which were not answered by the experimenters) about whether they should interpret the stimuli according to gravitational or bodily orientation. Thus it appears that Subjects were aware of the possibilities of perceiving stimuli according to either reference system. Also, Olson and Attneave (1970) found that both retinal and gravitational orientation played a part in how the orientation of simple figures were perceived within a group of similar items. This corresponds to Attneave and Reid's (1968) finding that by specifically instructing Subjects to learn visual stimuli according to their egocentric retinal orientation that the oblique effect can also occur relative to the egocentric reference system. They conclude that the orientations which are *perceived* as vertical or horizontal are recognised faster than those perceived as diagonal, and that this perception may be either egocentric (retinal) or exocentric (gravitational) depending on the intention of the subject.

Attneave and Benson (1969) also found that Subjects could use either an egocentric or an exocentric reference system. They taught Subjects to respond to vibrations at several locations on each hand, then the hands were switched so that the vibrations were in the same (exocentric) environmental locations, but were in contact with different (egocentric) bodily locations. Subjects could voluntarily respond equally well to vibrations at the same environmental location or to vibrations at the same bodily location. However, Subjects who were not blindfolded exhibited a greater tendency to respond to exocentric environmental locations, suggesting that vision tends to create a reliance on an exocentric reference system.

In some experiments the locations and orientations of visual objects appear to be represented in an egocentric body-relative code. Attneave and Farrar (1977) showed Subjects seven objects on a shelf and later asked questions (with the objects out of view) about whether an object (or a part of an object), was to the right or left of another object (or part of an object). The questions were answered fastest by "control" Subjects who remained facing the objects so that their egocentric and exocentric locations were unchanged. The questions were answered just as accurately (though with a slower response time) by other Subjects who were turned around (180°) and visualised the objects in front of themselves just as they had looked before (egocentric locations in the visual image were identical but exocentric room-relative locations were reversed). The questions were answered least accurately (and slower than the control Subjects) by Subjects who were turned around (180°) and visualised the objects behind themselves just as they actually are in the real world (egocentric locations in the visual image were reversed but exocentric room-relative locations were identical). These results indicate that remembering the egocentric body-relative locations of the objects was easier than remembering the exocentric room-relative locations of the objects.

The typical exocentric spatial representation is also identified in the mental representation of body movements in terms of a spatial location code. This has been demonstrated in spatial positioning tasks in which either limb can often recall a final location just as well regardless of which limb learned the location. That is, the same limb can learn and recall the location (intra-limb), or one limb can learn the location and the other limb can recall the location (inter-limb) (Larish and Stelmach, 1982; Stelmach and Larish, 1980). This exocentric spatial location code for the representation of body movements is more fully considered in section IIIB.

IIIA.14 Egocentric / Exocentric Translation.

An exocentric environment-relative location must be translated into an egocentric body-relative code in order to direct a bodily movement toward that location (Jeannerod, 1983; Saltzman, 1979, p. 104). If the location of an object is known relative to the environment, then the orientation of the body and its parts need to be known relative to that environment, and thus a body part can be moved in the correct direction toward the location of the object. An exocentric spatial code is valuable since it provides a knowledge of the structure of the environment or of an object, independent of the orientation or movements of the body. However, for the body to reach toward a particular exocentric location, the current orientation of the body in the environment must be used to translate the exocentric code into an egocentric code utilised by body movements.

IIIA.15 Misperceptions of Egocentric and Exocentric Directions.

The ability to determine the exocentric gravitational vertical is biased by other exocentric and egocentric influences. Many of these effects are related to "visual kinesthesia" in which visual exocentric information influences the perception of egocentric kinesthetic information (see IIA.12).

The visual environment can be experimentally tilted by having Subjects look through a tilted mirror (Asch and Witkin, 1948a) or by looking into a specially constructed tilted room (Asch and Witkin, 1948b). Under these conditions Subjects' perception of the true gravitational vertical or horizontal (by verbally indicating the orientation of a visual rod) is biased to correspond with the tilt of the environment. Thus, the (exocentric) "axes of the visual field" exert powerful influence on the perception of the (exocentric) gravitational vertical, regardless of the (egocentric) "position of the body" (Asch and Witkin, 1948a, p. 337). The effect is so robust that even with full knowledge about the experimental set-up Subjects and Experimenters both perceive a plumb-line within a tilted environment to be hanging at an angle to the vertical, and when standing in the environment they (incorrectly) perceive themselves to be standing off-vertical while the tilted room is perceived to be oriented upright (Asch and Witkin, 1948b). Similarly, in a "body adjustment test" Subjects are asked to adjust a chair so that they are sitting upright inside a tilted room, in which case many Subjects will adjust the chair so that their body posture is aligned with the tilted room rather than the gravitational vertical (Witkin et al., 1962, pp. 4-5).

Subjects can accurately adjust a luminous rod to the gravitational vertical in a dark room, but when a Subject's head or body is tilted then this (egocentric) information will cause perception of the (exocentric) gravitational vertical to be less accurate (Witkin and Asch, 1948a). This effect is greater when the Subject actively produces the body tilt than when the subject is passively supported during the tilt (Werner et al., 1951). Similarly, when electrical stimulation is applied to one of the sterno-cleidomastiod neck muscles, or audio stimulation is given to one ear (these conditions likely producing a subtle change in the perception of egocentric orientation) (Wapner et al., 1951a), or when the Subject undergoes a rotary acceleration or deceleration (creating vestibular stimulation) (Wapner et al., 1951b), then the rod will not be accurately adjusted to the (exocentric) gravitational vertical.

These same effects occurred when the rod was kinesthetically adjusted to the vertical (eg. blindfolded Subjects manipulated the rod with both hands, rather than giving verbal instructions for the experimenter to move the rod). Head tilt, body tilt, and rotary acceleration / deceleration all created kinesthetic misperceptions of the gravitational vertical (Wapner and Werner, 1952).

Misperceptions of the gravitational vertical when the head or body is tilted may be encouraged by the activation of reflexive righting reactions. For example, Hellebrandt and Colleagues (1962b) give several examples of the "Ikai stick" which is held by Subjects in a gravitational vertical alignment but which spontaneously deviates off of this alignment (because of asymmetric changes in the body's muscular tone) when the tonic neck reflex is induced by turning or tilting the head.

When a luminous frame is placed around the luminous rod (the "rod-and-frame task") then an (exocentric) tilt of the frame will create a misperception of the (exocentric) gravitational vertical of the rod (Witkin and Asch, 1948b). It appears that the tilted rod-and-frame visual display induces an illusion of egocentric self-tilt. Thus, attempting to align the rod to one's own bodily superior / inferior axis is more accurate than attempting to align the rod to the gravitational vertical (Sigman, et al., 1979).

In a similar way, the perception of the rod's (exocentric) orientation to the gravitational vertical is also biased by the initial (exocentric) orientation of the rod (Werner and Wapner, 1952). Apparently the initial position is perceived as closer to vertical than it actually is (analogous to the frame being perceived as vertical in the rod-and-frame task), and so this misperception continues to influence the adjustment of the rod to the gravitational vertical.

In all these conditions discussed above the (exocentric) tilt of the visual environment (eg. a tilted room, a tilted frame) exerts an influence of the perception of the (exocentric) gravitational vertical. Typically, all of these effects are even greater when the (egocentric) orientation of the body is also tilted off vertical (Asch and Witkin, 1948b; Witkin and Asch, 1948b)

In analogous experiments, Subjects indicated the location of their body's median plane, rather than the gravitational vertical. Subjects marked a point on a piece of paper (with an unseen outstretched arm) which indicated the location of their body's (egocentric) median plane. When the eyes were fixated right or left of centre (head facing forward), or the head was turned right or left of centre (with the eyes fixated forward) then the perception of the median plane was also shifted (Werner et al., 1953). Similarly, when the head is turned right or left, pointing at a target is less accurate than if the head is facing forward (Wyke, 1965). In these cases the egocentric direction forward for the eyes and the egocentric direction forward for the head were both influencing the perception of the egocentric direction forward for the shoulders. These three different egocentric "forward" directions are identical to the notion of "divided fronts" as developed in Labanotation (see below). Other Subjects kinesthetically manipulated a rod into alignment with the perceived median plane of their body. A tilt of the head or body in the frontal plane also caused the perception of the median plane to deviate (McFarland et al., 1962).

IIIA.16 Field-dependence, Field-independence.

In the research just considered (IIIA.15) it was often noted that, while the exocentric visual environment (eg. the tilted frame or room) exerted an influence of the perception of the gravitational vertical, there were considerable and consistent differences between individual Subjects. Some Subjects were consistently influenced by the tilt of the visual environment while other Subjects consistently adjusted the rod close to the true gravitational vertical regardless of the tilt of the visual environment (Asch and Witkin, 1948a; 1948b; Witkin and Asch, 1948b).

Research into these individual differences gradually developed into a theory of "field-dependent" and "field-independent" perceptual styles. Witkin and Colleagues (1962) describe how this was originally based on individual differences in Subjects' spatial perception but the course of research revealed how this was indicative of psychological aspects of personality, or of individuals' "'style of life'" (p. 4):

> . . . the way in which each person orients himself in space is an expression of a more general preferred mode of perceiving which, in turn, is linked to a broad and varied array of personal characteristics involving a great many areas of psychological functioning. (Ibid, p. 1)

> . . . These [field-dependent / independent characteristics] reflect the quality of the person's experience of his surroundings, his way of perceiving and using his body, the nature of his relation to other people, and aspects of his controls and defenses. (Ibid, p. 3)

The rod-and-frame test (see IIIA.15) is only one illustration of Subjects' field-dependence/independence. Some Subjects perceive that the rod is vertical when actually it is aligned with the (tilted) frame. Their perception can be described as being "dependent" on the surrounding visual field. Other Subjects adjust the rod close to the true vertical regardless of the tilt of the frame. Their perception can be described as being "independent" of the surrounding visual field. This effect in the rod-and-frame task has been reliably correlated with many other spatial tasks (eg. finding a hidden figure in a complex design, inkblot interpretation, picture completion, object assembly, picture drawing; for details see Witkin et al., 1962).

Witkin and Colleagues (1962) conceive of field-dependence and field-independence as being two poles along a continuum rather than distinct types. Generally speaking, field-dependent people are described as "guided by the axes of the surrounding visual field rather than by the sensations from within the body" (p. 2). This greater bodily awareness of field-independent Subjects was confirmed in later research. Field-independent Subjects (as assessed by the rod-and-frame task) were found to be more skilled than field-dependent Subjects in "postural pursuit tracking" which requires a high degree of kinesthetic awareness (Souder, 1972).

Witkin and Colleagues (1962) describe how this conception of being influenced by the surrounding visual field was expanded to include Subjects' tendency to be influenced by any type of exterior stimulation. For example, field-dependent people are "likely to change their stated views on a particular social issue in the direction of the attitudes of an authority" (p. 3). The field-dependent perceptual style (relying on exterior stimuli rather than interior sensations) is thought to indicate a poorly developed "sense of body" which is linked to the "sense of self", and so these Subjects may tend to "have a less developed sense of their identity" (p. 5).

IIIA.20 Labanotation and Choreutic Reference Systems

At least five different systems of reference can be distinguished within choreutics and Labanotation according to their egocentric/exocentric components. These are identical to reference systems identified in cognitive studies but provide more systematic detail about variations in kinesthetic spatial referencing.

Five reference systems identified here are; 1) the constant cross of axes; 2) fixed points; 3) line-of-travel; 4) standard cross of axes, and; 5) body cross of axes. In addition, "divided fronts" can be identified when more than one "forward" is evident within the standard or body reference systems. Choreutic and Labanotation reference systems are used to specify the "kinds of orientation" (Preston-Dunlop, 1984, pp. 9-12) of the dimensional (Cartesian) cross of axes (Hutchinson, 1970, pp. 414-432) like a type of "key signature" (Preston-Dunlop, 1969, p. 136).

IIIA.21 Constant Cross of Axes Reference System.

The "constant cross of axes" (Hutchinson, 1970, pp. 105-106, 421-424; Knust, 1979a,b, examples 258d, 854b), or the "space dominant" reference system (Preston-Dunlop, 1984, p. 11) refers to an exocentric reference system in which Subjects "relate all directions to the dimensions of the room" (Preston-Dunlop, 1969, p. 136). The vertical dimension is aligned with gravity. The sagittal dimension is aligned parallel to the front/back axis of the room. The lateral dimension is aligned parallel to the right/left axis of the room. This could be called a room-relative reference system since it is based on the principal axes through the room (or any other spatial environment).

IIIA.22 Fixed Points Reference System.

Another exocentric system of reference can be defined according to "fixed points" in the room (or any other environment) (Hutchinson, 1970, p. 430; Preston-Dunlop, 1984, p. 11). The spatial directions (forward, back, up, down, etc.) are conceived as always being toward a specific location (eg. toward the window) regardless of the location in the room where a person is located, or which way the person is facing.

IIIA.23 Line of Travel Reference System.

A system of reference can be defined according to the line along which a person is locomoting through space. This is variously referred to as the "direction of progression", the "line of dance" (Knust, 1979a,b, examples 308e, 859a), the "line of direction" (Hutchinson, 1970, p. 431) or the "line of travel" (the term suggested by this author). In this exocentric reference system "forward" is conceived as being the direction in which the locomotion is traveling towards while "backward" is conceived as being the direction which the locomotion is traveling away from (regardless which way the person is facing). Likewise, "right" and "left" are conceived as being towards the right and left of the line of travel. The line of travel reference system is useful when directions for steps are related to the direction of travel (eg. ballroom dance).

IIIA.24 Standard Cross of Axes Reference System .

A typical effect in psychology experiments is that when people are not oriented vertically (eg. lying on the floor) they tend to conceive of "up" and "down" to be relative to gravity rather than relative to the body (see IIIA.13). Laban (1966, p. 18) described this same phenomena as "the beginning of an intellectual complication" in which we "transpose" the body vertical to the gravitational vertical. In choreutics and Labanotation this reference system is referred to as the "standard cross of axes", the "line of gravity cross of axes" (Hutchinson, 1970, pp. 414-433; Knust, 1979a,b, example 258b) or as the "standard orientation" (Preston-Dunlop, 1984, pp. 9-11) which is the "normal method of judging direction" (Preston-Dunlop, 1969, p. 136). The notion of "standard" refers to how this is the most typically used cognitive reference system and is the reference system assumed to be used in Labanotation or choreutics unless specified otherwise.

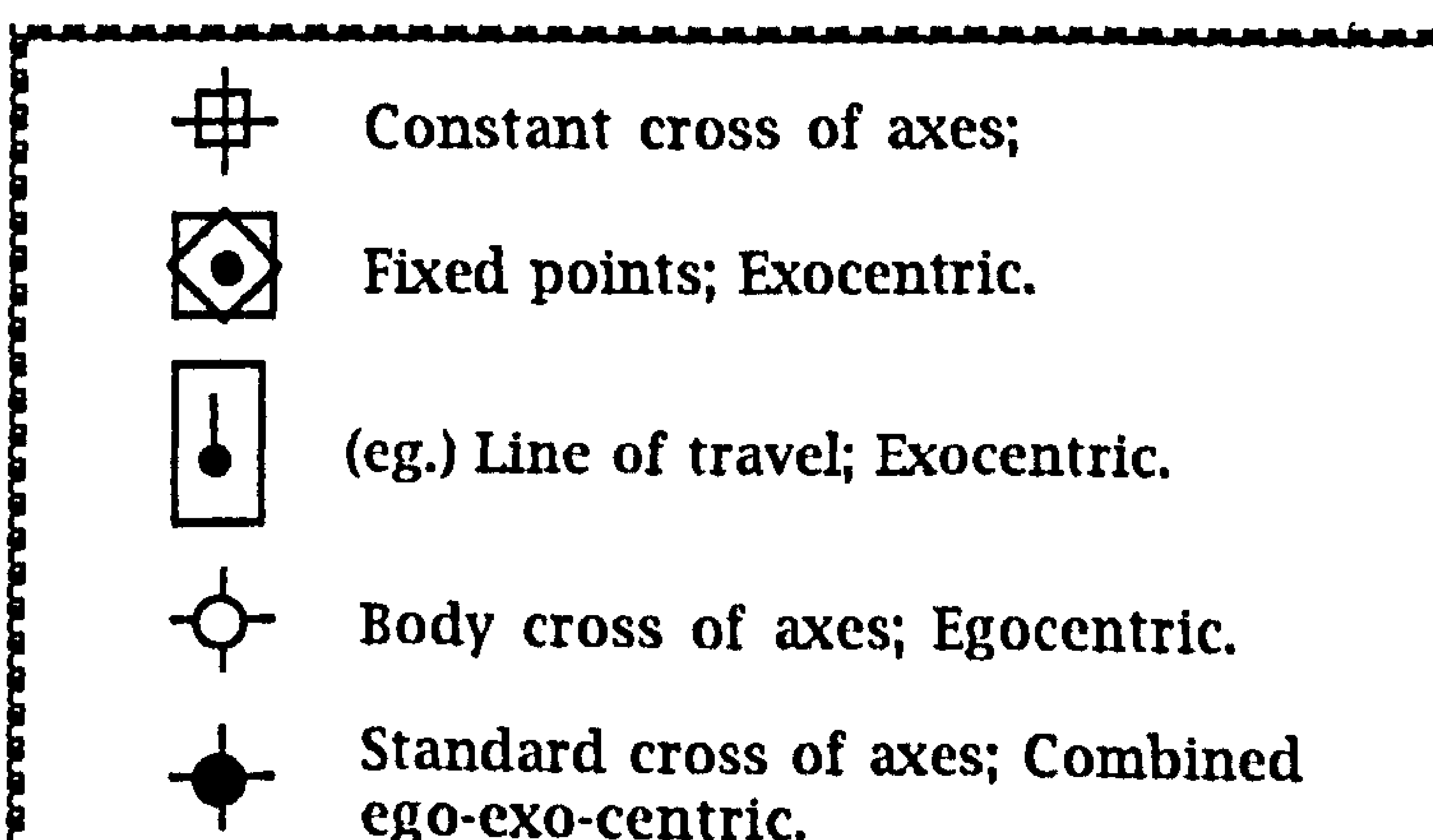

Figure IIIA-1. Labanotation symbols for reference systems (Hutchinson, 1970, pp. 416, 430-432; Knust, 1979a,b, examples; 258b,d,f, 308e, 854b, 859a; Preston-Dunlop, 1969, p. 137).

The standard cross of axes consists of a combination of egocentric and exocentric reference systems. The vertical dimension is oriented relative to the (exocentric) line of gravity. The sagittal and lateral dimensions remain always perpendicular to the line of gravity (ie. horizontal) and are oriented relative to the (egocentric) anterior/posterior body axis and the right/left lateral body axis.

IIIA.25 Body Cross of Axes Reference System.

In a purely egocentric reference system the vertical dimension is aligned with the superior/inferior bodily axis, the sagittal dimension is aligned with the anterior/posterior bodily axis, and the lateral dimension is aligned with the right/left lateral bodily axis. This is referred to in Labanotation and choreutics as the "body-cross of axes" (Hutchinson, 1970, p. 417; Knust, 1979a,b, example 258f) or as a "body dominant" reference system (Preston-Dunlop, 1984, p. 11) in which Subjects "relate all directions to the dimensions of the body" (Preston-Dunlop, 1969, p. 136).

IIIA.26 Location of "Centre".

The notions of egocentric and exocentric refer to the conceived location of the centre of a system of reference. Further specifications of the location of centre can also be made.

In Laban's (1963, p. 93) egocentric conception "the direction *c* [centre] is always in the body centre" (italics his). Preston-Dunlop (1978, p. 70) confirms that "Laban placed 'centre' at the body's centre, which is approximately at the navel. Medium level directions were thence, on level with the navel or waist and this applied to all limbs". Placing the centre at the body's centre is also advocated in other choreutic writings (Bartenieff and Lewis, 1980, pp. 25-28; Dell, 1977, p. 5; Laban, 1966, pp. 11-17).

An egocentric reference system can also be centred at any place within the body. For example, the hands are often described as creating a small kinesphere with the centre in the middle of the palm (Bodmer, 1974, p. 28; 1979, p. 7; Laban, 1926, pp. 72-73). It is also common to consider the space available to limb movement according to reference systems which are centred at the most proximal joint which is articulating (Bartenieff and Lewis, 1980, p. 26; Lamb, 1965, p. 52) and this is the conception of limb movement typically used in Labanotation (Hutchinson, 1970, pp. 32, 229). Different centres can also be distinguished within the torso; at the sternum, near the belly-button, and in the pelvis. Different dance styles can be observed to relate their movements to one of these three ego-centres in the torso (Bodmer, 1979, pp. 3-4; Preston-Dunlop, 1978, pp. 70-71).

These joint-centred systems of reference are used in this same way within motor control studies, for example as a "shoulder girdle-centred spatial coordinate system" (Saltzman, 1979, p. 104) or "retinocentric space" (Paillard, 1987). Likewise, in kinesiology when the reference planes are centred at the body's centre of gravity they are referred to as "cardinal planes" whereas if they are conceived as passing through a joint then they can be termed (eg.) shoulder joint planes (Rasch and Burke, 1978, pp. 97-98).

IIIA.27 Divided Fronts.

Further subdivisions can be identified within the standard or body reference systems. If the body is twisted (for example) it may be that the head is facing one direction, the chest is facing a different direction, and the pelvis is facing yet another direction. The question arises, which direction is "forward"? In Labanotation this situation is referred to as a "divided front" and three possible sub-reference systems are be used; 1) stance, 2) free-end of twisted-part, and 3) base of twisted-part (Hutchinson, 1970, pp. 307-310).

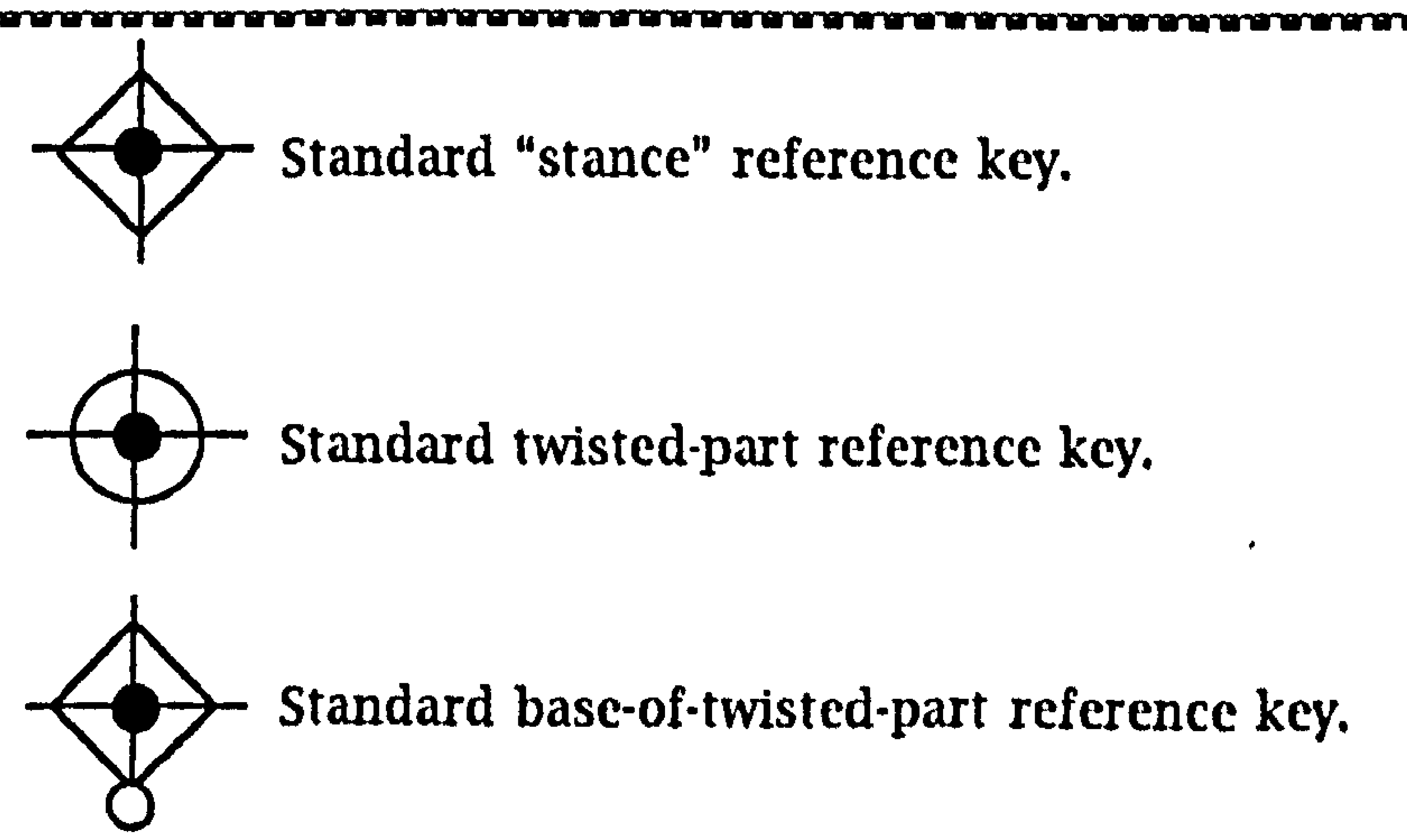

Figure IIIA-2. Labanotation symbols for standard cross of axes with a divided front (Hutchinson, 1970, pp. 309-310, 425-426).

The term "stance" is used to refer to a particular facing (towards front) which has been previously established by the facing of the entire body. This facing is then retained regardless of twistings of various body-parts. In Labanotation the forward direction determined by "stance" is usually used to determine the direction of steps (locomotion) regardless of the body twistings which occur during locomotor patterns (Hutchinson, 1970, p. 308).

The designation of the direction towards front can also be taken from the free-end or from the base of a twisted body-part. The "free-end" refers roughly to the distal extremity of the twisting body-part(s) while the "base" refers to the proximal point-of-attachment or to the body-part which is connected to the ground; for example (Hutchinson, 1970, p. 308):

Twisted body-part(s)	Base	Free-end
arm	shoulder	hand
whole-torso	feet	shoulders
head-neck	shoulders	head
chest	pelvis	shoulders
pelvis	feet	pelvis

The general rule used in Labanotation is that the forwards direction (ie. "front") is determined by the free-end when the pelvis, chest, shoulders, head, and neck are twisting, and is determined by the base of the body part when the arms or legs are twisting (Hutchinson, 1970, p. 308).

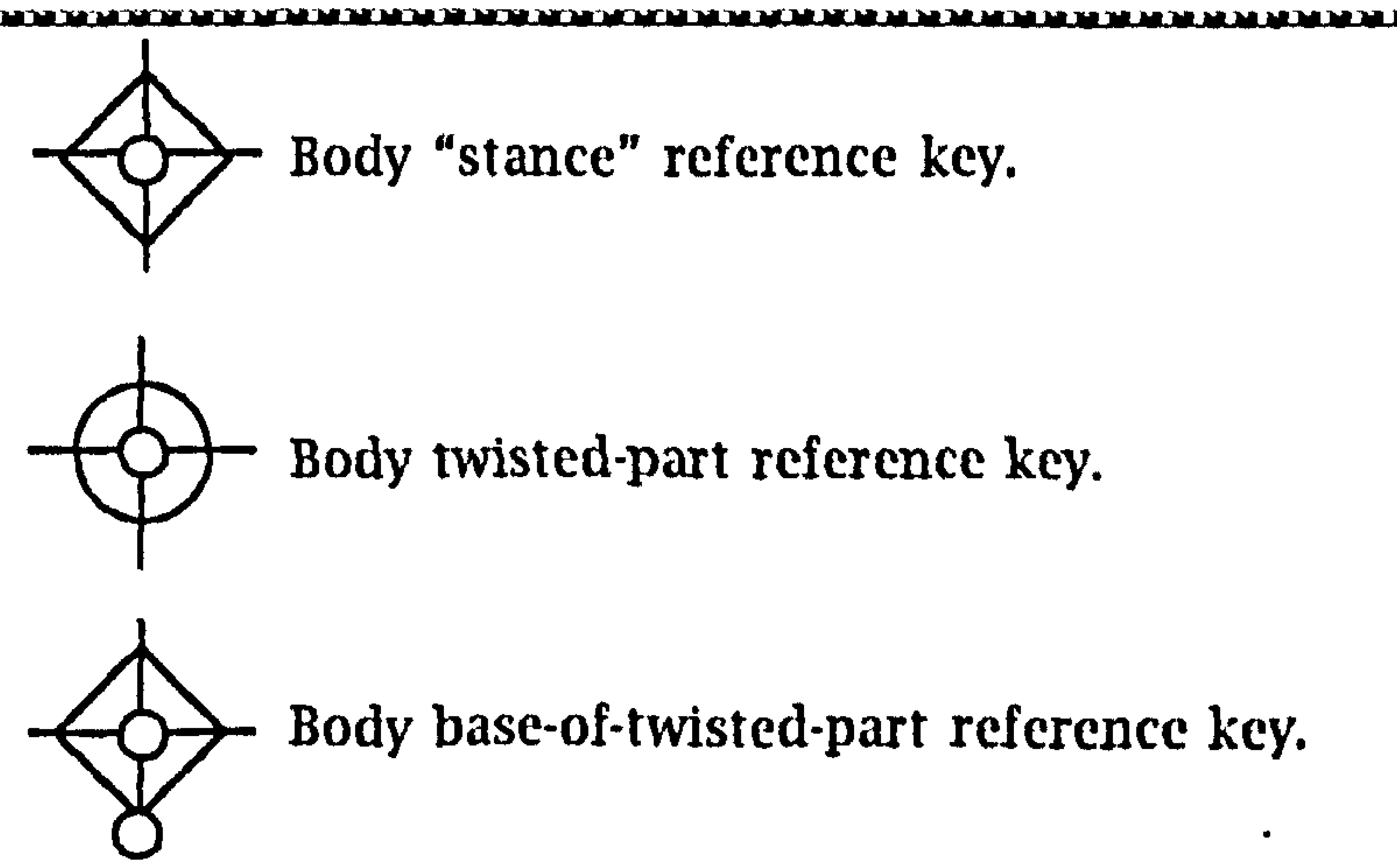

Figure IIIA-3. Labanotation symbols for body cross of axes with a divided front (Hutchinson, 1970, pp. 428-429).

IIIA.27 Labanotation Symbols for Reference Systems.

Labanotation symbols have been devised for the different reference systems (Fig. IIIA-1), for divided fronts in the body reference system (Fig. IIIA-2), and for divided fronts in the standard reference system (Fig. IIIA-3). These symbols might appear arbitrary but their orthography is based on a combination of components that are each used for similar meanings in other parts of the Labanotation system (this orthography is not reviewed here; see the references cited).

IIIA.30 Conclusions: Reference Systems

Spatial information must be defined relative to a system of reference. Types of egocentric (body-relative) and exocentric (environment-relative) reference systems have been identified in cognitive studies. Reference systems distinguished in Labanotation and choreutics are validated by the identification of similar reference systems within spatial cognition research. This similarity has not been heretofore explicitly identified and so constitutes new knowledge. A great deal of differentiation is provided in the Labanotation and choreutic reference systems which could serve as tools in spatial cognition research.

IIIB. Location Code

A variety of spatial cognition and motor control research indicates that the elemental units of spatial information used by the kinesthetic perceptual-motor system are individual locations (rather than distance moved, pathways followed, or particular muscles contracted). This validates Laban's conception of using individual locations as the basic kinespheric code for limb paths and poses in choreutics and Labanotation, which is virtually identical to the motor control model of "trajectory formation" (see IIIB.30).

IIIB.10 Spatial Positioning Tasks

Motor memory research often uses spatial positioning tasks in which Subjects grasp the handle of an apparatus which can be moved in a fixed direction along a straight line (linear positioning) or through an arc (angular positioning) (Appendix V).

IIIB.11 Location versus Distance Recall.

Subjects' ability to recall the end-locus of a positioning apparatus might be based on memory for the limb's location or on memory for the distance moved from the starting position to the final location. These two possibilities of distance recall or location recall can be experimentally isolated. The learning trial is undertaken normally. At the recall trial the beginning position of the apparatus is changed and the Subject attempts to reproduce either the distance moved, or the location moved to.

It is commonly demonstrated that locations can be recalled more accurately than distances (Kelso, 1977a; Marteniuk, 1973; Marteniuk and Roy, 1972; Posner, 1967; Roy and Kelso, 1977; Roy and Williams, 1979). Recalling the final location from a different starting location is just as accurate as recalling the final location from the same starting location. That is, information about the distance moved does not result in better location recall than when a different distance is moved (Keele and Ells, 1972; Roy, 1977). Thus, the fundamental code for the memory of limb-position appears to be the end-location rather than the distance moved.

These results were extended by Russell (1976) who used a task of moving a hand-held stylus from a starting to an ending locus (the direction of movement was not constrained as it is with a limb-positioning apparatus). One group of Subjects practiced recalling a final locus from a variety of different starting loci. They were then able to recall the final locus from a new (never before experienced) starting locus just as accurately as other Subjects who had repeated practices from this starting locus. Thus, the final location appears to have been encoded in memory rather than the direction or the distance moved.

Some researchers have found that after a retention interval distance recall exhibits a performance decrement while location recall is just as accurate as if recalled immediately. Filling the retention interval with a secondary task (digit computation or a visual-spatial reasoning) results in a performance decrement to locus recall but has no effect on distance recall (Laabs, 1973; Williams et al., 1969). This indicates that location information is mentally rehearsable while distance information is not. That is, the mental rehearsal of locus information causes it to not decay during an unfilled retention interval, but this rehearsal is disrupted by a secondary task during retention. Since distance is not rehearsable it decays an identical amount regardless of whether the retention interval is filled or unfilled. However, other research has demonstrated that recall of location and distance both suffer a performance decrement after an unfilled retention interval and neither suffers any further from a digit classification task during retention (Posner, 1967).

Regardless of rehearsiblity, location recall is always demonstrated to be more accurate overall than distance recall. This can be interpreted as evidence that limb movement is fundamentally encoded as an end-location. This is ecologically advantageous since an invariant end-location can be recalled regardless of variable movements which might be required to arrive at that location.

Distance information may be derived from location information by computing the change-of-stimulation from one position to another. Some researchers (Laabs, 1973; Roy and Williams, 1979, p. 237) suggest a strategy in which the duration of the movement is determined by counting to oneself. When starting at a different beginning locus the distance can be recalled by moving at the same velocity and for the same overall duration (measured by counting).

IIIB.12 Switched-Limbs in Positioning Tasks.

In contrast to the usual "same-limb" recall, Wallace (1977) used a "switched-limb" procedure in which the end-locus of a spatial positioning task is learned with one arm and recalled with the other. This is intended as a test of the "location code" or the "target hypothesis":

> According to the target hypothesis, kinesthetic information about a movement endpoint contacts the perceptual process, which, in turn, converts the actual kinesthetic signals into more abstract information. The location code is represented in memory as a point within the learner's three dimensional coordinate system. (Wallace, 1977, p. 158).

Similarly, Stelmach and Larish (1980, p. 167) refer to this as the "spatial location code" hypothesis which posits that "spatial localization is made on the basis of an abstract spatial code, rather than on stored proprioceptive information". If different body-parts can each recall a location equally well, this would indicate that the memory code is more abstract and not based on the actual muscles used.

Wallace (1977) found that an end-locus in a linear positioning task can be recalled equally well with a leftward or a rightward motion of the same arm. However, the location could be accurately recalled with the other switched-arm only in the same direction of motion as it was learned. This provides partial support for an abstract location code.

Larish and Colleagues (1979) found that recalling a location with the same arm was just as accurate as simultaneously matching the location with the other arm, but that recalling the locus later with the other arm was not as accurate. However in this "dual-track apparatus" the two arm-hands were actually recalling two different locations (p. 216) and so it is not directly comparable to Wallace's (1977) switched-limb task. Nevertheless the accuracy of matching the location with the other arm provides some support for the use of an abstract (body-part free) location code.

In further experiments, same-limb recall of a locus was more accurate than switched-limb recall for long (50-60cm) movements, but that these were equally accurate for shorter movements (Stelmach and Larish, 1980; Larish and Stelmach, 1982). This also provides partial support for the locus code. These researchers hypothesize that the less distant targets may fall within the Subjects egocentric, body-based reference system (see IIIA). However, this explanation appears contrived to fit their results and puts artificial limits on the range of spatial locations which can be mentally represented egocentrically.

IIIB.20 Mass-Spring Model for Motor Control

A dominate theory of motor control is known as the "mass-spring model" (Jordan and Rosenbaum, 1989, p. 732; Pew and Rosenbaum, 1988, p. 479; Sheridan, 1984, pp. 69-73) or as the "spring hypothesis" (Rothwell, 1987, p. 29) and posits that the muscular-skeletal system is controlled like a system of masses and springs. These are considered analogous to the mass of the limbs and external objects, and the spring-like character of muscles. The mass-spring model provides a theoretical foundation for a location code in movement memory.

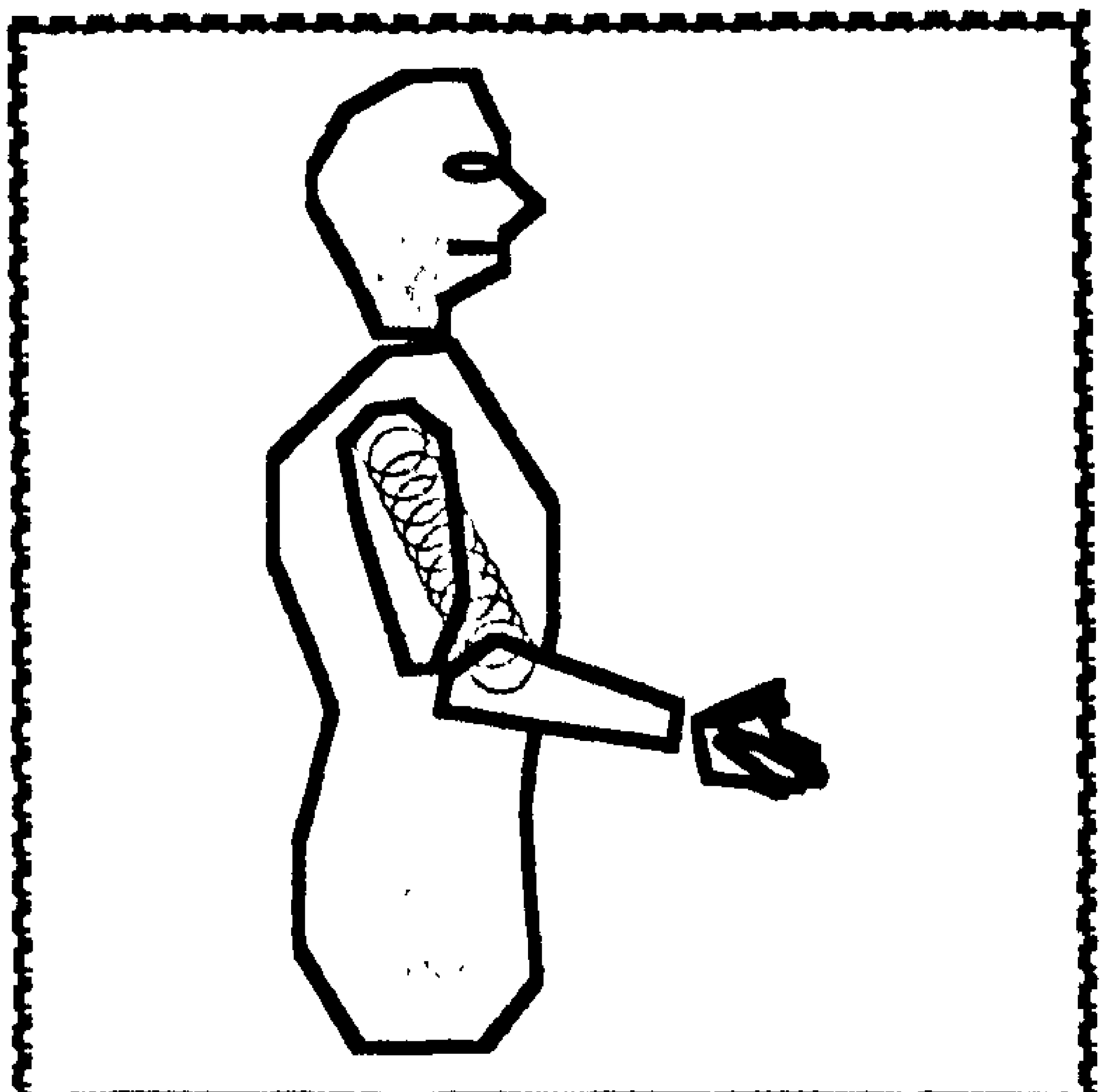

Figure IIIB-1. The biceps as a spring supporting the mass of the forearm.

IIIB.21 Mass-Spring System.

The simplest mass-spring system consists of a spring attached to a secure fixed support on one end and a free movable mass suspended on the other end (Tuller et al., 1982, p. 266). For example, the spring is analogous to the biceps muscle attached at the fixed end to the shoulder and at the free end supporting the mass of the forearm, hand, and any object held in the hand (Fig. IIIB-1).

A characteristic of springs is that when set in motion they oscillate back and forth until finally coming to rest at an equilibrium point. The same thing occurs if a person attempts to hold their forearm still when it is unexpectedly disturbed by an external force; their forearm will oscillate between lengthening and shortening until returning to the original position. This mimics the behaviour of springs and attests to the elastic characteristic of muscles. Because of this well known elastic property of muscles they are considered as "oscillatory systems" (Tuller et al., 1982, p. 267) and as analogous to springs (Bernstein, 1984, p. 79; Bizzi et al., 1976; Cooke, 1979; 1980; Kelso and Holt, 1980; Nichols and Houk, 1976; Rack and Westbury, 1969).

IIIB.22 Agonist / Antagonist Equilibrium Points.

The mass-spring model posits that static limb positions occur when the resultant forces of agonist and antagonist muscles are in equilibrium. This is known as the "equilibrium point" (Jordan and Rosenbaum, 1989, p. 733, Pew and Rosenbaum, 1988, p. 480; Polit and Bizzi, 1978). When a new equilibrium point is set then the limb will move in the shortest way possible to the new location of agonist/antagonist equilibrium.

Equilibrium points specify positions of the limbs without specifying the movement's distance or path. This can be referred to as "'final position control'" (Bizzi and Colleagues, 1982, p. 397; Hogan, 1984, p. 2745) and is synonymous with the concept of a "location code". The opposing tensions in agonist and antagonist muscles drive the limb towards the equilibrium point in the most direct way possible.

IIIB.23 Equifinality.

The mass spring model predicts that the limb will reach the intended equilibrium point regardless of temporary unexpected perturbations of the moving limb (eg. encountering an obstacle) and unplanned for variability such as joint viscosity, limb inertia, and external obstacles. "Interaction torques" will also be generated in which inertia from one body segment is transferred through a joint into another segment (Bizzi and Mussa-Ivaldi, 1989, p. 775). These have been shown to occur to a significant amount even during arm movements at medium speed and so must be accounted for in the control of movement (Hollerbach and Flash, 1982).

According to the equilibrium point hypothesis the spring-like behaviour of muscles will allow the limb to automatically adjust its path and arrive at the intended destination point without sensory feedback and regardless of these unpredictable physical variables. This is known as the property of "equifinality" (Jordan and Rosenbaum, 1989, p. 733; Kelso and Holt, 1980, p. 1183; Tuller et al., 1982, p. 268). This allows motor actions to automatically adjust to unplanned for variables without having to replan and reinitiate the movement (Berkenblit et al., 1986; Feldman, 1986; Sakitt, 1980; Saltzman and Kelso, 1987).

Equifinality has been demonstrated. Polit and Bizzi (1978; 1979) trained monkeys to point their forearm at a light in exchange for a reward (without sight of the limb). After the onset of the stimulus light (cuing the monkey to move) if the limb was briefly pushed away from its starting position the pointing movement was still just as accurate (even when kinesthetic feedback had been eliminated by surgical means). If the limb was unexpectedly pushed past the target it would reverse its motion and return to the target locus. This same effect occurred when exterior loads were temporarily applied to head movements toward a visual target in both normal and surgically deafferented monkeys (Bizzi et al., 1976; 1978; Cooke, 1979). Brief displacement of the finger also did not effect the finger's accuracy at achieving the final position for both deafferentiated (Pressure cuff around the wrist) and normal human Subjects (Kelso and Holt, 1980).

If a continuous (rather than temporary) additional force is applied to the limb then a greater force overall will be required to reach the target and so it will be undershot. This is analogous to the different muscular forces required for moving masses at different orientations to gravity. For example, Schmidt and McGown (1980) measured the accuracy in pointing a lever at a target within a particular duration of time (≈0.08-0.09 sec.). The mass of the lever to-be-moved was unexpectedly increased or decreased. When the lever moved in the horizontal plane (thus no additional weight to overcome, only inertia of moving a mass horizontally) the final target was recalled just as accurately but the duration of the movement changed (longer duration for greater mass, shorter duration with less mass). When the lever moved in a medial plane the addition of a mass requires greater overall muscular force to achieve the target position. In this case the target was undershot and the duration showed the same pattern as before. The target was also undershot when an additional continuous force was applied with increased spring tension to a horizontally moving lever. According to the mass-spring model a continuous additional force is compensated for by increasing the overall tension or "stiffness" in all muscles (Cooke, 1980; Tuller et al., 1982, p. 266), however the essential location code of the equilibrium point is unchanged.

<u>IIIB.24 Sensory Feedback Required for Fine Control</u>.

The mass-spring model describes a location code in movement control which is not reliant on kinesthetic feedback for its accurate recall. However, movement which requires fine adjustments and ongoing control will be dependent on feedback. Day and Marsden (1981; 1982) measured the accuracy of pointing to a target by thumb movement (interphalangael flexion). When the friction acting against the thumb's movement was unexpectedly changed it led to errors in arriving at the target when Subjects did not have guidance from sensory feedback ("digital nerve block" eliminated joint and skin sensations). A case study is also reported about a patient with relatively normal movements but having a lack of sensation below the elbow.

Gross forearm/hand movements could be performed well without visual guidance (eg. drawing figures in the air, imitating piano playing, moving to a target), however perturbances of the thumb, and other tasks requiring fine adjustment to environmental stimuli (eg. carrying a cup of water, grasping and writing with a pen) were quite difficult without visual guidance (Day et al., 1981; Rothwell et al., 1982). It is concluded that afferent feedback is essential for the fine control required in this type of movement. This is consistent with Sanes and Evarts (1983) findings that unexpected brief perturbations to a limb when recalling a limb position (via forearm pronation/supination) did *not* effect the accuracy for large movements (30°) but *did* effect greater errors in accuracy for smaller movements (3°, 10°).

IIIB.25 Virtual Positions and Virtual Trajectories.

In accordance with the mass-spring model Hogan (1984) distinguished between the abstract conceptual representation of the "movement organization" and the actual physical embodiment of the "movement execution" (p. 2745). The term "virtual position" is used to refer to an intended limb position which would be produced by a new equilibrium point, and "virtual trajectory" refers to a sequence of virtual positions (p. 2746). Variable factors such as limb inertia, joint viscosity, and external forces acting on the limb may cause the execution of the actual trajectory to deviate from the conception of the virtual trajectory.

This is identical to the distinction identified in choreutics between the conceptual plan of movements ("choreutic form") and the actual dancing, embodiment, or "utterance" of the movements (Preston-Dunlop, 1981, p. 29; 1980, p. 202). The notion of deviations created by anatomical and external factors is also identical to the theory of organic deflections identified in choreutics (see IVA.40).

IIIB.26 Multi-Joint Mass-Spring.

Most research on agonist/antagonist equilibrium points has measured movement occurring at only one joint (typically the elbow). Mussa-Ivaldi and Colleagues (1985) extended the notion of equilibrium points to refer to the total forces of muscles within a multi-joint linkage. They measured the spring-like behavior of the entire arm (resulting from the combined elastic forces of all muscles) when the hand was unexpectedly displaced during an attempt to reach at a target. Regardless of the brief perturbations, the hand still approached the target within a small elliptical-shaped range of deviation ("elastic force field"). The size of this range of deviation is considered to be an indication of the "stiffness" of the entire arm's elasticity.

Jordan and Rosenbaum (1989, p. 731) describe this behaviour as "basins of attraction around points that correspond to desired movement endpoints". Bizzi and Mussa-Ivaldi (1989) characterise a range of deviation around a target locus, as an "elastic-force field", or as a "stiffness ellipse". They point out that all Subjects had the same elliptical shape and orientation of their range of deviation, but that its overall size differed between Subjects. When continuous forces were unexpectedly added to the arm from different directions, the sizes of the ellipses changed but their shape and orientation were only slightly effected.

IIIB. 27 "Location" as Joint Angle or Distal Member Locus.

The location code might be mentally represented as the angle of the joint or as the location of the distal end of the limb. These two possibilities have been referred to in various ways.* Morasso (1981) used a two-segment apparatus which measured Subjects' multi-joint arm movement in the horizontal plane (Fig. IIIB-2) and allowed free articulations in both the shoulder and elbow joints. Subjects' task was to move the handle of the apparatus to target locations indicated by lights.

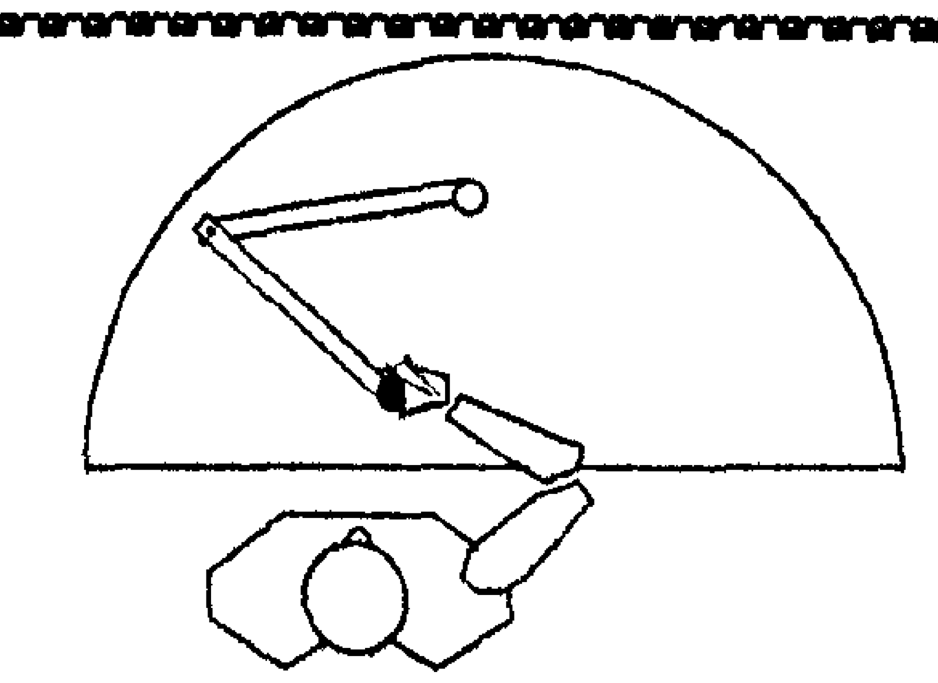

Figure IIIB-2. Planar positioning apparatus (adapted from Morasso, 1986, p. 18).

Velocities of shoulder and elbow joint articulations did not occur in any regular pattern but varied depending on the direction of the movement. This absence of a regular pattern is taken as an indication that these components are not actively controlled. However, the velocity of the hand exhibited an identical pattern for all movements regardless of direction. This regularity of the behaviour of the hand

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* The locus as either the distal member versus the joint angle is referred to as "the 'extrinsic' space of the hand" (coordinates of the distal end of the limb) versus the "'intrinsic' space of the joints" (joint angles) (Morasso, 1986, p. 21), as "spatially referenced coordinates" versus "anatomically referenced coordinates" (Soechting, 1987, p. 38), as "extracorporeal space" versus "corporeal space" (Hogan, 1984, p. 2747), as "hand coordinates" versus "joint coordinates", or as "the metric of the environment" versus "the metric of the musculoskeletal system" (Bizzi and Mussa-Ivaldi, 1989, pp. 770-771).

motion is taken as an indication that this is the component of the movement which is being controlled. Morasso (1981, p. 224) refers to this as "spatial control" of movement (as opposed to joint-angle control). Likewise, Vaina and Bennour (1985) computed the requirements for visual recognition of body movement and found that representing arm movement as the path of the hand was much more efficient than representing arm movement in terms of joint angles (p. 227). They also recommended that the recognition of movements be based on "biological constraints" which limit the variety of body movements which can occur (p. 224; see IVA.70).

Similarly, Bernstein (1984, pp. 106-117) argued that the "principle of equal simplicity" indicates that movements which are equally "simple" to produce must be mentally represented and produced in the same way. A movement "trace" (p. 106) (a geometric pathway of the hand such as a star or circle) can be transformed in a variety of ways (eg. sizing, translation, rotation; see IIID) and these transformations can often be executed as simply as the original (just as accurate, just as fast). The joint and muscle usage can differ widely between the different transformation, however the exterior spatial form is essentially identical. Thus, according to the principle of equal simplicity, the movement and its transformations are not produced by specifying and controlling muscle contractions or joint angles (since these are variable depending on the transformation) but are produced by controlling the exterior spatial form (since this is constant regardless of the transformation) (see IIID.25). This is comparable to results found with switched-limbs in spatial positioning tasks in which locations are accurately recalled regardless of the body use (see IIIB.12).

In contrast, Hollerbach and Colleagues (1987) demonstrate how regular patterns of joint articulation velocities can be identified according to a principal of "staggered joint interpolation". Thus, motor control might also specify commands in terms of joint angles. In a different type of task, Soechting (1982) demonstrated that the perception of elbow angle was accurate only when the upper-arm was oriented vertically (elbow by the side). When the upper-arm was not vertical then the perception of forearm orientation was superior to the perception of elbow angle. This is an indication that the perception of the orientation and location of the limb in space is more fundamental to motor control than the perception of the angle of the joint. Perceptions of joint angles may be derived from the more basic perception of limb-orientations.

IIIB.30 Trajectory Formation

IIIB.31 Path Segments, Curvature Peaks.

Abend and Colleagues (1982) continued to use the multi-segment apparatus which allows free movement of shoulder and elbow joints in a horizontal plane (Fig. IIIB-2). Subjects moved their hands along curved trajectories according to three conditions: 1) Producing a curved path between two loci; 2) Following a curved path guided by a template; 3) Moving directly to a target while being forced to deviate around an obstacle. In all cases, rather than smoothly curved paths Subjects produced a series of straight or gently curved "path segments" which were separated by "curvature peaks" (a slight bump in the curve of the path). The velocity of the hand exhibited a corresponding pattern, being fastest during the path segments and slower during each curvature peak. The same pattern of path segments and curvature peaks was also identified in relatively unrestrained arm/hand movements in three dimensions (Morasso, 1983b) and in other movement studies such as a frog's wiping reflex which is composed of five "phases" which are "punctuated by marked breaks in the limb's movement trajectory" (Berkinblit et al., 1986, p. 595).

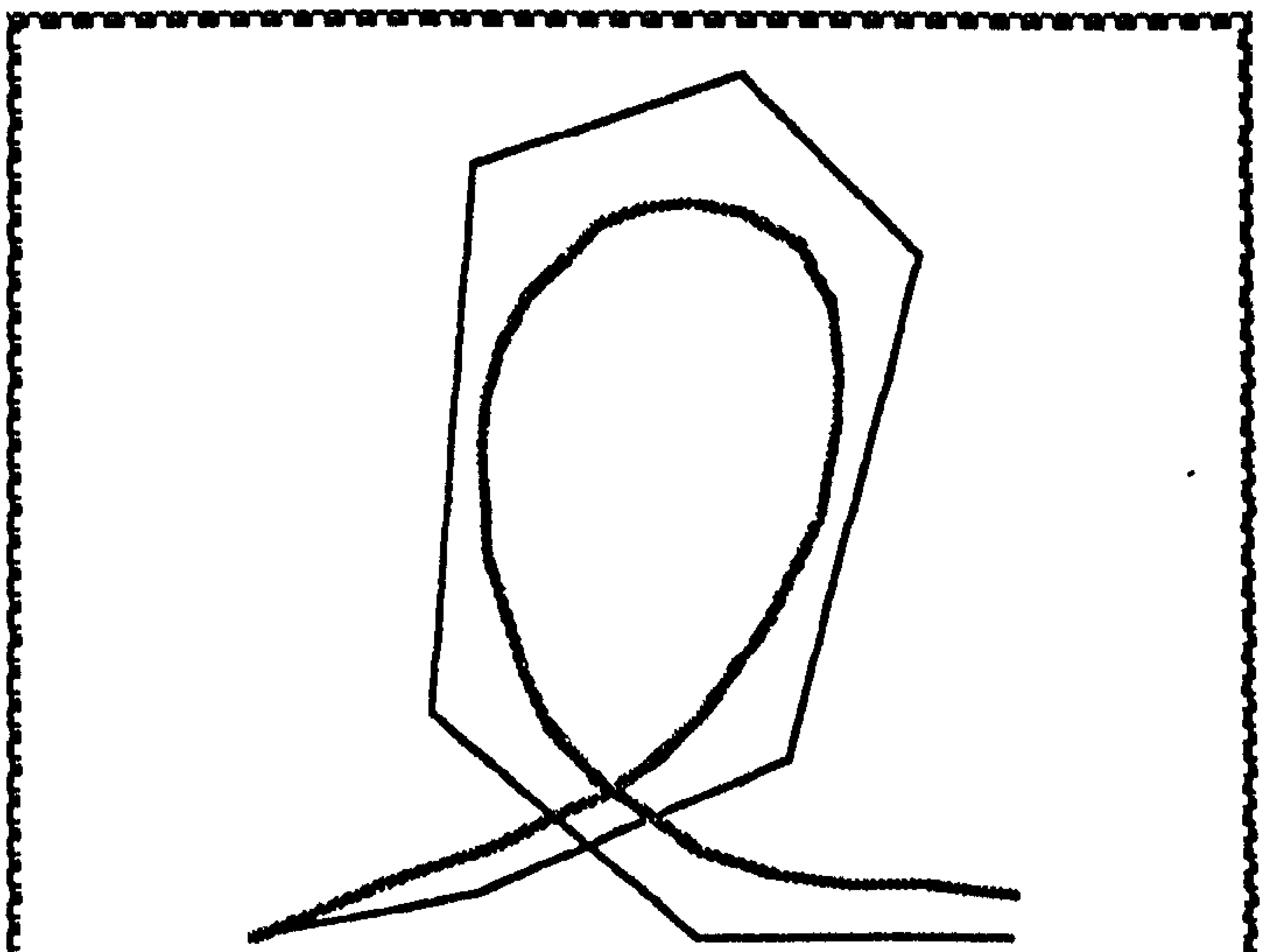

Figure IIIB-3. Deriving a curved path from a polygonal representation (adapted from Morasso, 1986, p. 45).

IIIB.32 Deriving Curved Paths from Straight Strokes.

Morasso and Colleagues (1983) developed a mathematical model describing how the overall curvature of a path can be produced from a series of straight path segments. Each path segment is considered to be a "stroke" and a series of strokes to be "the sides of the polygon" (p. 85). When strokes are performed in a discontinuous manner then angular transitions occur between them. When the strokes are overlapped, beginning the next stroke before the last one is finished, then smoothly curving transitions occur between strokes (Fig. IIIB-3).

Thus, Morasso (1986) considers strokes to be the "primitive movements in the motor repertoire" (p. 44) and identifies this as similar to "spline functions" which are used to generate curved lines from a series of straight vectors in computer graphics (pp. 38-42). In spline functions "the desired shape is approximated by means of a polygon" and the amount of overlap between polygon sides determines whether the actual shape is more curved or angular (Morasso et al., 1983, p. 86). In the language of spline functions, each vertex of the polygon serves as a conceptual "guiding point" for the bodily production of the trajectory (Morasso, 1986, p. 40).

IIIB.33 Polylinear Trajectories.

Morasso (1986) also measured the trajectory of the shoulder when the trajectory of the hand takes it beyond arm's length requiring shoulder displacement (scapula sliding across the back) and thus shifting the body's centre of gravity sideways and/or upwards (pp. 23-24) or actually requiring the Subject to locomote (p. 34). In these cases the shoulder and hand begin moving simultaneously and move towards the same locus or along parallel directions. In either case it can be said that "the trajectory of the shoulder 'mimics' the trajectory of the hand" (p. 34). Both the shoulder and the hand exhibited the same pattern of path segments and curvature peaks. The shoulder path was a reduced and translated version of the hand path (see IIID.25).

IIIB.34 Locomotor Trajectories.

Baratto and Colleagues (1986, pp. 61-65) reviewed how locomotor patterns (eg. walking) have been traditionally distinguished from trajectory formation (eg. reaching and manipulating) but that these are actually derived from the same underlying process. The "direct function" of a limb or "kinematic chain" is when the proximal end is "grounded" and the distal end is free to move. In contrast to this, the "reverse function" is when the distal end of the limb is "grounded" (ie. stabilised in the environment) and the proximal end of the limb moves through space (eg. the pelvis moves forward during walking). The same equilibrium point between sets of agonist and antagonist muscles acting on the leg can push the foot backwards if the pelvis is grounded, or can push the pelvis forwards if the foot is grounded. Walking involves both the direct function (trajectories of the foot) and the reverse function (trajectories of the pelvis) and the foot prints can be considered as the "aiming or guiding points" (locus code) for the overall path.

IIIB.40 Choreutic Peaks and Phases

Laban appears to have anticipated this location-based model of motor control which was later developed by trajectory formation researchers. The choreutic conception of pathways is almost identical to the trajectory formation model. Laban (1966) advised that "In describing movement, we must make a mental note of the most important intermediary positions" (p. 46) and observed that the pathway of a body movement was made up of "several outstanding characteristic peaks" which were joined by different "phases of its pathway" (pp. 27-28):

> Since it is absolutely impossible to take account of each infinitesimal part of movement we are obliged to express . . . [it] by some selected 'peaks' within the trace-form which have a special quality. . . . [and] which strike us by their spatial appearance. (Laban, 1966, p. 28)

Accordingly, Laban (1966, pp. 23-26) conceived of each "peak" as a spatial "accent" at which point the "circuit line" changes direction, and creates a type of "spatial rhythm" or "polygonal rhythm" (p. 26). Thus, limb paths are identified as being "cornered" and entire movement circuits are considered as "tetragonal", "six-cornered", "hexagonal", "seven-cornered", "heptagonal", "octagonal", etc. (see IVB.33). Choreutic polygonal rhythms are identical to the trajectory formation model of polygonal representations. What Laban (Ibid.) calls the "science of harmonic circles" or "laws of interdependent circles" whereby "harmonious movement follows the circles which are most appropriate to our bodily construction", is fundamental to choreutics and comprises the "second fact of space-movement":

> Our body is the mirror through which we become aware of ever-circling motions in the universe with their polygonal rhythms. Polygons are circles in which there is spatial rhythm, as distinct from time rhythm. A triangle accentuates three points in the circumference of a circle, a quadrangle four points, a pentagon five points, and so forth. Each accent means a break of the circuit line, and the emergence of a new direction. These directions follow one another with infinite variations, deflections and deviations. (Laban, 1966, p. 26)

Laban (1966, pp. 46-47) compares a movement path to the opening of a fan in which the "ribs" or "spokes" of the fan are analogous to the spatial accents or peaks along the pathway. A path can be performed in a "broken or angular way" by giving a "special accentuation" thus creating "imperceptible pauses" at each peak, or it can be performed "smoothly in a continuously curving pattern". This description corresponds to the method of deriving curved paths from polygonal representations in the trajectory formation model (see IIIB.32).

Body movement has commonly been represented as a series of poses simply because of the ephemeral, transient nature of movement. For example, dance texts can do nothing else except present drawings or photos of static poses and possibly represent movement with lines signifying the path of a body-part (eg. Kirstein and Stuart, 1952). The poses selected for the description of body movements may indeed occur at the moment of a curvature peak. However, in the choreutic conception particular intermediary poses are explicitly identified as occurring at the points of curvature peaks (rather than an arbitrary segmentation of the path) and are used as conceptual guiding points for the production of curved and angular paths. Curvature peaks are linked into a series and mentally abstracted as having polygonal shapes. This corresponds closely to the trajectory formation model.

"Peaks" can also be conceived within static body poses. Anatomical points (eg. skeletal joints) can be perceived as the corners of a polygonal shape. Skeletal segments, or perceived lines between anatomical points (eg. a "connection" between the two hands) can be perceived as linear segments within the polygonal rhythm. In body movements, the spatial accents (peaks) may be perceived from the changes in speed which occur when changing direction from one path segment to the next. In static body positions the spatial accents (peaks) may be perceived from the changes of orientation from one body segment to the next (see IVB.20).

IIIB.50 Location Code in other Motor Tasks

IIIB.51 Motor Control of Handwriting.

Body movements occurring during the production of handwriting are typically considered to be miniature variations of the larger movement paths created by the full body (Bernstein, 1984, pp. 105-106; Laban, 1966, pp. 83-84). Therefore, models of the motor control of handwriting have developed which are compatible with the models of equilibrium points and trajectory formation.

Denier van der Gon and Colleagues (1962; Denier van der Gon and Thuring, 1965) proposed a model for handwriting according to which the relative temporal duration of strokes used to draw a particular shape or letter remains invariant regardless of the overall size of the writing. When Subjects increase the overall size of their handwriting the duration of strokes is increased by the same percentage throughout the movement. The relative timing between strokes is identical but the duration of every stroke is extended and so the writing gets larger (Wing, 1980). Therefore, the essential pattern of the movement, the particular series of strokes and peaks, remains invariant regardless of size. The velocity of pen motion is greatest during the middle of each stroke and slowest at the points of more abrupt curvature (Viviani and Terzuolo, 1980) thus confirming the same segmented structure as found in studies of trajectory formation.

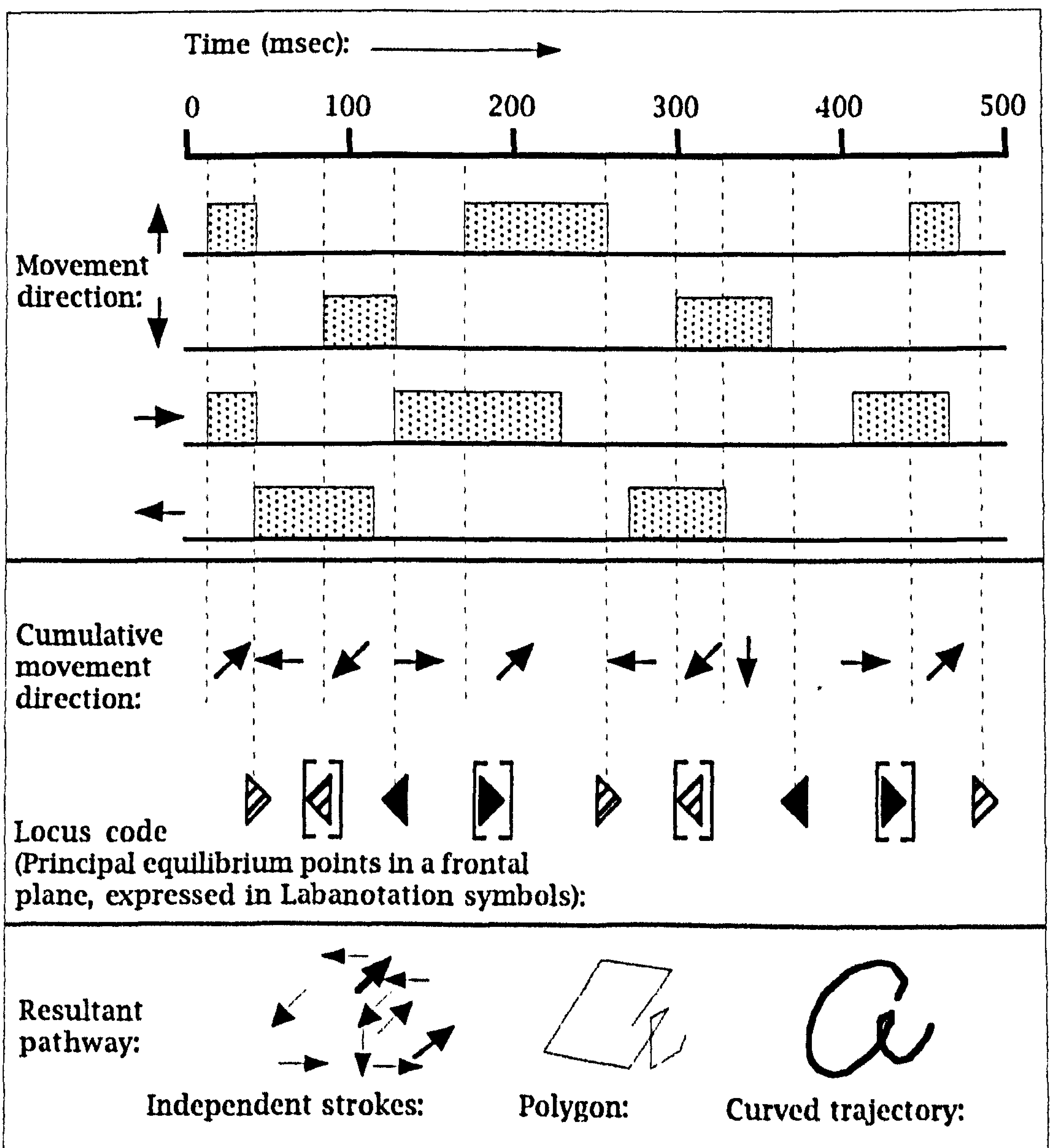

Figure IIIB-4. Relative timing of four motors (analogous to muscles) in Vredenbregt and Koster's (1971) mechanical handwriting simulator (adapted from Schmidt, 1982, p. 325; Van Galen and Wing, 1984, p. 159).

Vredenbregt and Koster's (1971) mechanical model for handwriting demonstrated how shapes of letters can be produced with four fundamental strokes produced by four motors which move a stylus along two dimensions (vertical or lateral). Each pair of motors is analogous to an agonist/antagonist pair of muscles. Shapes of letters were controlled by the relative duration that each of the four motors is active. Transitions between the strokes was smoothed out because of the inertial forces present within the mechanical apparatus. This is analogous to the conditions in actual body movement control.

Vredenbregt and Koster (1971) represent the relative timing of the four motors in a graphic figure (Fig. IIIB-4). The action of each motor is represented as the length of a hatched area (Also in Schmidt, 1982, p. 325; Van Galen and Wing, 1984, p. 159). By changing the relative timing of the motors the shapes of the written letters could be modified in a way analogous to individual styles of writing. Here the relative timing changed the length of various strokes and so the writing appeared different, but the order and directions of the strokes remained identical so the letter could still be recognised. This type of analysis is used in this research as a basis of a taxonomy for distinguishing between categories of kinespheric paths (see Appendix XVI).

Hollerbach (1981) used the spring-like properties of muscles to explain handwriting movement (according to the mass-spring model). If the up/down and left/right motions in handwriting are thought of as being controlled by springs, then when the handwriting motion begins all four springs will begin to oscillate. If the mass attached to the springs (the fingers and stylus) is propelled into a diagonal direction (eg. up+right) then the stylus will continue to oscillate in a circle. If the "stiffness" (the amount of overall muscular tension) is unequal between the up/down and right/left springs then the oscillation will produce an oval or another shape. Different trajectories are produced by varying the order and timing of the impulses.

IIIB.52 Motor Control of Speech Articulations.

Similar locus-based theories of motor control have been developed for the movements of speech. The basic speech sounds are termed "phonemes". Each phoneme might be produced by a particular movement of the tongue and mouth. However, the articulatory movements to produce a particular phoneme will be altered by the previous position of the articulators. That is, articulatory movements for a given phoneme vary depending on the surrounding phonemes. This is referred to as "the problem of motor equivalence in speech" that is, "achievement of relatively invariant motor goals [a phoneme] from varying origins" (MacNeilage, 1970, p. 182).

The movements required to produce a particular phoneme may be varied slightly because of a simultaneous preparation to produce the following phoneme. This overlap of phoneme movements ("coarticulation") allows phonemes to be joined together in smooth rapid sequences (Benguerel and Cowan, 1974; Kent and Minific, 1977; Moll and Daniloff, 1971; Öhman, 1966). However, a huge amount of information would need to be stored in order to encode all possible movements. This same problem occurs in other motor activities such as playing a piano. The movement to a particular key will always be dependent on the previous key.

MacNeilage and DeClerk (1969) used electromyographic (EMG) recordings of muscular involvement during the production of phonemes. It was observed that the EMG pattern for a particular phoneme is variable depending on the adjacent phonemes. However, the final position of the tongue during each phoneme was identical regardless of adjacent phonemes. Therefore MacNeilage (1970, p. 182) proposed that speech is controlled "by an internalized space coordinate system which specifies invariant 'targets'". The production of a phoneme is not considered to require a particular movement, but rather the production of a particular position of the tongue and mouth. The location of the target is stored in memory and movements are spontaneously generated in order to attain the target (Also in MacNeilage, 1973; MacNeilage and MacNeilage, 1973).

IIIB.53 Stimulus-Response Compatibility.

In a simple demonstration of "stimulus-response compatibility" Subjects are required to press a right or left button with their right or left hand in response to a visual or audio stimulus in the right or left sensory field. When stimulus and response are both on the right, or are both on the left (compatible), then the response time is less than if the stimulus is on the right and the response is on the left, or vice versa (incompatible) (Brebner et al., 1972; Simon, 1969; Wallace, 1971).

The compatibility of the response (pressing the button) might be based on the bodily right or left hand or the spatial right or left position of the button. To distinguish these possibilities in tests with visual and audio stimuli Subjects crossed their arms so that the right hand pressed the button on the left and the left hand pressed the button on the right (Brebner et al., 1972; Callan et al., 1974; Simon et al., 1970; Wallace, 1971). In other tests only the fingers were crossed (ie. the right hand on the right side presses the left button) or sticks were held in each hand which crossed and pushed the button on the other side (Riggio et al., 1986). In all cases the compatible (fastest) response was to the button in the same spatial position (right or left) as the stimulation, regardless of whether it is the bodily right or left hand, or whether the hand was to the right or left of the Subject's midline. This indicates that compatibility is based on spatial locations rather than particular body parts.

These results led to the "coding hypothesis of spatial S-R compatibility, which says that the relative spatial positions of stimuli and responses are encoded and compared irrespective of the anatomical response organs" (Heister et al., 1990, p. 121). Similarly, the "spatial coding hypothesis" posits that the location of the stimuli and the location of the responding body-part are both coded relative to external space (Umiltá and Nicoletti, 1990, p. 106).

If the hand is turned over (forearm pronation / supination) then the spatial position of the two fingers will be reversed from when the palm is turned up versus when the palm is turned down. In both these positions the spatial position of the finger and button determined which was compatible, regardless of which finger was used (anatomical position) (Heister et al., 1986; 1987). Thus, the compatibility effects are biased on the spatial position rather than the anatomical position.

The spatial distance between the two response buttons and the anatomical distance between the two responding body-parts (eg. the ring finger and index finger versus the thumb and little finger) can each be varied, closer or farther. In this case the spatial distance also determines the size of the compatibility effects, regardless of anatomical distance (Heister et al., 1990, pp. 122-126).

However, when the response buttons are not arranged in the lateral dimension but are placed in a line along the vertical or sagittal dimension then compatibility cannot be based on right/left spatial position (since it is unavailable). In this case compatibility effects occur according to the anatomical position of the responding body-part regardless of which button is pushed (Ehrenstein et al., 1989; Heister et al., 1990, pp. 128-131; Klapp et al., 1979). These results led to the "hypothesis that an anatomical right/left distinction becomes effective [in compatibility] if the right/left distinction between response positions is eliminated" (Heister et al., 1990, p. 127).

Thus, compatibility will tend to be based on spatial locations, regardless of which body-parts are used, but when this information is not useful (eg. the response buttons are not in the same dimension as the stimuli) then compatibility can also occur according to the anatomical positions of body parts (Heister et al., 1990, pp. 131-136).

The influence of anatomic mapping is evident in all studies of compatibility. Reaction-times are slower overall in conditions when the anatomical right/left is not identical with the spatial right/left. This is assumed to arise because of a "mismatch" between the spatial code and the anatomy code (Heister et al., 1990, p. 133). In other situations when the body or head is tilted away from vertical during the compatibility task there is an increased tendency to rely on anatomical locations (Ládavas and Moscovitch, 1984). In similar tasks when the head was tilted compatibility effects occurred according to either spatial or anatomical position depending on which cues were most readily available for the Subject (Heister et al., 1990, pp. 135-136). Thus, in stimulus-response compatibility effects it appears that the spatial location code is most dominate, but that an anatomical code can be used when the body is in an unfamiliar orientation or when a clear spatial location code is not obvious.

IIIB.54 Spatial Motor Preprogramming.

The primacy of location information is also seen in studies where the direction of movement can be prepared for and planned in advance before other aspects of the movement (ie. distance, body-part usage) are known. This indicates that the basis of the mental representation of motor information is independent of the body-parts used or the size of the movement.

Rosenbaum's (1980) Subjects used arm movements to push buttons varying along three attributes: 1) The body-part to be used (right or left hand); 2) The direction to be moved (forward or backward); 3) The distance to be moved (near or far). Subjects were told beforehand about one of the attributes and this precue would (theoretically) allow this particular bit of information to be prepared in advance. After time was given to preprogram this bit of information the other two bits of information were given and the time required for Subjects to initiate the movement (reaction time) was measured.

Rosenbaum (1980) found no difference in reaction times between the type of precue (direction, body-part or distance). However several problems with Rosenbaum's experiment have been identified (Goodman and Kelso, 1980; Larish and Frekany, 1985; Zelaznik, 1978; Zelaznik et al., 1982). For example, secondary tasks (translating the colour of a light into the location to be moved to) were not accounted for and the number of choices required at the moment of movement initiation were not equalised across conditions.

In Larish and Frekany's (1985) improvement of Rosenbaum's experiment, regardless of the type of precue Subjects always chose between two possible locations (2-choice reaction time). Either one, two, three, or no attributes (body-part, distance, direction) were given as precues. When the direction was precued the time required to initiate the movement was always shorter than when the direction was not precued. The reaction time when body-part and distance were both precued (direction unknown) was no faster than when nothing was precued. Sometimes Subjects were falsely precued (the precue was wrong) and so this information would have to be re-programmed before the movement could be initiated. False cues about direction resulted in longer reaction times than false cues about body-part or distance. In addition, false cues about all three attributes resulted in the same reaction time occurring after a false cue about the direction only.

These results indicate that the first attribute of a movement to be prepared, and thus the most elemental code, is the direction to be moved towards and that body-use and distance are prepared later. Body-use and distance cannot be planned without knowledge about the movement direction. Larish and Frekany (1985, p. 185) characterise this as a hierarchical relationship between these three parameters. Comparable results by Klapp (1977) and Proteau and Girouard (1984) also demonstrated that movements can be prepared without any "muscle-specific" (ie. body-usage) information.

IIIB.60 Coordinative Structures, Muscle Collectives, Kinematic Chains

The location code for a movement trajectory specifies only a series of locations to be moved through by the distal end of a skeletal linkage. In most cases many articulations must take place in mid-limb and proximal joints to accommodate for this intended trajectory. This is the problem of "intersegmental coordination" (Golani, 1986, p. 608; Jeannerod, 1981), also discussed as Bernstein's (1984) problem of "motor equivalence" (Berkinblit et al., 1986; Kelso et al., 1979b); that different limb configurations could all accomplish the same path of the distal end of the limb. The problem for motor control is how these many possibilities of articulations within the skeletal linkage are coordinated while accomplishing a goal of the distal end.

Automatic, "reflexive" interactions among muscles have been observed to provide accommodation for the path of a distal body-part. This aspect of movement coordination, "the ability to regulate movement activity over many sets of muscles and different limbs" (Smyth et al., 1987, p. 100) are considered as "coordinative structures" of the motor system. These provide the bodily articulations required to achieve the locations planned for a distal point of the limb.

The theory of coordinative structures (see Appendix VII) is compatible with the mass-spring model (IIIB.20). A target location can be specified for a movement (ie. an equilibrium point for an entire multi-joint linkage) without specifying the particular muscular actions. Functional groupings of muscles automatically accommodate to the desired target according to an available "library" of reflex movements (Easton, 1972). Original thoughts on coordinative structures are usually credited to the famous Soviet physiologist N. A. Bernstein who's writings from the 1930s onwards have led to a conception of motor control sometimes called "The Bernstein Perspective" (Fitch et al., 1982; Tuller et al., 1982; Turvey et al., 1982) and has received recent reattention (Whiting, 1984).

Bernstein (1984) observed that muscles automatically cooperate during movement and referred to these as "structures of movements", "integral formations" or "integration of movements" which are "The most important feature implied by 'motor co-ordination'" (p. 83). The terms "synergy" (Kelso et al., 1979a; and others) or "coordinative structure" (Easton, 1972; 1978; and others) are variously used to describe a group of muscles crossing several joints which function cooperatively together as an integrated system.*

An analogous concept is a "kinematic chain" (Bernstein, 1984, p. 82), or "kinematic linkages" (Turvey, 1977, p. 219) used to refer to a group of body segments and joints linked in a series. "An appendage such as an arm or a leg is a biokinematic chain -- that is, it consists of several connected links, so that a change in an one link affects the other links" (Turvey et al., 1982, p. 248). The notion of a kinematic chain implies some amount of coordination among its parts.

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* Coordinative structures are variously described as "a group of muscles often spanning a number of joints that is constrained to act as a single functional unit" (Kugler et al., 1982, p. 60), "a group of muscles functioning cooperatively together" (Turvey, 1977, p. 219), "functional synergies" (Sheridan, 1984, p. 49), "functional groupings of muscles", "synergies", "muscle collectives", "muscle linkages" and as "a group of muscles whose activities covary as a result of shared efferent or afferent signals" (Kelso et al., 1979a, pp. 229-235).

Similarly, Bartenieff and Lewis (1981, pp. 21, 105) referred to a "kinetic muscular chain" which exhibits an active coordination within the linkage and is described as the quality of being "connected". They consider this to be the "body" aspect which compliments the "spatial" aspect of choreutics.

Bernstein (1984, p. 91) describes movement "coordination" as having the qualities of "homogeneity, integration and structural unity". One of the simplest examples of a coordinative structure, or the "integration of movements", is the "gradual transfer of innervation" within a muscle collective:

> The simplest and most easily observed phenomenon in this category [of integrated, coordinated movement] is the appearance of gradual and smooth redistribution of tensions in muscular masses, which is particularly clearly expressed in cases of phylogenetically ancient or highly automatized movements. A muscle never enters into a complete movement as an isolated element. Neither the active raising of tension nor the . . . inhibition in antagonistic subgroups is, in the norm, concentrated in a single anatomical muscular entity; rather, there is a gradual and even flow from one system to others. (Bernstein, 1984, p. 83)

Bartenieff and Lewis' (1980, p. 247) similar example is the even gradation of rotory articulation in the shoulder which can occur as the arm moves in a large circle. This gradation of innervation is also similar to Laban's law of "flowing-from-the-centre":

> . . . allowing the movement to flow out from the centre of the body. Such an arm-movement then has the sequence: torso impulse, leading of the shoulder blade, upper-arm, fore-arm, and lastly the hand. This movement comes out from the body-centre and ensures a light volatility. (Laban, 1926, p. 18)

A hierarchy of coordinative structures are envisaged from the lowest order reflexes in single muscles and reciprocal muscles, to higher order muscle collectives governing actions within an entire limb, to even higher order reflexive patterns of the entire body. These are not fixed ("knee-jerk") responses but can be "tuned" (adjusted) in accordance with environmental conditions (Berkinblit et al., 1986; Evarts and Tanji, 1974; Gurfinkel et al., 1971a).

A full review of functional relationships within muscle collectives is out of the scope of this research (for an introduction see Appendix VII). Coordinative structures are considered here to be an essential body counterpart to the spatial location-based motor code.

IIIB.70 Location Effects in Visual and Verbal Memory

IIIB.71 Automatic Processing of Location Information.

Location information also appears to be fundamental in the recall of words or pictures. If the identity of an item is remembered then the location of that item will also likely be remembered (even though there had not been any intention to try to remember the location). This has been shown for a variety of stimuli and conditions.* When a focused intention is made to remember the locations they are recalled no better than when no intention is made (Schulman, 1973). Therefore it is concluded that "location information is automatically coded into long-term memory storage in the sense that active processing is not required" (Mandler et al., 1977, p. 10). This appears to be a basic trait of perception rather than being learned since the same results have been found for age groups from kindergartners to adults (Ibid).

IIIB.72 Locus-specific Memory Storage.

When abstract line drawings are presented in the same location, then the last presented drawing is recognised better than earlier presented drawings (recency effect), however when each drawing is presented in a separate location then all drawings are recognised equally well (Broadbent and Broadbent, 1981). Similar effects occur in verbal cognition. Verbal information presented from a variety of locations is recalled better than if it is presented entirely from the same location (Rothkopf et al., 1982). Distracting words spoken from the same location as other words to be recalled cause greater interference than if spoken from a different location (Crowder, 1978). These results indicate that parallel memory resources are provided for separate spatial locations or regions. Items in memory interfere in as much as they are encoded from the same environmental location.

IIIB.73 Locus-based Mnemonic Strategies.

Many mnemonic strategies have a long history of use, from the ancient Greeks through to modern times, which are based on mentally establishing a relationship between an image of an item-to-be-remembered and a particular imagined environmental location (eg. a room in a building). During recall Subjects mentally travel through the imagined space and recall the items present at each location. A

* Automatic processing of location information has been shown for verbal passages within a page or within the page sequence (Rothkopf, 1971); words arranged within spatial arrays (Schulman, 1973); locations of small toys, objects, and words arranged in a matrix (Mandler et al., 1977; Pezdek et al., 1986); and the right/left position of a line drawing or word (Park and Mason, 1982).

variety of these strategies have been reviewed in detail by Bower (1970a), Paivio (1979, pp. 153-175), and Yates (1966).

IIIB.80 Conclusions: Location Code

A variety of research indicates that mental representations of spatial information are based on individual locations. For example, the final location of a body movement can be recalled better than the distance moved and the location of one body-part can be recalled (virtually) just as well with a different body-part. These effects indicate that spatial locations are recalled rather than particular movements. The mass-spring model for motor control provides a theoretical basis for a location code. The elemental unit of body-movement is thought to be a single motion toward a new "equilibrium point" between tension in agonist and antagonist muscles. Each equilibrium point comprises one elemental location. A location code is also evident in studies of "trajectory formation" where measurements of path curvature and velocity revealed that a path is composed of "path segments" separated by "curvature peaks". The "primitive movements in the motor repertoire" are thought to consist of path segments ("strokes") and curvature peaks ("guiding points" for the production of the trajectory). Angular or curved transitions depends on how much two consecutive strokes are "superimposed". The "abstract representations" of a body movement are posited to be cognitively planned according to a series of locations in which "the desired shape is approximated by means of a polygon" (one location at each polygonal corner), and then "the sides of the polygon are generated and superimposed" in actual body movement.

Similar location-based models have been developed for handwriting production, motor control of speech, stimulus-response compatibility, spatial motor preprogramming, and in visual and verbal memory. Coordinative structures are identified as the body-level counterpart to the spatial-level of the location code.

These models of motor control and spatial cognition give psychological validity to the choreutic conception where Laban identified "'peaks' within the trace-form" and "phases of its pathway". Accordingly, kinespheric paths and poses are conceived as being polygonal-shaped (one "peak" at each polygonal corner). Curved or angular trajectories are produced depending on whether successive strokes are smoothly blended together or if the curvature peaks are abruptly accented. This choreutic conception is virtually identical to the trajectory formation model.

IIIC. Map-like Images of Spatial Knowledge

After individual locations are well learned they are typically linked together and mentally represented within a map-like image. This identification of cognitive maps in psychology validates the map-like conceptions of the kinesphere used in art, architecture and in Laban's unique method of using polyhedral-shaped cognitive maps of the kinesphere in choreutics.

IIIC.10 Cognitive Maps

"Cognitive maps" are often considered synonymous with "spatial representations" (Kosslyn et al., 1974, p. 708). This refers to the "representation of information from a geographic area that cannot be perceived simultaneously" (Allen et al., 1978, p. 617) and is "picture-like, that is, embodied in a visual image much like a map" so that during spatial tasks Subjects report that they "formed a picture of the path" and recall consists of "searching for the correct picture" (Levine et al., 1982, pp. 160, 166). "Cognitive mapping generally refers to the process by which individuals collect, organize, store, retrieve, and manipulate information concerning location in space" (Sadalla et al., 1979, p. 291). Thus, Neisser (1976, p. 111, 118, 123-125) uses "'orienting schema' as a synonym for 'cognitive map'" since the representation will accept sensory information about a particular environment and also direct further bodily movements within that environment. "Mental images" or "spatial imagery" are considered to be aspects of this orienting schema.

Tolman's (1948) classic article reviews work with Students and Colleagues on experiments in which Subjects (mostly rats) must find a path through a maze toward a reward (food). In the typical maze-learning behaviour a hungry rat will gradually learn her way through a maze so that each successive trial will be faster and have less errors (wrong turns) than previous trials. Two theories are proposed to account for this behaviour (pp. 189-193): 1) The rats learned a stimulus-response chain in which each action serves as the stimulus for the next action (eg. turn right, go forward, turn left); or 2) That the rats learn a "field map" or a "cognitive-map of the environment" in which the entire environment is laid out in the rat's mind as a map-like spatial image. These two possibilities might also be described as 1) "route learning" or "associative learning" versus 2) learning a "cognitive map" or "survey map" (Levine et al., 1982, p. 160).

IIIC.11 Equiavailable, Path Free, Spatial Knowledge.

Levine and Colleagues (1982) state the "cognitive-map hypothesis" and the "principle of equiavailability" in three axioms:

> AXIOM 1: From a sequence of movements in space, one is able to construct a representation (eg. a picture) of the path. . . . that people have the ability to convert a limited degree of sequentially obtained spatial information into a simultaneous system. . . .
> AXIOM 2: From a picture of a path, one can move appropriately among the points of the path itself. . . . the information is presented simultaneously to the Subject, who reads it out into a sequence of movements. . . .
> AXIOM 3: After learning a sequence of connected points, humans behave as through the information has been placed into a simultaneous system. That is, they behave as through they have a picture available. . . .
> (Levine et al., 1982, pp. 160-161)

The implications for experimental research are that Subjects should be able to execute paths which have never before been experienced (shortcuts). These "new" paths and the "old" paths should be "equally available" within this picture-like or map-like image .

Tolman (1948, p. 193) also distinguishes between the path-specificity of maps. If the mental maps are "relatively narrow and strip-like" then only the particular paths experienced during learning will be encoded into this "strip-map" (path-specific). If the mental maps are "relatively broad and comprehensive" then the rat has derived the structure of the overall environmental layout from her experiences of individual paths. In this case the rat would still know the correct overall direction to travel towards the food even if some of the intermediary paths changed (path free). .

Similarly Moar and Charleton (1982, p. 382) distinguish between different hypotheses: The "route hypothesis" posits that "schemata based on individual routes are an essential unit or representation in our acquisition of cognitive maps" versus the "network hypothesis" which posits that "if two or more different routes have to be learned, and if the routes intersect in an obvious manner, then schemata based on a network of these routes may be used". These are closely associated with the "sequential hypothesis" which posits that "when we initially learn a route, we build up a linear sequence of associations containing information only about the serial order of the landmarks and the direction of turns" versus the "spatial-map hypothesis" which posits that "the route would be functionally represented as a series of landmarks on a map".

Tolman (1948, p. 203) reports that equiavailability is often noted when rats who have learned a maze crawl out of the starting box onto the top of the maze and run directly to the location of the food-box. This indicates that the rats have knowledge of the location of the food which is independent of the particular maze paths which they had experienced. Similar results are reported for monkeys who move directly towards food regardless of the pathways through which they had experienced the locations of the food (Neisser, 1976, p. 118).

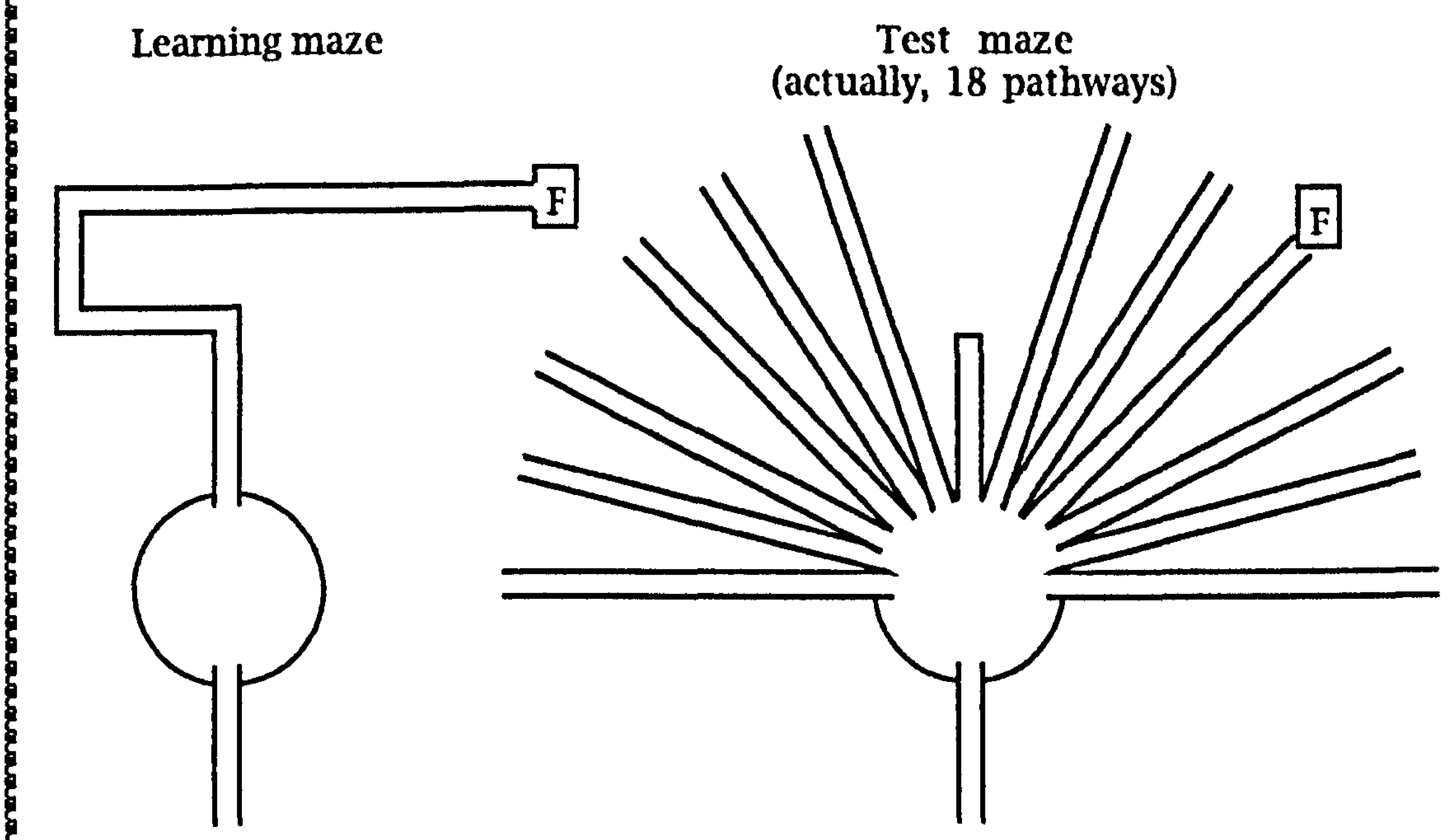

Figure IIIC-1. Tolman's rat maze; learning maze and test maze; F = food box (adapted from Tolman, 1948, pp. 202-203; Tolman et al., 1946, pp. 16-17).

Tolman (1948, pp. 202-204) also reports on previously published work (Tolman et al., 1946) in which rats began by thoroughly learning a maze which crossed a large circular table, then went down a tunnel through a roundabout path ending at a food-box. Next, a semi-circle of radiating tunnels was added around the circular table and the old path was blocked (Fig. IIIC-1). After the rats realised the old path was blocked they explored the other options and the majority of rats chose to go all the way down the path that led most directly to the location of the food box. Thus the rats had learned the direction to the food independently of the path used to get there.

Levine and Colleagues (1982) experimented with two types of space. In the "tabletop-terrain" the arm-hand-finger movement occurred within a paper-sized space ($8^1/_2$ x 11 inches) and in the "floor terrain" Subjects walked within a small room (32 x 50 feet). In both cases blindfolded Subjects were guided through a "four point path" (eg. three path segments joining points 1-to-2, points 2-to-3, and points 3-to-4)

(Fig. IIIC-2) and then were tested on their ability to execute four different types of paths: 1) A "simple forward movement" consisted of a repeat of a previously experienced path (eg. points 1-to-2, 2-to-3, or 3-to-4); 2) A "simple reverse movement" consisted of a previously experienced path executed in retrograde (eg. points 2-to-1, 3-to-2, or 4-to-3); 3) A forward direction "shortcut" consisted of a "new" movement in the forward order (eg. points 1-to-3, 1-to-4, or 2-to-4) and; 4) A reverse direction "shortcut" consisted of a "new"movement in the retrograde order (eg. points 4-to-3, 4-to-1, or 3-to-1). Results showed that accuracy was equivalent regardless of which type of path was being performed. This supports the principal of equiavailability in a path-free map-like spatial representation. This also occurred regardless of various transformations (or not) required between learning and recall (see IIID), these included: 1) Learning and recalling the tabletop terrain with the same arm; 2) Learning the tabletop terrain with one arm and recalling it with the other arm; 3) Learning from a visual picture and recalling with an arm in the tabletop terrain; 4) Learning and recalling in the floor terrain by walking. These transformations indicate that recalling spatial locations is not dependent on the particular muscles used during learning and so supports the use of an abstract spatial location code (see IIIB).

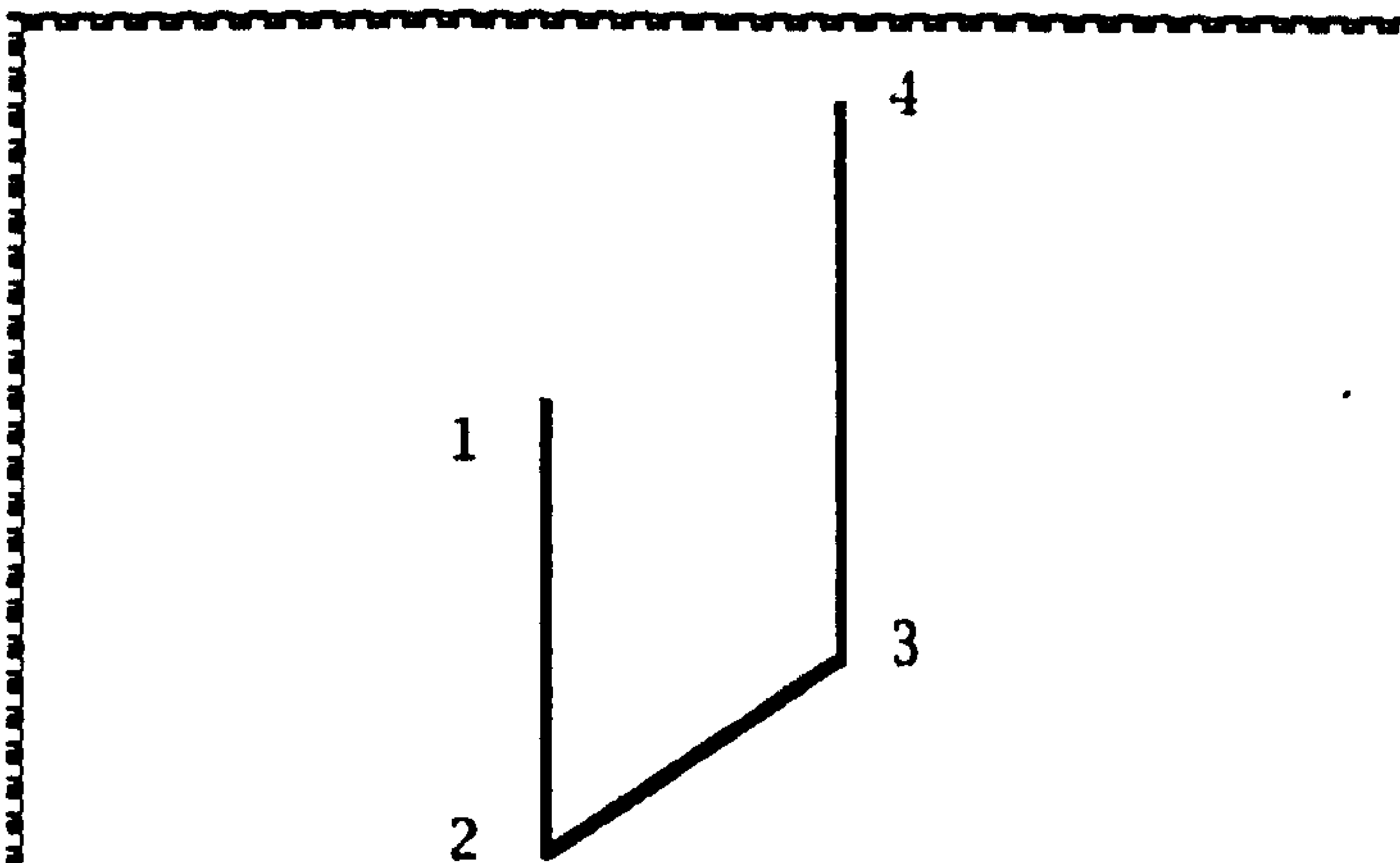

Figure IIIC-2. Four point path followed with arm movements or walking (Levine et al., 1982).

Many researchers have probed cognitive maps by using photographic-slides depicting several scenes along a walk. This slide-show stimuli is an impoverished form of the actual perceptual experience which the Subjects would have if they actually took the walk. Even with this degree of sensory impoverishment a map-like image of the overall spatial layout is developed in Subjects' memories.

Moar and Carleton (1982) showed Subjects one slide for every eight meters of two different intersecting paths (240 meters for each walk) through an unfamiliar city area. Subjects then drew lines on paper the appropriate length and direction to judge the distance or direction between two loci in the paths. Judgments were proportionately accurate regardless of whether the two loci were in the same or different paths. This supports the hypothesis that individual paths are integrated into an overall network rather than remaining separate.

Moar and Carleton (1982) also found that after initial viewing of the slides judgments of distance or direction along the normal order of the route were proportionally more accurate than judgments along the retrograde route order. However after viewing the slides four times this difference disappeared. This indicates that during initial acquisition the spatial representation is based on the path-specific "sequential associations" within certain routes but with further learning the spatial representation becomes more map-like and path-free (p. 392). Likewise, learning environments by walking initially creates knowledge only of the particular paths experienced, but with more learning these are integrated into map-like, path-free knowledge (Moar, 1978; Thorndyke and Hayes-Roth, 1982).

IIIC.12 Locations, Landmarks, Reference Points .

Particular locations are identified in the spatial environment which are used as "landmarks". These might consist of distinct features along a route which assist in navigation, distinct features within a region which assist in maintaining orientation, or the most easily recognised features from a particular environment.

Allen and Colleagues (1978) showed Subjects a series of thirty slides of a 360 meter path in either the normal or a random order. Regardless of the presentation order Subjects could distinguish other slides from a different walk but could not distinguish between the slides which had been seen and other slides (not previously seen) of the same walk. Distance judgments between landmarks along the walk were also in proportion to real-word distances. This indicates that Subjects "'fused'" the slides into an "integrated context" (p. 621) which "can be attributed to their ability to extract information from the perceptual overlap between scenes" (p. 624). That is, if a landmark (eg. a tall building) appeared in two different slides it could be used to link those scenes together. The overall map-like image of the space appeared to be developed by linking together the various landmarks into a network, regardless of the particular pathways. This use of landmarks as the basis of cognitive maps was further supported since distance judgments between slides rated as "high landmark potential" were more accurate than between slides with "low landmark potential".

Sadalla and Colleagues (1980) distinguish these landmarks from "reference points" which are special landmarks used as prototypical loci so that "the position of a large set of (nonreference) locations in a particular region is defined in terms of the position of a smaller set of reference locations" (p. 516). They found that certain locations in a university campus or small city appear to be used as cognitive reference points in that they are judged to be farther from another location than vice versa. This approach of probing for asymmetric distance judgements was developed earlier by Rosch (1975a) and is used in this research to probe whether reference points are used in cognitive maps of the kinesphere (see IVA.110).

IIIC.13 Hierarchy of Map-like Spaces.

IIIC.13a Higher-order regions and borders.

Spatial environments appear to be segmented into higher-order regions separated by borders. These are indicated in various ways, including the speed of direction judgements, and when the judged distance or direction between two locations is biased towards the distance or direction between the higher-order regions.

Wilton (1979) asked Subjects whether one town is in a particular direction (eg. north) from another town. When the two towns were far apart, or were nearby but within separate regions (ie. two different countries) the direction judgment was made quickly. Wilton reasons that the relations between towns cannot be represented as strings of connections between neighboring towns since this would require a longer time to verify the overall direction between distant towns. The alternative explanation is that fast judgments are made between towns which are in different high-order regions (eg. different countries) because this can be determined by consulting a high-order "coarsely graded" mental map, whereas cities within the same region require longer time for the direction judgment because a lower-order "finely graded" mental map must be inspected.

Similarly, Lehtiö and Colleagues' (1980) Subjects imagined they were standing at a location in a well known city and judged whether another location in the city was to the right or left of their imagined line of sight. Reaction times to make the direction judgment were quicker when the distance between the two locations was more distant, or when self-rated familiarity with the locations was greater. They interpreted this as indicating a hierarchical structure with different "degrees of resolution" at the different levels. In the higher-order "fuzzy" mental map distant and well known locations can be quickly compared while more specific information must be retrieved from a lower-order "detailed" map.

Stevens and Coupe's (1978) Subjects imagined a city at the centre of a circle (with north indicated) and drew a line from the centre of the circle towards the judged location of another city. The direction judgments between cities tended to align with the directions between the higher-order regions (eg. states or countries). Similar results were also obtained after studying page-sized (21 x 21 cm) maps of imaginary environments. Therefore it appears that directions between real or imaginary cities were remembered according to the directions between their higher-order regions.

McNamara (1986) found three types of effects indicative of the space being divided into higher-order regions. They used a room-sized (20 x 24 feet) or a page-sized (8.5 x 11 inches) space containing four borders and thirty-two objects (or names of objects). In a recognition task an object was recognised faster when it was preceded (primed) by an object within the same region. Direction judgments between two objects tended to align with the direction between the two higher-order regions. And distance judgments were overestimated between two nearby objects when they were in different higher-order regions.

Hirtle and Jonides' (1985) Subjects recalled thirty-two locations from the centre of a city with no "strict boundaries" between regions. Nonetheless, higher-order regions were identified within the spontaneous groupings in Subjects' recall orders; locations within the same subjective region were recalled in the same cluster and these groupings did not change in a test six weeks later. Distances between two locations were judged to be larger when they were in different subjective regions and judged to be smaller when they were in the same Subjective region. These hierarchical effects occur even in a space with no obvious regions.

Allen and Kirasic's (1985) Subjects viewed 60 slides of a 1000 meter walk through a residential area and were asked to divide the route into segments, or "what appeared to them to be a new part of the walk" (p. 219). Five segments were distinguished. Other Subjects (who had not consciously divided the path into segments) then made distance judgments and it was found that when locations were in different higher-order regions they were judged to be further apart. Thus, the hierarchical effect occurred regardless of whether Subjects intended to divide the space into regions.

McNamara and Colleagues (1989) looked for hierarchical effects in spaces least likely to produce it. Subjects learned the locations of twenty-six objects (eg. coin, shoe, egg) randomly distributed throughout a room-sized (20 x 22 feet) or a page-sized space. Subjective regions were identified according to the repeated grouping of objects into clusters during their free recall. The use of these subjective regions was confirmed by priming effects (an object is recognised faster if the preceding object was from the same region) and because distance judgments were biased by the higher-order region (distance between objects is judged smaller if they are in the same region). Again, a hierarchical structure was evident in the spatial representation even in the absence of any obvious higher-order regions in the space. They propose that the hierarchy emerges as a strategy to increase memory capacity by grouping information in to "chunks" (eg. Ericsson et al., 1980) or "clusters" (eg. Miller, 1956; see IVB.51) and that these spatial clusters become higher-order regions.

Kosslyn and Colleagues (1974) used children (4-5 years) and adults who learned the locations of 10 toys in a room-sized space (17 x 17 feet) by walking in the space and placing or removing toys from their designated locations. Movement was restricted to walking directly to the toy's location and back to "home base", and by four barriers which divided the space into quadrants. Two barriers blocked vision (opaque) and two did not (transparent). Results indicated that distance judgements were bias toward the distances between regions (two objects in different regions were judged as more distant than two objects in the same region, regardless of their actual distance). A developmental process was also indicated in which children tended to separate the space into four regions (with both types of barriers as boundaries) while adults tended to separate the space into two regions (opaque barriers only) (duplicated by Newcombe and Liben, 1982).

IIIC.13b Continuity of spatial extensions.

In addition to different sized regions, the notion of cognitive maps has also been used for different sized spaces (from the size of a piece of paper to the size of Earth). Similar learning and recall effects typically occur regardless of the size of space studied which indicates that there is a continuity of representation across sizes of spatial extensions. The notion of cognitive maps is equally applicable to all sizes of space from geographical directions to directions of limb movement.

The notion of "cognitive maps" typically refers to "the acquisition and use of spatial knowledge of large-scale environments", and thus "macrospatial cognition" (Allen and Kirasic, 1985, p. 218), or to a "large-scale spatial image" while the space of a small object or the size of a table-top are considered to be "microspaces" (Hardwick et al., 1976, pp. 1, 3). However, in other cases "cognitive maps" refer to spatial representations of any sizes of "environments committed to memory" (Hintzman et al., 1981, p. 155), including buildings within a city, objects in a room, drawings on a piece of paper, or directions of body parts. Ability for spatial orientation is considered to be a behavior which ranges from large-scale "geographical orientation" through to small-scale "limb orientation" (Stelmach and Larish, 1980, p. 168). "Space perception" is considered to range from "detection of a stable framework of the environment" through to "finer manipulative movements of skill" (Souder, 1972, p. 14). Likewise, Siegel and White (1975, p. 13) consider that "fundamental concepts" of space (eg. reaching toward directions, manipulating objects, locomotion) and "macrospatial cognition" (eg. knowledge of large-scale routes and loci) "are not independent - they are merely two aspects of the same generic problem" within spatial cognition.

Neisser (1976, pp. 113, 123) describes how "a cognitive map is essentially a perceptual schema" and thus is similar to other spatial representations (eg. of solid objects) in that large-scale environments are encoded into memory in a way very similarly to small-scale objects. Indeed, directions and movements of body parts are at the basis of knowledge of cognitive maps of any sized space since they are used during the actual physical process of spatial learning and recall (see IIC.33). For example Hochberg (1975) recorded eye movements and observed that when Subjects observe a small-scale object it is subdivided into several landmarks that receive the most repeated fixations. That is, an observer gathers information about large-scale and small-scale terrains in a similar way, by guiding locomotor movements in a large-scale space, and by guiding eye and limb movements in a small-scale space.

The spaces studied are freely varied from small-scale to large-scale spaces. Stevens and Coupe's (1978, Ex. 3) "map" of an imaginary country was a page-sized space which was learned by visual inspection. Recall of directions between map loci was then made by drawing appropriately oriented lines on paper. This task was considered to be analogous to cognition about a large scale environment but in practice it takes place entirely within the Subject's kinesphere. Likewise, Thorndyke's (1981) Subjects learned a map by drawing it. In these cases a large-scale environment is learned through vision and kinesthesia in a small-scale space within reach of the limbs. McNamara and Colleagues (1989, Ex. 2) refer to a page-sized array of thirty-two object names (eg. fan, candy, soap, shoe) as a "map" of the locations of the objects. Two ranges of space are used for the "map"; the locations within a room-sized space experienced by walking (placing the objects at their correct location), and the locations within a page-sized space experienced by eye and arm movements (placing the names at the correct location).

Levine and Colleagues' (1982) Subjects undertook the same groups of tasks in a "tabletop terrain" (experienced with arm/hand movements) and a "floor terrain" (experienced with locomotion). Similarly, Presson and Hazelrigg's (1984) Subjects learned about an environment by walking along a floor path or looking at a (50 x 50cm) map. In all cases spatial recall effects were identical regardless of the size of the space used.

Hintzman and Colleagues (1981) refer to a small circular area (6cm) as a "visual map" (p. 155), the remembered locations of objects in a tiny (1.6 x 1.6 m) room as a "cognitive map" (p. 162), and the perception of points touched on one's head as a "tactile map" (p. 175). In all cases the information in the "maps" is recalled by the direction of an arm movement through a small (9 cm) diameter circle. Recall effects are similar regardless of the size of the space.

Likewise, the "symbolic distance effect"* was found to occur for distance judgements about buildings on a campus (learned by locomotion) and for states of the U. S. A. (learned from maps) (Evans and Pezdek, 1980). This indicates that map learning and locomotion learning lead to a similar type of spatial memory representation.

Many researchers also refer to "mapping" processes within body movement perception and recognition of small-scale objects. Paillard and Brouchon (1974, p. 283) discuss how kinesthetic "position cues have a real function of 'marking' space . . . [within] some internal map necessary for the elaboration of a complex program of spatially coordinated motor activities". Saltzman (1979, p. 113) refers to the "task-

* The closer in length are two distances (or sizes), the longer time is required to determine which distance (or size) is larger.

space mapping" of limb movements within the workspace. Heister and Colleagues (1990) refer to perceptions of external space according to the relation with anatomical locations as "spatio-anatomical mapping". Humphreys (1983, p. 151) discusses how recognition of objects is achieved by "mapping" the sensory information into a memory representation. Ruff and Perret (1982) refer to a "spatial mapping" process by which a form is derived by auditory tracking the pathway of an unseen sound source. This indicates how many spatial ranges and activities can be considered to consist of "mapping".

Studies in the choreutic tradition also use an analogy in which polyhedra "are like maps" and the paths of movement are like "specific routes" along the map (Bartenieff and Lewis, 1980, p. 29). Laban (1926) describes how "we must construct particular points around us", that paths are created by connecting "point to point" (pp. 21-22), and that these are used as "orientation points" for the mapping of the path (p. 11). A "choreutic map" is used for "mapping choreutic configurations" (Salter, 1983, p. 166), and the three Cartesian planes can be used as "points of reference" in order to undertake a "mapping" of body movements (Moore, 1982, pp. 68-69).

In summary, there appears to be a continuity of spatial representation ranging along a continuum from small spaces (explored and learned via limb movement) nested within large spaces (explored and learned via locomotion). Map-like images have similar cognitive characteristics regardless of the size of the space.

<u>IIIC.20 Kinespheric Image as a Map, Grid, Net, Scaffolding, etc.</u>

The bodily reach space, work space, or "kinesphere" (see IIB.38) has been conceptualised as a map-like image by artists, architects and within choreutics. The image of the kinesphere might be referred to as a map, grid, graph, network, framework, scaffolding, or a lattice. These terms express the same general idea in slightly different ways.

Body movements are often considered to be organised into a mental representation analogous to a map within choreutics and motor control research (see IIIC.13b). A "map" is essentially defined as a diagrammatic representation of anything:

> a diagrammatic representation of the . . . geographical distributions, positions, etc., of natural or artificial features such as roads, towns, relief, rainfall, etc., . . . a diagrammatic representation of the distribution of stars or of the surface of a celestial body . . . a map-like drawing of anything. (Collins, 1986).

Laban (1966, pp. 68, 101-107) uses the analogy of the kinespheric structure as a "scaffolding" which can be defined as "a temporary metal or wooden framework that is used to support workmen and materials during the erection, repair, etc., of a building or other construction" (Collins, 1986). This emphasizes Laban's architectural analogy evident in many places, for example the famous statement that "Movement is, so to speak, living architecture" (Laban, 1966, p. 5), the referral to movement as being a "'building process'" (Laban quoted by North, 1972, p. 9), the conception that movements are "constructed" (Laban, 1926, pp. 28, 88 ["*gebildet*"]), and so "we must construct particular points [of the kinesphere] around us" (Laban, 1926, pp. 21-22). Laban (1966, p. 124) regards the scaffolding much like a map in that "trace-forms following the simple lines of the scaffolding can be represented mentally without great difficulty".

Bernstein (1984, p. 109) refers to the spatial organisation of body movements as the "co-ordinational net of the motor field". Networks consist of "a number of parts, passages, lines, or routes that cross, branch out, or interconnect" (American, 1982) and are used in a variety of applications such as analysing railroad tracks and airline routes (Frank and Frisch, 1970). The network analogy emphasizes the flow of motion along "links" in the net from locus to locus.

The kinespheric structure is sometimes considered to be analogous to a "grid" in choreutics (Preston-Dunlop, 1984, p. 17) and in architecture (Le Corbusier, 1980, pp. 37-44). The grid analogy emphasizes a regular "pattern of horizontal and vertical lines . . . used as a reference for locating points" (American, 1982), for example the pattern of latitude and longitude lines on the map of the earth.

The term "lattice" is used to refer to the regular pattern of molecular arrangement in crystals or as decorative landscaping woodwork. It is defined as an "open framework made of strips of metal, wood, or similar material interwoven to form a regular pattern . . . [and] A regular, periodic configuration of points, particles, or objects throughout an area of space, esp. the arrangement of ions or molecules in a crystalline solid" (American 1982). This is similar to the choreutic conception of polyhedral structures of the kinesphere.

Kinespheric structures could also be referred to as "graphs" which are defined as "depicting the relation between certain . . . quantities by means of a series of dots, lines, etc., plotted with reference to a set of axes" (Collins, 1986). Choreutics uses polyhedra which can be considered to be "platonic graphs" (Wilson and Watkins, 1990, p. 38) when each node of the graph is located at each polyhedral vertex.

In summary, each term has a slightly different emphasis. The most general term is a "framework", defined as "a structure or frame supporting or containing something" (Collins, 1986). "Scaffolding" emphasizes Laban's architectural metaphor. "Grid" or "graph" emphasize the loci and reference lines used in maps to specify particular loci. "Map" emphasizes the identification of loci and paths of various kinespheric forms. "Lattice" emphasizes the polyhedral crystalline structure. "Network" or "net" (following Bernstein, 1984, p. 109) is used here since it is descriptive of the linking together of multiple loci in any formation. The choice of a term is somewhat arbitrary. "Scaffolding", "grid", "graph" and "lattice" may indicate a fixed, stable kinespheric structure, whereas the notion of a net is more pliable and lends itself nicely to conceptions kinespheric forms deflecting across variously shaped polyhedral nets (see IVA.80; IVB.34).

IIIC. 30 Cognitive Structures of the Kinespheric Net

IIIC.31 Cartesian Coordinates and Planes.

The most common kinespheric network consists of the "x", "y", and "z" axes of the Cartesian coordinate system and the corresponding three "Cartesian planes" ("xy" plane, "yz" plane, "zx" plane) which are used in anatomy and kinesiology to specify the locations and movements of body-parts (Kapit and Elson, 1977, p. 1; Rasch and Burke, 1978, p. 97; Wells and Luttgens, 1976, p. 21). The three dimensions and three planes have been referred to with various terms (see Appendix VIII). In this study the following terms will be used:

<u>Planes</u>:

Medial	(or paramedial to specify a non-central plane)
Frontal	(or midfrontal to specify a central plane)
Horizontal	(or midhorizontal to specify a central plane)

<u>Dimensions</u>:

Vertical	(up/down)
Sagittal	(forward/back)
Lateral	(right/left)

IIIC.32 Spheric Shape of Kinesthetic Space.

The most general conception of kinesthetic-space is as a sphere, hence the notion of the "kinesphere" (see IIB.38). This spheric conception of kinesthetic space is presented in choreutics (Bartenieff and Lewis, 1980, p. 25; Laban, 1966, p. 10; Lamb, 1965, p. 58), underlies conceptions of directions in bodily movement notation systems (Eshkol and Wachmann, 1958, p. 53; Hutchinson-Guest, 1983, p. 54), forms part of the "space module" of ballet theory (Kirstein and Stuart, 1952, pp. 2, 20, 30), and is drawn by artists (Strauss, 1974, p. 2579). The principal elements of a sphere are its centre and the periphery (see IVA.21). The centre is conceived as located at the centre of the body near the naval or as located at any skeletal joint (see IIIA.26). The location of the periphery is dependent on the degrees of extension of the body-parts (Hutchinson, 1970, p. 162) and also the physical size of the body.

Except for the centre and the periphery, the sphere is undifferentiated and so is not very useful for the mapping of kinespheric forms. Individual locations must be designated within the kinesphere and these loci can be grouped into higher-order nets within which forms can be mapped.

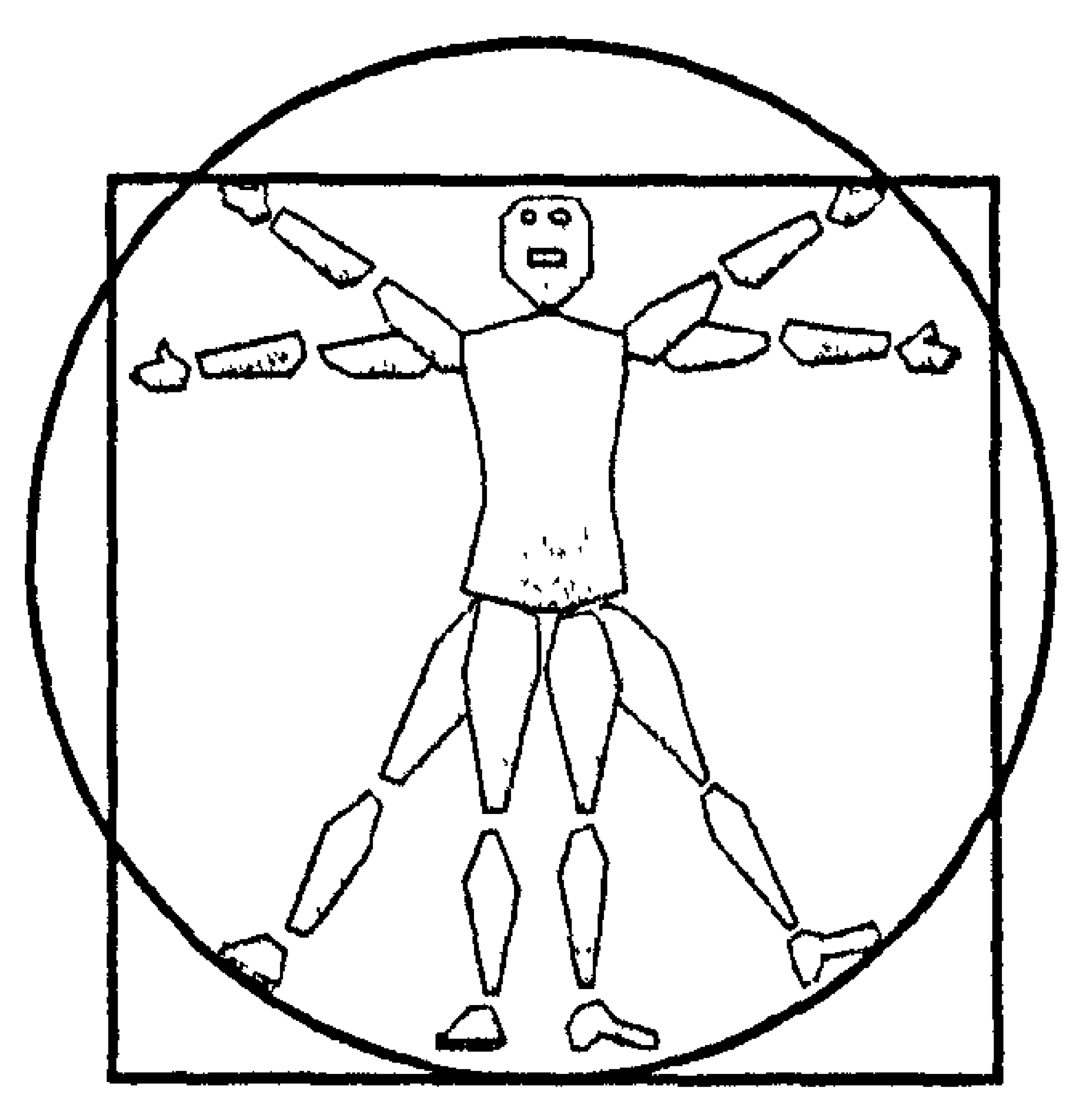

Figure IIIC-3. Proportions of the human figure (adapted from Leonardo Da Vinci's drawing; Heydenreich, 1928, p. 10; Strauss, 1974, p. 2475).

IIIC.33 Planar Networks.

The kinesphere is often partitioned by representing it as variously shaped planar networks. Much of this has been with the intention of defining the proportions of the human body. The most famous example is probably Leonardo Da Vinci's "sketch showing the proportions of the human figure" (Heydenreich, 1928, p. 110; also in Strauss, 1974, p. 2475) in which the body is presented within a square-shaped frontal plane and circumscribed by a circle (Fig. IIIC-3). Doczi (1981, p. 93) reports that this conception originated from earlier books on architecture published by the Roman Marcus Vitruvius Pollio.

The Renaissance painter Albrecht Dürer (eg. Strauss, 1974) also aligned a circle and square with the body's frontal plane (p. 2426), experimented with conceptions of the human chest as a frontal pentagon-shaped plane (p. 2465), and placed the entire body or various body-parts within square and rectangle nets in the frontal or medial planes (pp. 2476-2477). Similarly, Doczi (1981, pp. 96-100, 143) and Ghyka (1977, pp. 97-109) lay various frontal planar networks of squares, rectangles, and circles over the entire body or individual body-parts in an analysis of body proportions and directions of movement.

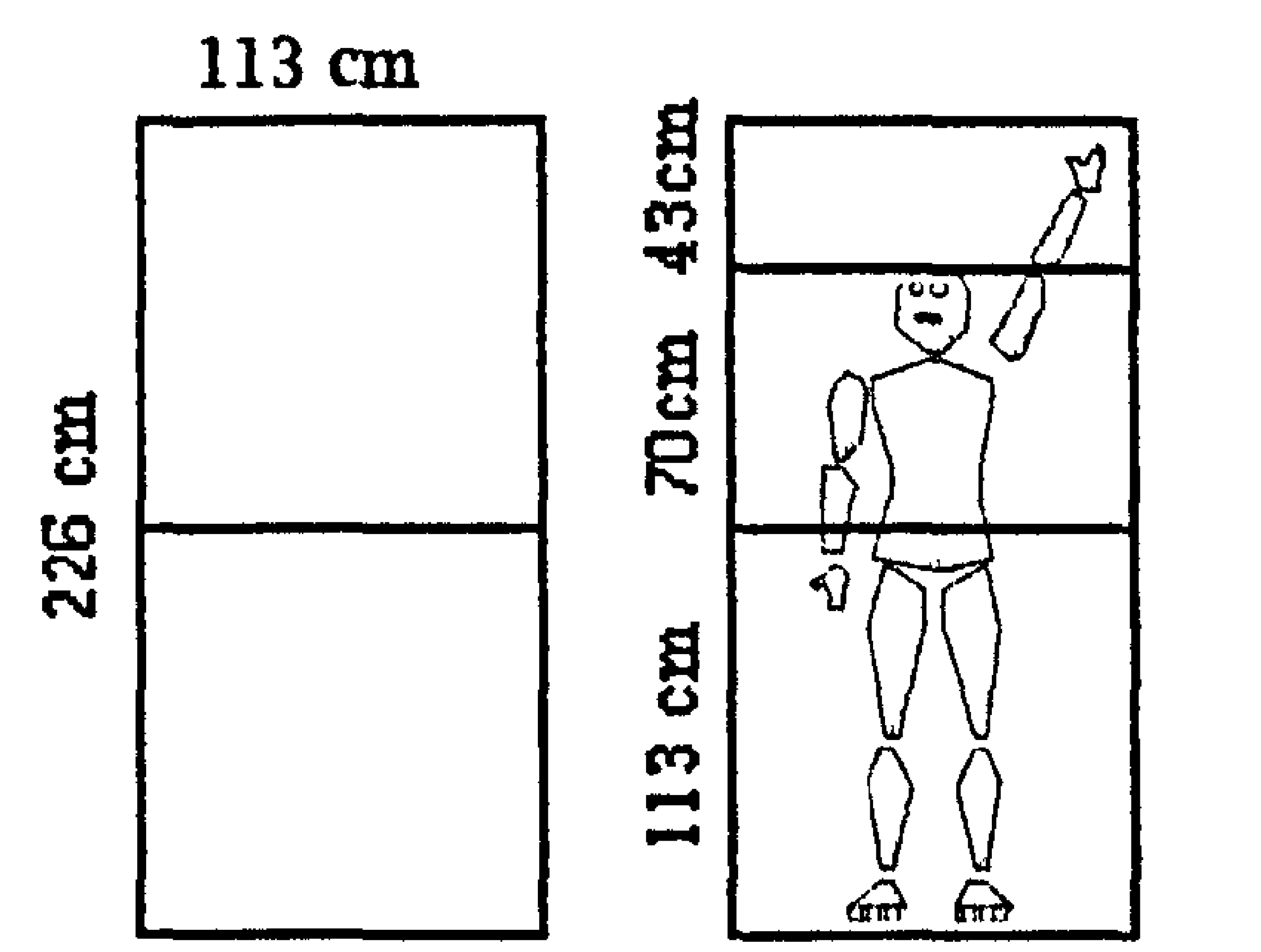

Figure IIIC-4. Grid of proportions (adapted from Le Corbusier, 1980, p. 66).

The architect and painter known as Le Corbusier (1980 pp. 37-44, 53-58) describes the process of deriving a "'grid of proportions'" which is "designed to fit the man placed within it" (p. 37) and so "mathematical order is adapted to the human stature" (p. 41). This grid was intended to provide a body-scaled system of measurement which "should be set above both the system of the foot-and-inch and the metric system" (p. 45):

> . . . a "grid of proportions" . . . will serve as a rule . . . a norm offering an endless series of different combinations and proportions; the mason, the carpenter, the joiner will consult it whenever they have to choose the measures for their work; and all the things they make . . . will be united in harmony. That is my dream. (Le Corbusier, 1980, p. 37)

Le Corbusier's (1980) kinespheric net is oriented in the frontal plane and is based on two squares forming a rectangle (226 cm high, 113 cm wide) (p. 66) based on the average height of a human of six feet (182.88 cm) (p. 56). Within this basic network many other relations are constructed, including right angles, the golden proportion, and measurements corresponding to the Fibonacci series (Fig. IIIC-4).

Laban (1966) briefly discusses planar arrangements of poses in which the body has a "two-dimensional feeling . . . resembling the plane-like formation of the leaves of plants" (p. 18). One of these typical poses creates a pentagon/pentagram-shaped planar network (Fig. IIIC-5) which is described as an "elementary posture" in which "Our flat bodily structure encourages a division into five principal zones: the zone of the head, the two zones of the arms, and the two zones of the legs" and is "like a star with five equal pulls towards five points of the kinesphere" (pp. 19-20 [also pictured by Bartenieff and Lewis, 1980, p. 113]). Laban conceives of this pentagon pose as possibly transforming into a quadrangle pose (Fig. IIIC-6):

> Sometimes an awareness of the extended arms and legs prevails, when the arms are somewhat raised and tension is particularly stressed in the extremities. We then becomes less conscious of the vertical direction [in the pentagon pose], but have rather the feeling of a quadrangular construction. This tension tends to evoke a more ecstatic feeling than that ["intellectual awareness"] accompanying the pentagonal attitude. (Laban, 1966, p. 20)

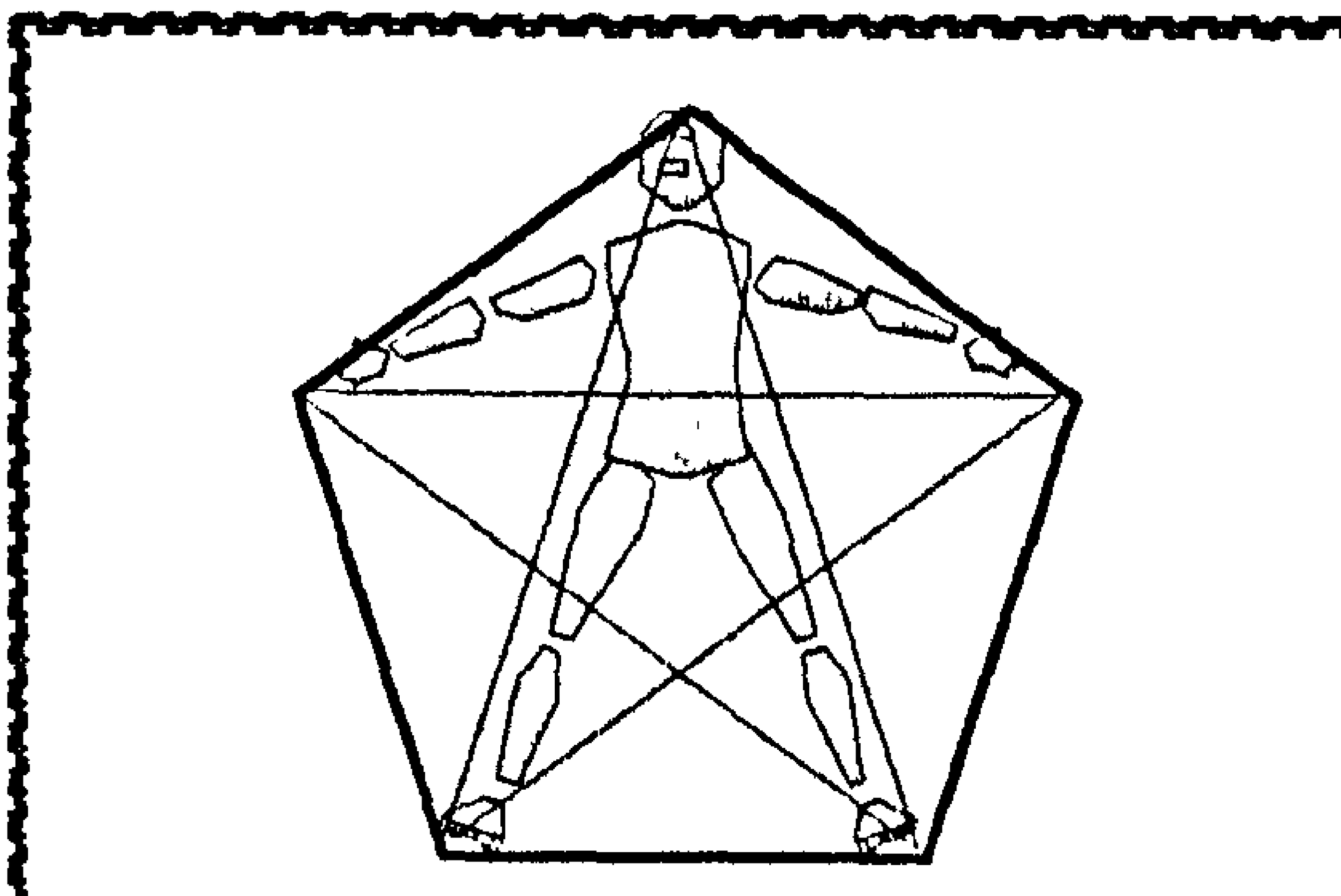

Figure IIIC-5. Pentagonal body pose (adapted from Laban, 1966, p. 19).

Quadrangle poses are conceived to transform further into tetrahedral poses when the arms and legs are no longer within the same plane (Fig. IIIC-7). These are described as "plastic variations of the flat quadrangle (Laban, 1966, pp. 20-21) or as "tetrahedral tensions" (Bartenieff and Lewis, 1980, pp. 97-99). Laban (1984) made many drawings of variously shaped tetrahedral nets for different body poses.

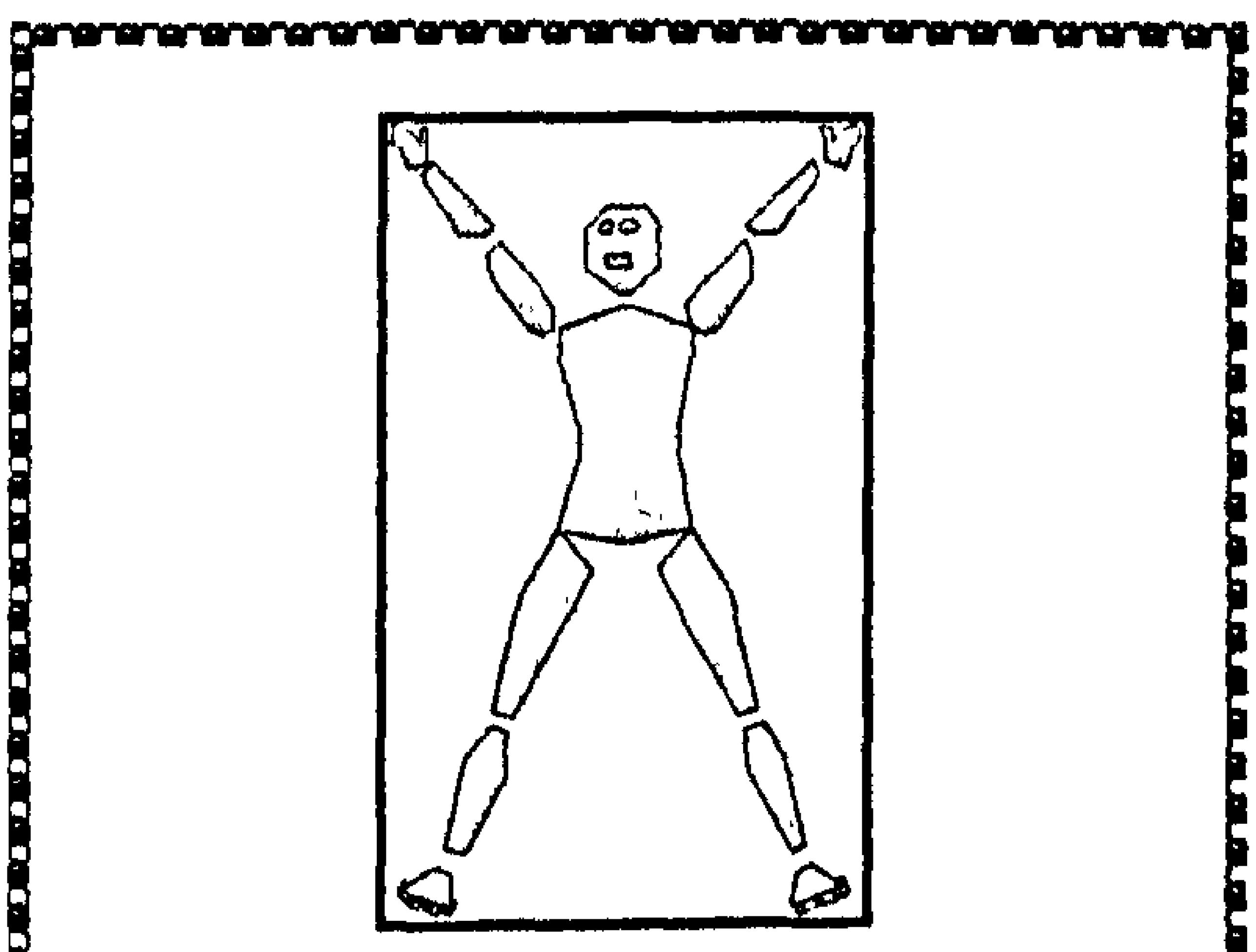

Figure IIIC-6. Planar quadrangle network .

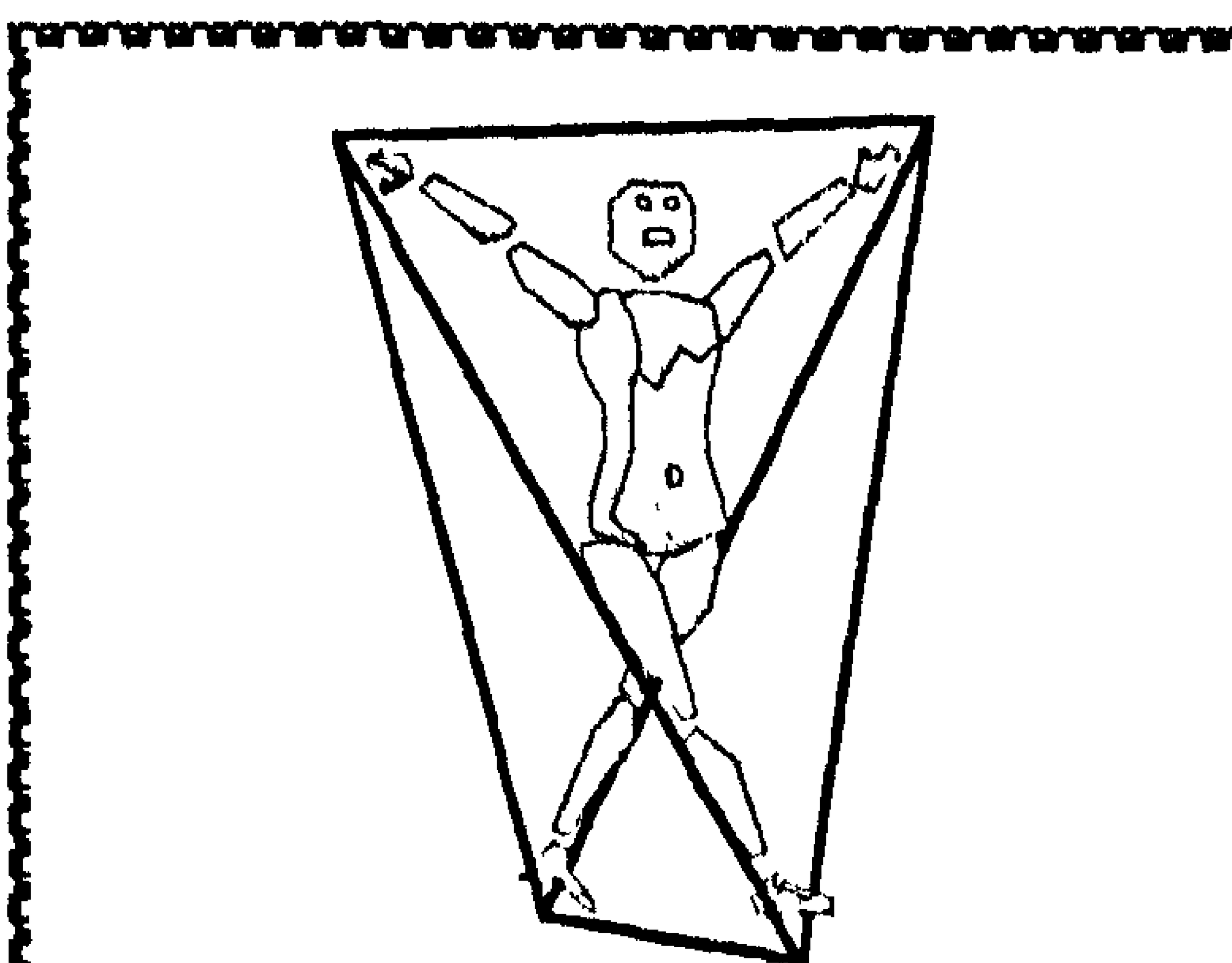

Figure IIIC-7. Tetrahedral network (adapted from Laban, 1984, p. 18).

IIIC.34 Choreutic Conception of Polyhedral Nets.

One of the most unique components of the choreutic conception is a system of polyhedral nets used as cognitive maps for the representation of kinespheric forms. Laban made abundant illustrations of paths and poses represented according to loci in various polyhedral nets and a small selection of these has been published (Laban, 1984).

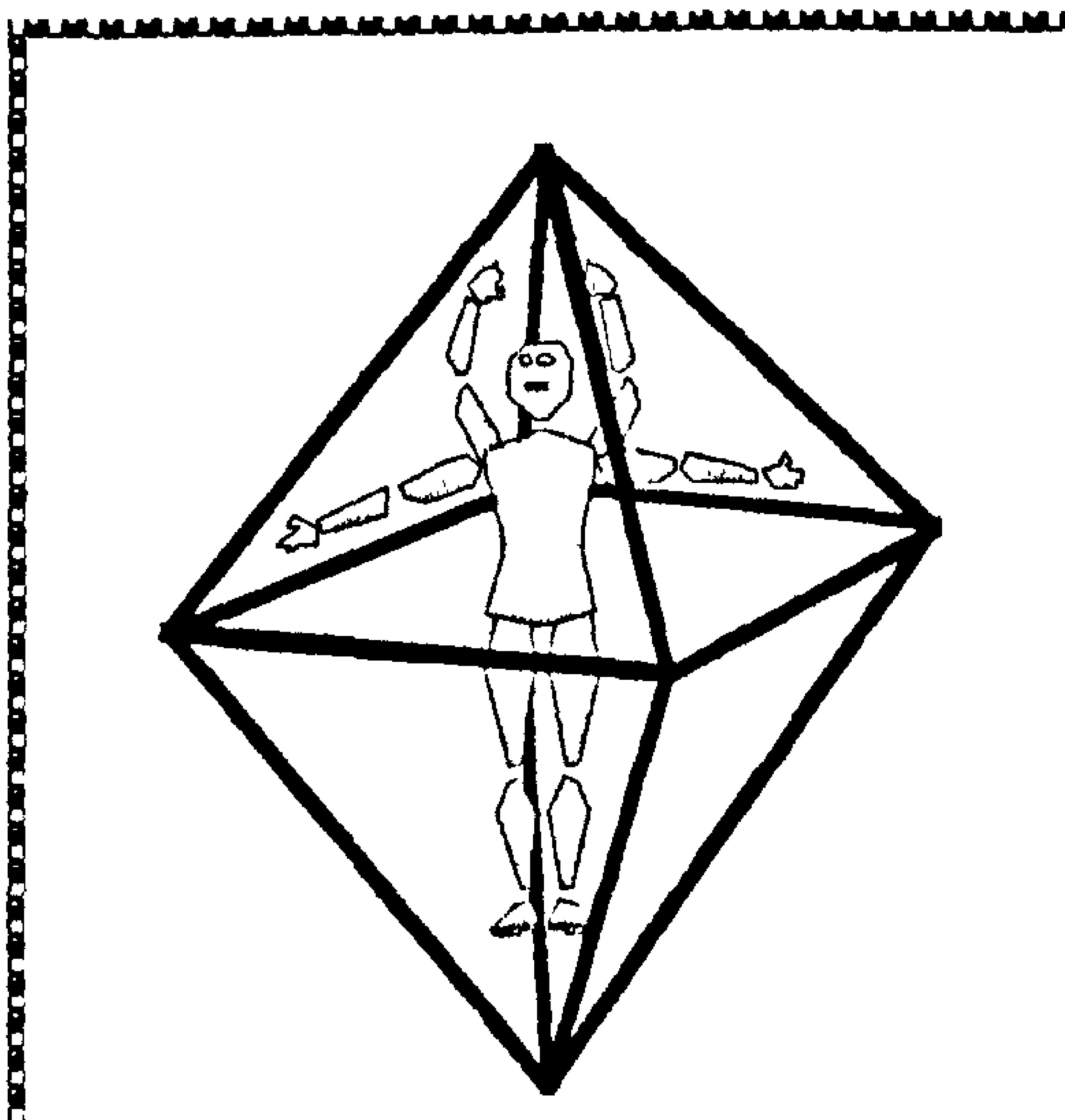

Figure IIIC-8. Octahedral net (adapted from Laban 1926, p. 20).

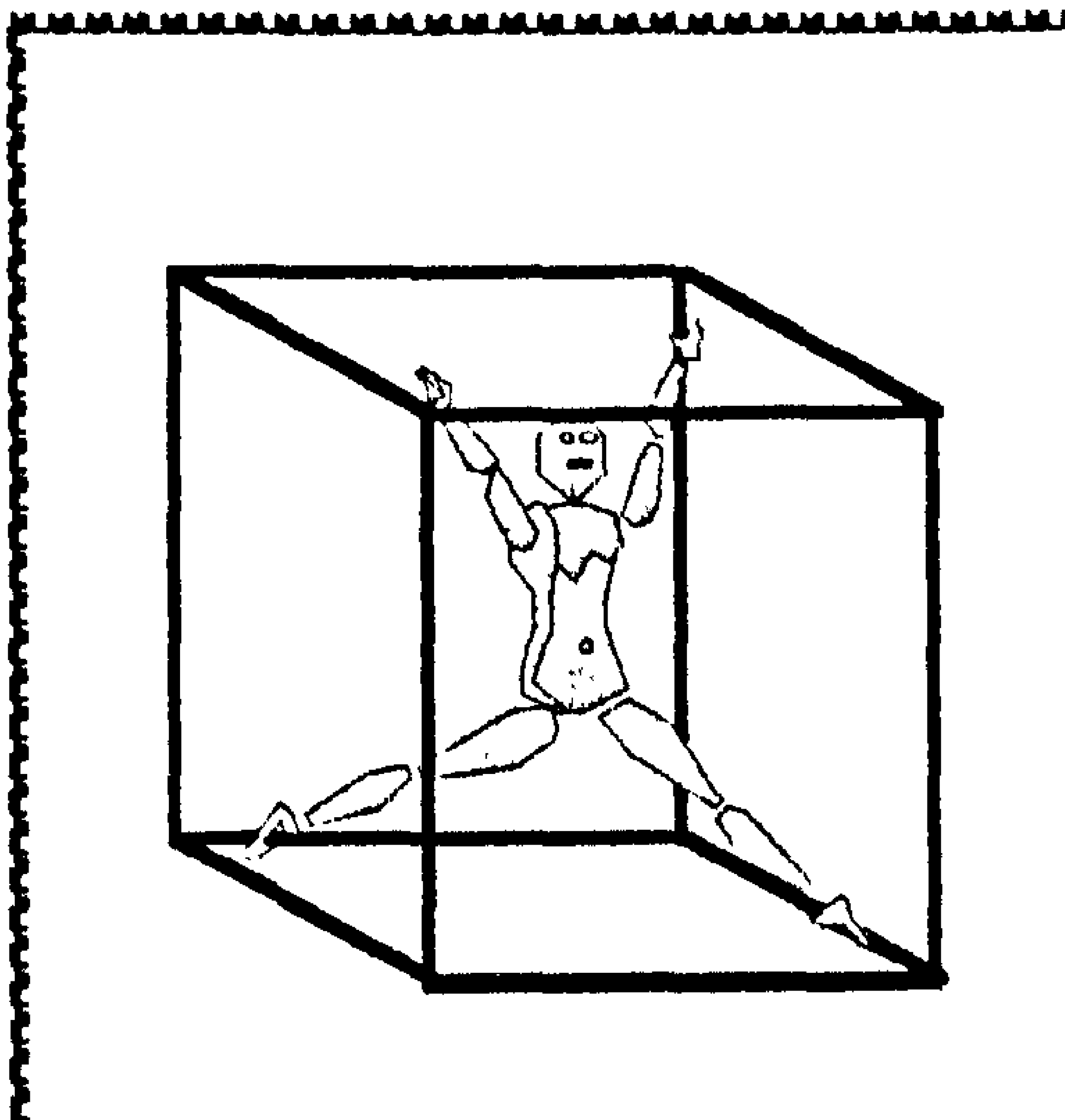

Figure IIIC-9. Cubic net (adapted from Laban 1926, p. 21).

The five regular polyhedra* are principally used which are representative of the most equalised, symmetrical divisions of three-dimensional space.[#] Occasionally other irregular polyhedra are also used (see below). The possibilities for polyhedral nets are endless, for example Wenninger (1971) presents over one-hundred varieties and states that this includes "only some polyhedral forms . . . [with] obvious omissions" (p. 204). However, the vast majority of the irregular polyhedra are themselves derived from the five regular polyhedra (via operations such as truncation, stellation, and interpenetration; see Holden, 1971), and so the five regular polyhedra can be considered to be higher-order networks while the other irregular polyhedra are

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* A "regular" polyhedron contains all edges of equal length, all angles of equal degree, and all polygonal surfaces of identical shape. The five regular polyhedra (also called "platonic solids" since they are mentioned in Plato's Timaeus) are the tetrahedron (four triangle surfaces, four vertices), hexahedron (ie. cube; six square surfaces, eight vertices), octahedron (eight triangle surfaces, six vertices), dodecahedron (twelve pentagon surfaces, twenty vertices) and the icosahedron (twenty triangle surfaces, twelve vertices) (For discussion of polyhedra, truncations, etc. see Holden, 1971).

\# Whereas an infinite number of regular polygons divide two-dimensional space into equal parts (eg. triangle, square, pentagon, heptagon, octagon, etc.), only five regular polyhedra are possible which divide three-dimensional space into equal parts.

lower-order variations. These polyhedral nets are briefly mentioned here and are considered in more detail later (see IVA.20).

IIIC.34a Octahedron and cubic nets.

The dimensional directions are joined to build an octahedral network (Fig. IIIC-8). The diagonal directions are joined to build a cubic (hexahedral) network (Fig. IIIC-9). Many variations of the cubic net are used. Laban (1966, pp. 12-71, 95-99) represents kinespheric forms on a net of three parallel horizontal planes or "three levels in cubic space" (p. 16) which correspond to a higher-order cubic-shaped network. A cubeoctahedral network is also used (p. 104) which can be derived from the cube or the octahedron by connecting the mid-points of their edges. Occasionally a rhombic dodecahedron is used (Laban, 1984, p. 66) which is derived by linking the six vertices of the octahedron together with the eight vertices of an interpenetrated cube. Cubic nets have also been used as a "space module" for the conceptual representation of ballet positions and movements (Kirstein and Stuart, 1952, pp. 2, 20, 30).

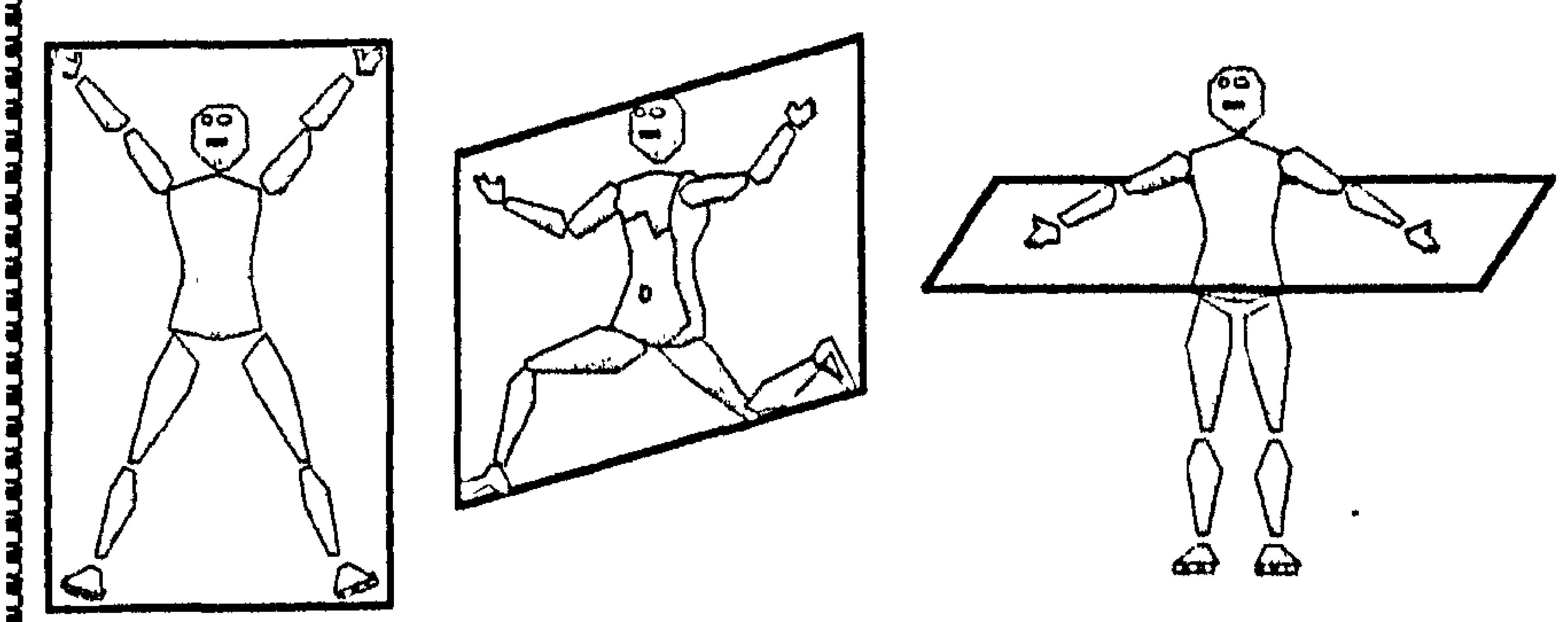

Figure IIIC.10. Rectangle-shaped Cartesian planes (adapted from Laban, 1926, p. 23).

IIIC.34b Icosahedral and Dodecahedral nets.

The corners of the three Cartesian planes are joined together to create variously-shaped networks. The hypothesised shape of the Cartesian planes is one aspect of the choreutic prototype/deflection hypothesis (see IVA.24). When the Cartesian planes are square-shaped (ratio between sides 1 : 1) then their corners can be joined into a twelve-loci cubeoctahedral net which is a variation of the octahedral or cubic net. If the Cartesian planes are rectangle-shaped with the proportion of the "golden section" (ratio between sides $\approx$ 1.618 : 1) (Fig. IIIC-10) then their corners can be joined into a twelve-loci icosahedral net (Fig. IIIC-11) (Laban, 1926, p. 23;

Ullmann, 1966, p. 142). If the Cartesian planes are shaped in long narrow rectangles (ratio between sides ≈ 2.618 : 1) then they can be linked together with the eight diagonal directions into a twenty-loci dodecahedral net.

The actual shape of the kinespheric net during certain movements has been measured by ergonomic and motor control researchers (eg. Dempster et al., 1959). This is considered in more detail within the discussion of the choreutic prototype/deflection hypothesis (see IVA.90).

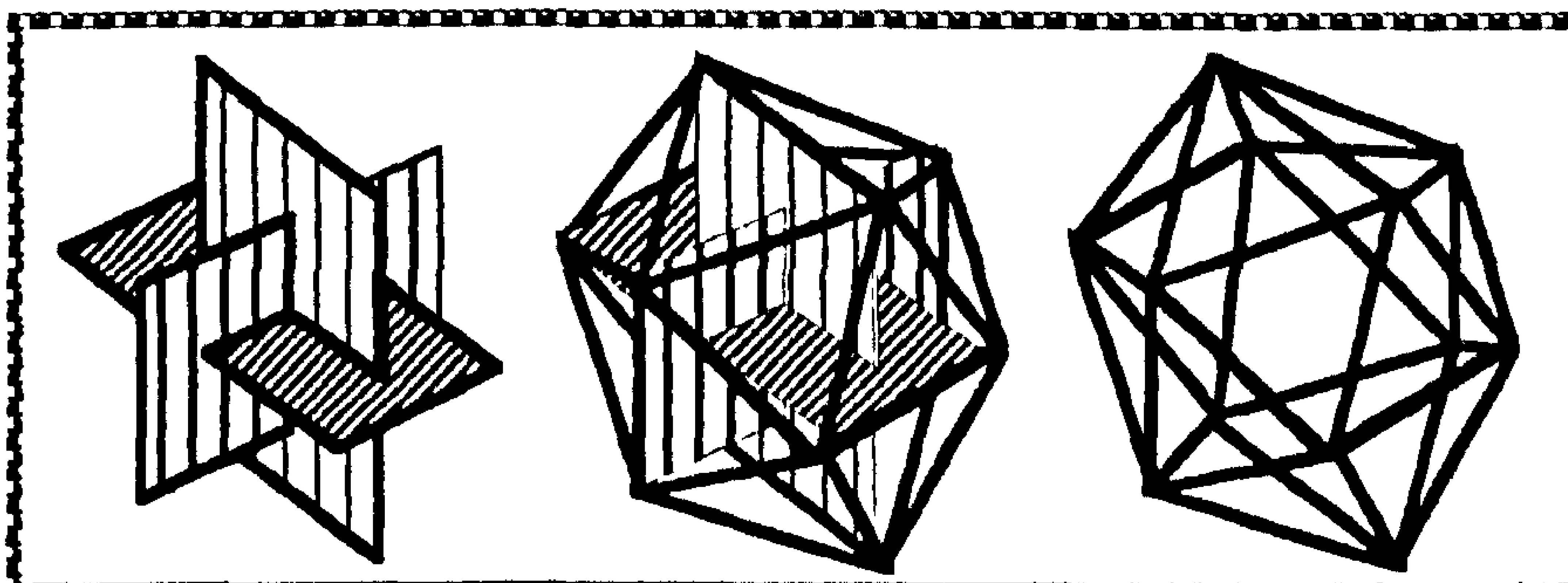

Figure IIIC-11. Linking the corners of the Cartesian planes builds an icosahedral net.

In an anthropometric and ergonomic study, Critchlow and Robinson (1962; Critchlow, 1969, pp. 86-89) used Laban's work as their basis and developed a kinespheric network consisting of a truncated octahedron containing a truncated icosahedron. Since each point of the octahedral or icosahedral net had been truncated (ie. cut off) a small polygonal surface remained where each vertex used to be. This can be conceived of as expanding the area of each locus so that each single locus is now surrounded by a small polygonal network of locations.

IIIC.34c Tetrahedral net.

A tetrahedral network is used in choreutics as an underlying basic or elemental net. Laban (1966) considers that "almost all positions of the body can be reduced or related to a tetrahedral form for they are plastic variations of the flat quadrangle" and that even in "many-directional movements a tetrahedral kernel can, nevertheless, be recognised as the simplest expression of the whole tension" (p. 21). This conception may be based on the transformation of the frontal planar net into the tetrahedral net whenever the body twists and so cannot be contained within a single plane (IIIC.33). The four limbs or the four proximal joints can each be conceived at one of the four vertices of the tetrahedral net. Ergonomic researchers have also identified tetrahedral forms within body poses which provide a high degree of structural stability (Dempster, 1955, p. 564).

Since a tetrahedral net can be built by linking the body's four limbs, or four global joints, it can always be identified within other kinespheric nets. For example, if a body stands on one leg with the other leg reaching dimensionally forward and each arm reaches to the side this pose could be conceived within a higher-order octahedral net or a lower order tetrahedral net (Fig. IIIC-12).

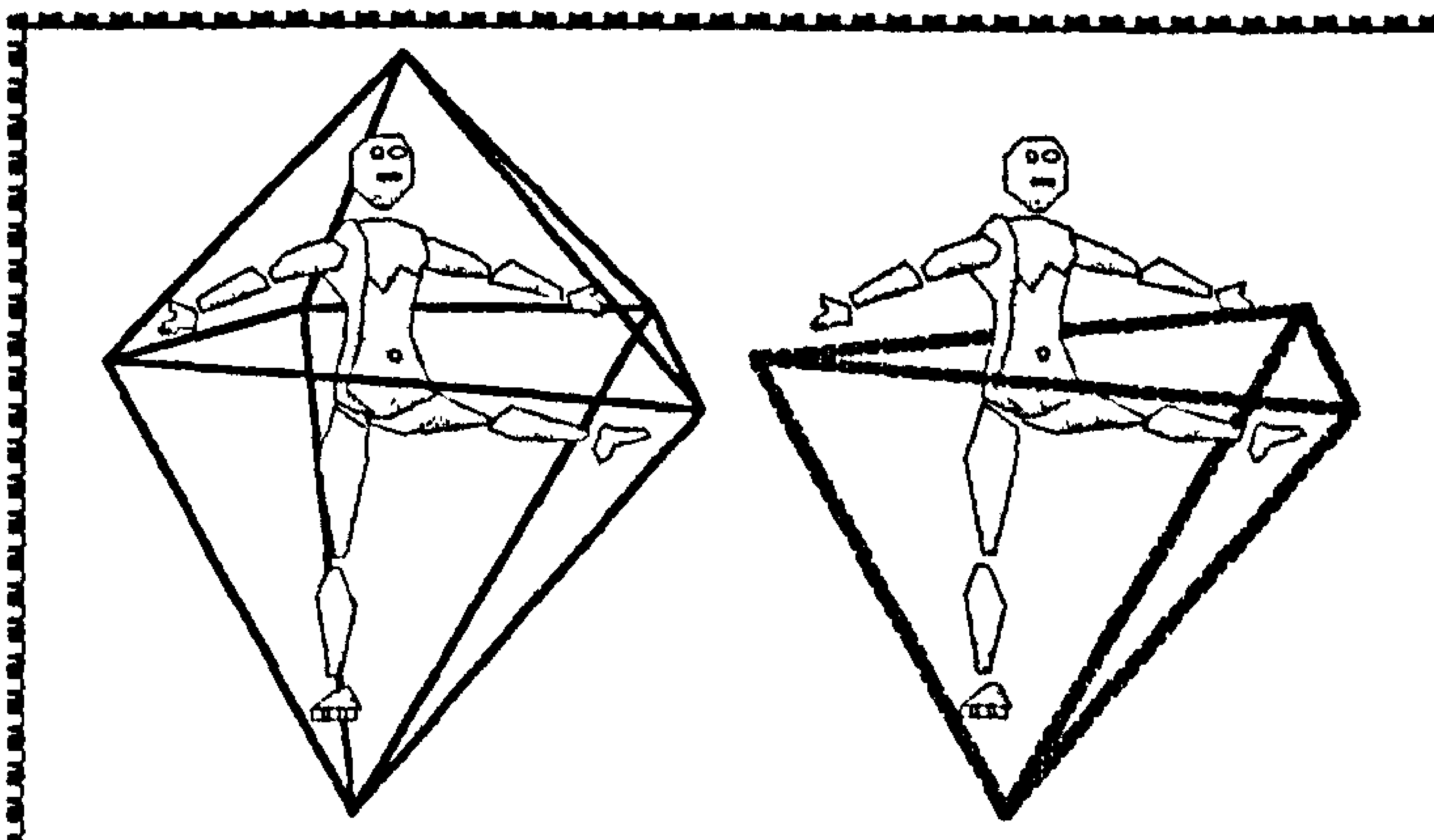

Figure IIIC-12. Higher-order octahedral and lower-order tetrahedral nets for a kinespheric pose.

IIIC.40 Conclusions: Map-like Images

Sequences of locations which have been well learned will be conceptually joined together into map-like images which simultaneously represent an entire spatial environment. A great deal of "cognitive map" research has explored characteristics of these spatial images for environments ranging from small page-sized spaces accessible to eye and arm movements through to large country-sized spaces accessible by traveling. This provides psychological validity for Laban's use of geometric map-like images of the kinesphere (termed grids, networks, or scaffolding). Similar geometric kinespheric maps have been depicted by artists and architects (eg. Leonardo Da Vinci; Le Corbusier). In the choreutic conception bodily paths and poses are represented as groups of locations within polyhedral-shaped conceptual map-like images of the kinespheric network.

IIID. Symmetrical Transformations

Spatial information can be mentally and physically transformed according to various symmetrical operations. Many types of symmetrical transformations are also used in dance technique and choreography. Choreutic practice includes exercises in transforming kinesthetic spatial information into new variations. Choreutic "scales" consist of kinespheric forms which are symmetrical in three dimensions.

IIID.10 Necessity of Symmetrical Transformations

The ability to perform symmetrical transformations is essential for normal everyday spatial cognitive processes. Whenever we move in an environment our memory image of the locations of objects in that environment must likewise be transposed or rotated relative to the location and orientation of our body (Hintzman et al., 1981). When giving directions from a real or imaginary map, one must either physically or mentally rotate the map to fit the environment in order to know the correct (right, left) directions (Hardwick et al., 1976, p. 5). Rotations around two different axes may also be necessary if the map and the environment are not in parallel planes. It is the ability to manipulate spatial knowledge that makes it useful:

> . . . the content of a cognitive map really cannot be considered in isolation from its *manipulation*. The functions of a cognitive map assume the manipulation of internalized spatial information.
>
> . . . [for example, a road map] if one cannot manipulate the map, that is, key it to one's own location and extract its information, it has no functional value. (Hardwick et al., 1976, p. 4 [italics theirs])

Similarly, Piaget and Inhelder (1971) refer to the "figurative" and the "operative" aspects of cognition. The figurative is concerned with static configurations while the operative aspect is concerned with changes from one static figure to the next. In Piaget and Inhelder's (1967) scheme, children are observed to gradually develop through phases in the ability to perform operations on figural knowledge and thus transform it into new orientations and situations.

Ability to perform rotation, translation, and sizing operations (see below) on visual stimuli is necessary for recognition since objects may often occur in different orientations, in different places (egocentric and exocentric), and will have a larger or smaller visual image depending on their distance from the observer. In all these cases a symmetry operation is necessary for the successful recognition of the object (Rock, 1973, p. 6).

Symmetrical operations also appear to be used to organise spatial information into higher-order groupings. This type of strategy has the effect of increasing verbal memory capacity by remembering a large number of individual items according to a smaller number of groups, "clusters", or "chunks" of items (eg. Miller, 1956; Tulving, 1962; 1966; Reitman and Rueter, 1980; see IVB.51). Jordan and Rosenbaum (1989) point out that not only do hierarchical groupings allow one to "minimize the load on peripheral memory structures, which have limited storage capacities" but that they are also "convenient structures for the application of transformational rules such as repetition, mirroring, and transposition" (p. 742). This was found to occur in motor memory. Restle and Burnside's (1972) Subjects learned a movement sequence of 24 fast key-taps on a display of 6 keys. The sequence of key-taps contained a structure which would enable Subjects to organise them into higher-order clusters. For example, the key-tap series might consist of a run up the keys in sequence (#1, #2, #3), a retrograde of that series (#3, #2, #1), successive repetitions of the same key (#6, #6, #6), or alternations between two keys (#5, #6, #5, #6). Subjects' errors (ie. tapping a key out of sequence) indicated that the sequence of movements were being organised in groups according to the symmetrical relationships amongst its members (ie. most errors occurred at the end of a symmetrical grouping). When another layer of hierarchical structure was available, for example a translation of a series (#1, #2, #3, #2, #3, #4), or a mirror image of a series (6-key display; #1, #2, #3, #6, #5, #4) then the movement sequence is learned easier. This indicates that Subjects search for and use symmetrical groupings among kinesthetic spatial items as a strategy to facilitate memory. Likewise, the time required to initiate a series of key-tapping movements is dependent on the length of the series. However, when symmetrical groupings are present within the series then the reaction time is shortened (Inhoff et al., 1984).

Memory groupings based on symmetrical transformations correspond to other hierarchical models of motor memory and speech movements in which limited storage capacity is accommodated for by grouping individual movements (eg. key-taps) into higher-order clusters based on a "rule" about the transformation that will generate all the members of the cluster (Collard and Povel, 1982; Gordon and Meyer, 1987; Greeno and Simon, 1974; MacKay 1982; Restle, 1970). For example, if an initial item of a cluster is known, then the other members can be derived by applying transformational rules which define the cluster. Keele and Summers (1976, p. 134) concluded from this that symmetrical relationships between movement elements are a basis for developing a hierarchical motor memory structure which can facilitate the learning process.

Clusters of movements may also be defined by a temporal rhythmic symmetry, that is, the relative timing or "phasing" between the elements within the sequence (Martin, 1972). For example, an 8-part series of tones was more easily remembered than a 7-part series of tones, presumably because the 8-part sequence could be more easily divided into two equal 4-part series, but this symmetry is not possible with a 7-part series (Sturges and Martin, 1974).

IIID.20 Varieties of Symmetry

The notion of symmetry is often used to refer to bilateral reflection symmetry. While this may be predominate because of the bilateral symmetry of the body structure (see below) it is only one out of many types of symmetrical transformations (see reviews by Holden, 1971; Wechsler, 1990; Weyl, 1952). A review of symmetrical transformations in spatial cognition and motor control tasks, and within dance and choreutic practice, has distinguished the following types of symmetry:*

Body symmetry:	Transferring the form to different body-parts
Spatial symmetry:	Translation to a different area
	Reflection across any plane
	Rotation around any axis
	Retrograde the previous motion (end-to-beginning)
	Size scaling (enlarge or reduce the overall size)
Temporal symmetry:	Velocity and overall duration

Symmetry can be conceived as the symmetry present within a figure (or group of figures) or it can be conceived as operations which are applied to a figure to derive a symmetrical variation. The latter conception follows the geometric definition of a "transformation" as "A change in position or direction of the reference axes in a coordinate system without an alteration in their relative angle" (Collins, 1986). That is, the axes of a figure can be changed (reflected, rotated, translated) but the shape of the figure itself is unchanged. Examples of these two types are given with the particular types of symmetry (see below).

In choreutics the term "transposition" (borrowed from music theory) is sometimes used to refer to symmetry operations (Laban, 1966, p. 113; Preston-Dunlop, 1980, p. 182; 1984, p. x; Ullmann, 1966, p. 172; see IIID.50). The terms

* Spatial symmetry is the focus here. Most forms of temporal symmetry (eg. canon) are not considered (see Blom and Chaplin, 1982).

"transformation" and "operations" are used in geometric and spatial cognitive studies (Bundesen et al., 1981; Cooper and Podgorny, 1976; Hardwick et al., 1976; Kosslyn, 1980) and so are adopted here.

All types of symmetry must be defined relative to a system of reference (see IIIA). For example, a form may be translated relative to the body (egocentric) but if the body also translates itself through space the form could occur in the same location relative to the room (exocentric). Or a form may be reproduced in the same egocentric location, but if the body travels and turns in the room then the form will be also be translated and rotated relative to the room (exocentric).

A characteristic of spatial representations is that a form is sometimes more easily enacted or recognised in a particular transformation. This is indicative of (for example) an "orientation-specific" representation. However, in many cases a form can be easily enacted or recognised in many different transformations. In this case it can be said to be more "flexible", or to be (for example) an "orientation-free" representation (Presson and Hazelrigg, 1984; Presson et al., 1987). Spatial information might be mentally represented freely from, or specific to, a particular body use (ie. muscle-free or muscle-specific), size (size-free or size-specific) etc. These are considered with the particular types of symmetry (see below).

IIID.21 Body Transfer.

The term "body transfer" is proposed here to refer to a translation of producing a spatial form with different body-parts. For example, a cyclic form can be produced by the right-arm and then transferred to the left-arm. Body transfers are a fundamental type of transformation which typically occurs together with other spatial transformations (see IIID.25). Body transfers may occur intentionally, resulting in other incidental spatial transformations. Or body transfers might occur incidentally as a result of other intentional spatial transformations:

> It is clear that each of the variations of a movement (for example, drawing a circle large or small [size scaling], directly in front of oneself or to one side [translation], on a horizontal piece of paper or on a vertical blackboard [rotation], etc.) demands a quite different muscular formula; and even more than this, involves a completely different set of muscles in the action. (Bernstein, 1984, p. 109).

Body transfers within the kinesthetic perceptual-motor system can be very accurate. The two hands can be set into parallel orientations within 1° (4° variability) of accuracy (Gibson and Backlund, 1963, p. 148) and the two hands can be placed at an equal distance in front of the body (on either end of a line parallel to the frontal plane) within 1° (4° variability) of accuracy (Willott, 1973, p. 578).

Different body-parts, especially the two hands, appear to be functionally linked within the kinesthetic perceptual-motor system. The classic example is the difficulty experienced when attempting the two different spatial forms and rhythms of patting your head while simultaneously rubbing your stomach (eg. Smyth et al., 1987, chapter 5). This linkage across different limbs is valuable in that it encourages whole-body coordination during certain motor activities (eg. walking). These functional linkages have been studied as coordinative structures (see IIIB.60).

Body transfers are typically indicated in studies of "bilateral transfer", "indirect learning", or "transfer of training" across the right/left body-sides. For example, strength training for the wrist flexors and extensors of one arm also results in increased strength of the wrist flexors and extensors of the other arm (Hellebrandt and Waterland, 1962). Learning a fast key tapping task with one hand transfers to the other hand (Laszlo and Baguley, 1971). Similarly, interference to recalling hand configurations is caused by extraneous movements of either hand during a retention interval (Smyth and Pendleton, 1989) and a pressure cuff eliminating sensory feedback to one hand creates interference of recalling locations with the index finger of the other hand (Roy and Williams, 1979).

The spatial forms produced in handwriting movements will also retain their particular style even if executed with the non-dominate hand (Smyth and Wing, 1984, p. 12), with the wrist and hand immobilised (elbow and shoulder articulations only), with the pen held in the teeth, or the pen held by the foot (Raibert, 1977; Reviewed by Schmidt, 1982, p. 305). These are all cases of body transfer in which the "shakiness" of the trajectory increases but the essential "style" of the overall shapes and relative sizes of letters remains invariant. Handwriting forms also retain their essential style when increased in size by writing on a blackboard (Merton, 1972, p. 32) or in a variety of arm-hand positions (Bernstein, 1984, p. 114). The body use is different within each writing posture but the form of writing is essentially identical.

Bairstow and Laszlo (1980) have shown that efferent motor commands can cause a change in the spatial form produced by the two hands. When tracing around the inside of an abstract unseen curved stencil pattern with the right arm-hand (thus the motor commands are continually pushing a hand-held stylus outward against the stencil), concurrent tracking of the same pattern by the left hand produced the same form but slightly larger than the original. Conversely, when tracing around the outside of a stencil with the right arm-hand (motor commands continually pushing inward against the stencil) then concurrent tracking by the left hand produced the same form but slightly smaller than the original. In this body-transfer the shape was accurately produced although a sizing transformation (enlarged or reduced) also occurred in the same direction in which the motor actions were commanded.

Perceiving a spatial form with the eyes alone can be conceived as another type of body-use. Visual spatial perception relies to a great extent on extraretinal eye movements and covert head-neck movements when gathering information (see IIC.33). Thus, visual-motor movements will also follow a particular path when perceiving a spatial form. Transformations are also possible. Arm-hand movements which are used to manipulate a visual target are spontaneously transferred to eye movements which track the movements of the target (Angel et al., 1973). A spatial path on a table top can be learned with visual-motor movements and then transferred to arm-hand movements (without sight) for recall. This body transfer (from eyes to hand) retains more accuracy than learning the path with one hand and transferring it to the other (Levine et al., 1982, p. 166).

Body transfers typically occur together with translation and sizing transformations. Therefore, particular examples of these are discussed as combined transformations (see IIID.25).

IIID.22 Temporal Transformations: Velocity and Duration.

The temporal aspects of velocity and overall duration of a movement are included here since these effect the movement's spatial form. In many cases the velocity and the duration of a movement increase and decrease together, however they can also vary independently. For example, if the movements in hand-writing are increased in size the actual movement velocity may be faster but there is more space to traverse (since the hand-writing is larger) so the entire word may use the same duration of time to complete. Velocity refers to faster or slower speed while duration refers to longer or shorter periods of time. The velocity and overall duration of movements can be freely transformed but the relative timing among components of the movement remain unchanged. It is this relative timing or "phasing" among components that gives the path its characteristic style (eg. in writing). Increasing the overall duration, while retaining the relative timing (rhythm) among the components appears to be a principal mechanism for producing an overall increase in the size of written words (Wing, 1978; 1980).

Velocity and duration patterns commonly transfer across body-parts. Kelso and Colleagues' (1979a; 1979b) Subjects performed point-to-point movements with both arm-hands simultaneously (either both hands move laterally outwards, both hands move laterally inwards, or both hands move forwards). "Easy" movements (a nearby, large target) required shorter durations of time to perform than "difficult" moves (a distant, small target). However, when one hand moved toward an easy target while the other hand simultaneously moved toward a difficult target, then the duration of the easy movement was transformed so than both hands were using the same duration to complete their movement. The two hands begin moving, reach peak acceleration, reach peak velocity, and end moving at the same moment even though the movement to the difficult (distant) target has the fastest velocity.

In another experiment (Kelso et al., 1979b, p. 1030) Subjects were asked to intentionally hit one target just before the other. However, this did not allow the easy (nearby) target to be reached quicker. Instead, the reaction time for both hand movements increased (these more complex parameters appeared to require more processing time). This indicates a "tight coordinative coupling between the two hands" or a "tight interactive coupling between the limbs" (Kelso et al., 1979a, p. 229; 1979b, p. 1031) which is referred to as a "coordinative structure" in which both arms together act as a single unit (see IIIB.60). Constraining the two arms into a single functional unit simplifies this type of problem for the motor system (of reaching to two different targets simultaneously).

Morasso (1983a) also found a consistent relationship between the velocity and spatial patterns during simultaneous trajectories of the right and left arm-hands (either synchronized or out of phase by one-half cycle). The velocity pattern transferred across limbs is referred to as "a strong coupling among the two motor commands" for the two arms.

IIID.23 Translation Symmetry.

"Translation" is used in geometric studies to refer to reproducing a form at a new place and is defined as:

> A transformation in which the origin of a coordinate system is moved to another position so that each axis retains the same direction or, equivalently, a figure or curve is moved so that it retains the same orientation to the axes. (Collins, 1986)

For example, translation symmetry is evident within the shape in Figure IIID-1A, and the shape in Figure IIID-1B has been reproduced by translating it to a new location.

Movement itself can be conceived to be a fundamental form of translation symmetry. During any movement a body-part will be transported from one location to another. The new location is a translation of the body from the prior location and so body movement can be conceived as a continual process of translation to new locations. This translatory motion will also likely (but not necessarily) be accompanied by a rotary transformation of the body-part as it changes its orientation.

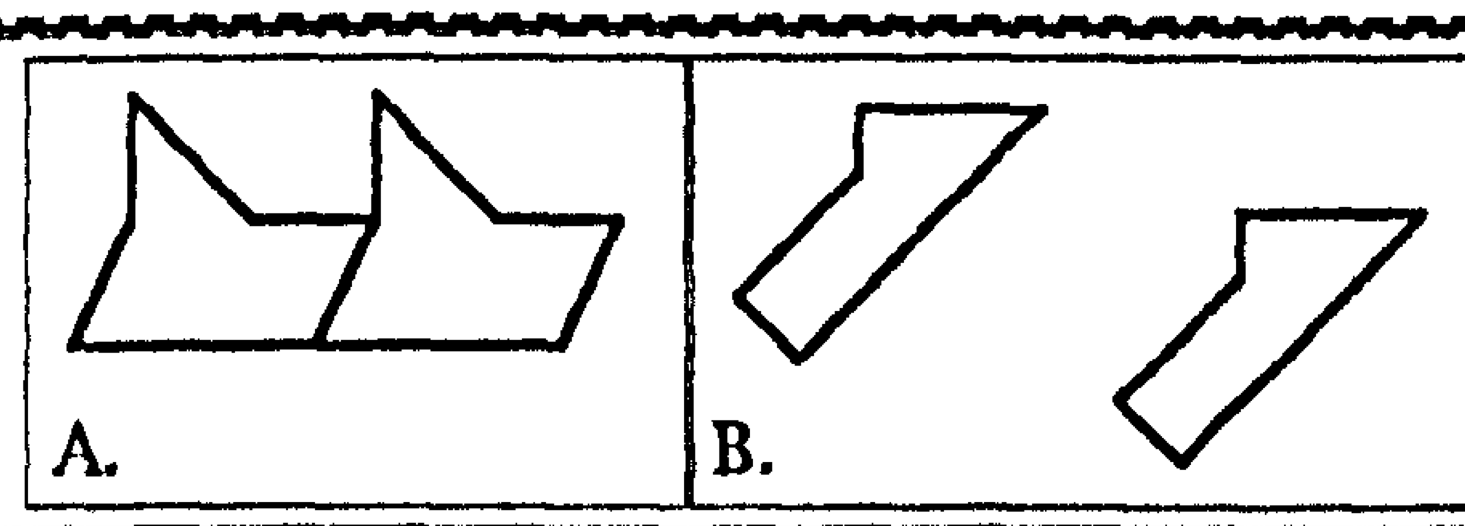

Figure IIID-1. Translatory symmetry within a shape (A), and translation of a shape to a new location (B).

Translations can also be conceived across time in which a form might be reproduced at a later moment. If time is considered to be the fourth dimension, then time itself can be conceived as a continual translation process in which items occur again and again in new temporal locations.

A basic example of translatory symmetry in body movement are the parallel paths of eye movements which occur when both eyes observe a moving object or scan across space while the eyes remain focused at a fixed distance from the Subject. In this case the movement of one eye follows a parallel path to the movement of the other eye (Hallett, 1986).

Common translation symmetries in dance are when two different dancers perform the same form, or when one dancer performs a form and then moves to a new place to perform it again. Translations also occur in ballet technique when a leg movement might be executed low with the toe touching the floor (eg. "*Rond de jambe* *á terre*") or translated higher with the entire leg in the air (eg. "*Rond de jambe en l'air*") (Grant, 1982).

Translation symmetry in body movement typically occurs together with body transfer and sizing transformations. Therefore, particular examples of these are discussed as combined transformations (see IIID.25).

IIID.24 Size Scaling: Reduce / Enlarge.

Spatial forms can be reproduced as larger or smaller versions of the original. This adjustment of the size of a form can be termed "size scaling" (Sekuler and Nash, 1972) or simply "sizing". The possibilities are referred to here as "reducing" or "enlarging".

Size scaling spontaneously appears in illusions such as the perceived enlarging or shrinking of a briefly presented visual object. This "gamma movement" indicates that size scaling is an automatic visual process (Arnheim, 1974, p. 438; Lindemann, 1922).

The greater the size difference between two rectangles, the more time is required to decide whether they are the same or different shapes. This indicates that a mental image of the rectangles is transformed so that they are imagined at the same size before comparing their shapes. When the two rectangles are not in the same orientation then even more time is required (presumably for mental rotation) in addition to the time required for size scaling (Sekular and Nash, 1972). This addition of the times required to mentally transform the orientation and size of the figures has been observed by others (Bundesen et al., 1981) and indicates that sizing and mental rotation are distinct transformational processes which each require their own processing time.

The overall temporal duration appears to be the principal mechanism in size scaling of kinespheric forms. Wing (1978) observed that when letters are written larger that the time required to write the letters increases. This increase in the overall duration of time is termed "time scaling" (p. 156) and appears to be the temporal counterpart to size scaling. Later, Wing (1980) demonstrated that when words are written larger that all letters require about 25% longer duration to write. Enlarging the size of hand cranking movements (rotating either forward or backward in the medial plane) also did not cause any changes in the relative timing (phasing) of the actions of six arm muscles (Glencross, 1973a; 1973b). This indicates that the same basic movement is being produced regardless of the size.

Size scaling can be identified within ballet technique. Many movements occur as a small variation (eg. "*petit Assemblé*") and also can be transformed into a large variation (eg. "*grand Assemblé*") (Grant, 1982). The differently-sized movements are basically the same motor action, one variation simply executed with more expansive movements than the other.

Size scaling typically occurs together with body transfer and translations. Therefore, particular examples of these are discussed as combined transformations (see IIID.25).

IIID.25 Combined Body Transfer, Translation, and Size Scaling.

Body transfer, translation, and sizing transformations of kinesthetic forms typically occur together. Changing the size of a kinespheric form is accompanied by a body transfer (different muscular use) and the form is often also translated to a new location.

An occasional example occurs in dance classes (especially ballet) when a dancer rehearses leg movements of a dance sequence by mimicking their directions with hand movements (personal observation). The body transfer, size scaling, and translation from hand movements to leg movements and vice versa appears to be accomplished effortlessly and to be a useful strategy for learning and memory.

Handwriting forms have been observed to occur in an identical style regardless of the size of writing, body transfers and translations (Bernstein, 1984, pp. 106, 109; Merton, 1972, p. 32; Raibert, 1977; Smyth and Wing, 1984, p. 12; Wing, 1980). Similarly, Bernstein (1984) observed that forms can be produced anywhere in the "motor field". This translation symmetry would also include a body-transfer since different muscles are used when the form is produced in a different location:

> . . . the process of carrying out a habitual action, for example, writing a word or playing over a passage which one has learnt by heart on the piano, is carried out with approximately the same facility and with the same degree of accuracy independently of the position of the hand [on the paper] or of the register on the piano. (Bernstein, 1984, p. 107; also noted on p. 109)

Morasso (1986, pp. 23-24, 34-35) recorded hand and shoulder trajectories when the target for hand movement was beyond arm's length. To increase the reach of the arm the shoulder may be displaced in the direction of the hand, or the entire body may be transported by stepping. In both cases the shape of the spatial trajectories and the pattern of velocities revealed that the shoulder movements were reduced and translated versions of the hand movements, that is, "the trajectory of the shoulder 'mimics' the trajectory of the hand" and "the trajectories of the shoulder are a more or less distorted version of the hand trajectories" (p. 34). Both the hand and the shoulder were spontaneously creating the same kinespheric form, regardless of the body transfer, sizing, and translation.

A combination of size scaling, translation, and body transfer can also be identified in tasks which require Subjects to walk through a floor pathway and later draw that path on a piece of paper. This task is performed easily (Levine et al., 1982, p. 160) and requires a reduction of the path size, a translation from the room to the paper, and a transfer in the body parts which produce the path.

The freedom for body transfer, sizing, and translation of kinespheric forms is described by Bernstein's (1984, pp. 110-117) "principle of equal simplicity" which essentially posits that if two operations are equally "simple" to produce (eg. equally accurate, equally fast), then the apparatus must be producing them similarly. Bernstein observes that the "trace" of movement paths can be transformed in various ways (eg. size scaling, translation) and that the transformed movement can be executed as simply as the original (pp. 106-109). The body-use can differ greatly between different transformations, however the exterior spatial form is nearly identical. Therefore, according to equal simplicity, it is logical to assume that all of the transformations are produced by the same movement memory code which is based on the exterior spatial form rather than particular muscles. Bernstein calls this memory code the "higher engram" which is the "engram of a given topological class" and "it is extremely geometrical, representing a very abstract motor image of space (p. 109):

> The almost equal facility and accuracy with which all these variations [symmetry transformations] can be performed is evidence for the fact that they are ultimately determined by one and the same higher directional engram. (Bernstein, 1984, p. 109)
>
> This allows us to conclude with a high degree of probability that the structure of the central complex which governs the production of a given series of movements is much more closely related to the spatial form than to muscle scheme. (Ibid, p. 114)

This is also discussed in terms of "the principle of motor equivalence" whereby the motor representation is "largely independent of the specific sets of muscles involved in the actual performance" (Morasso, 1983a, pp. 208-209; also

Saltzman, 1979, pp. 94, 103). The ready performance of body transfers, sizing, and translation indicates that kinespheric forms are remembered in a format which is free from any particular body usage, size, or location.

Smyth and Colleagues (Smyth et al., 1988; Smyth and Pendleton, 1989; 1990) also identified a type of body-part free spatial representation. They used dual-task interference studies (see IIC.10) to distinguish between movements to a "location of a target in space" which can be mentally represented "without specifying which effectors [body-parts] are to be used to reach those targets" versus movements consisting of a "configuration of the body parts themselves" which must be represented in a format specific to the body-parts used (Smyth and Pendleton, 1990, p. 292). These type of "locational" movements would have a body-part free representation and so would be easily transferred to new body-parts while "configured" movements would have a body-part specific representation and so would not readily be transferred to new body-parts.

Body transfer, sizing, and translation of kinespheric forms appear to occur at a secondary, lower level in motor planning than changing the directions (eg. reflection or rotation) of a form. If the direction of a movement is known but the size or body-use is not, there can be a short reaction time to initiate the movement after the size and body-use are indicated. However, if the size and/or body-use is known beforehand but the direction is not, then the reaction time to initiate the movement after the direction is indicated will be longer. This indicates that the movement direction must be known first, whereas the size and body-use can be specified at a later stage in the movement preparation process (Larish and Frekany, 1985; see IIIB.54).

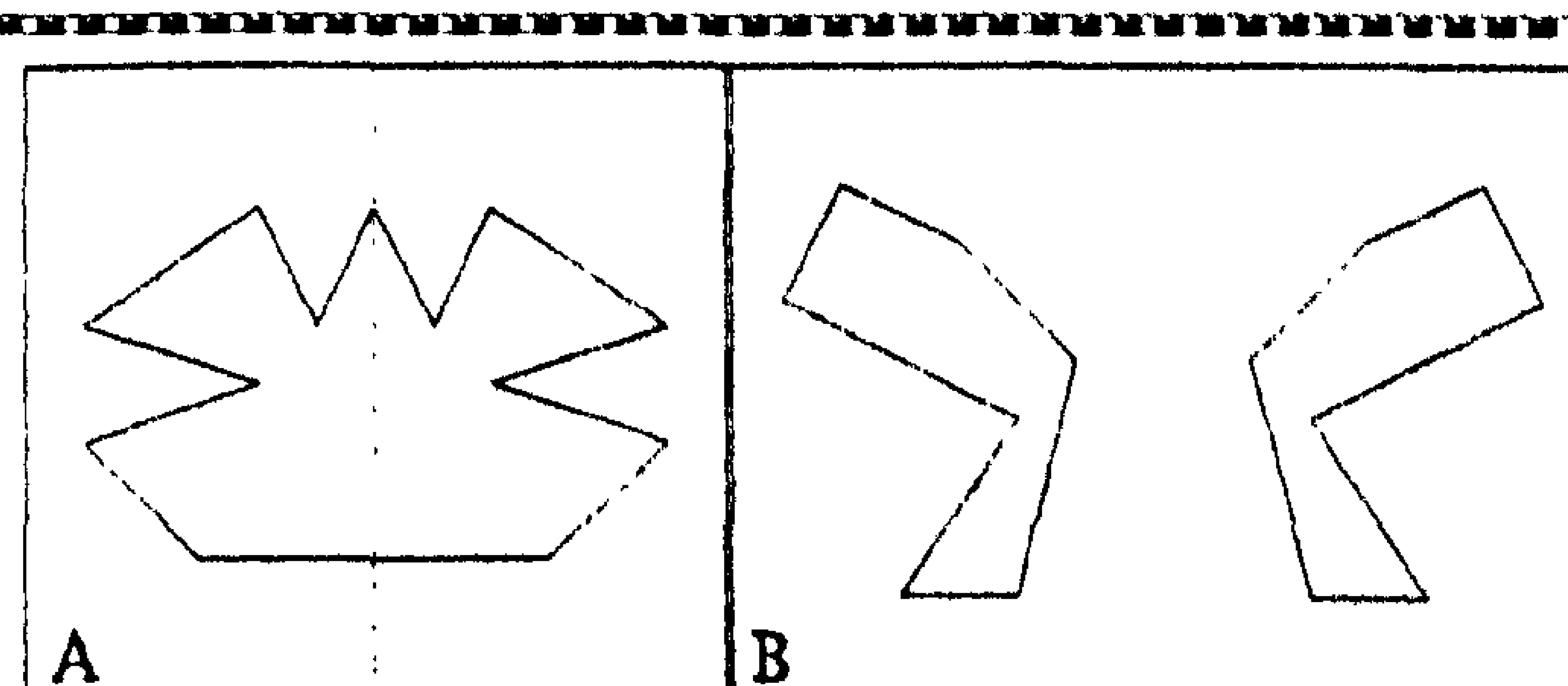

Figure IIID-2. Reflection symmetry within a shape (A), and a reflected version of a shape (B).

IIID.26 Reflection Symmetry.

"Reflection" refers to a mirror-image reversal, defined as a "transformation in which the direction of one axis is reversed or changes the polarity of one of the variables" (Collins, 1986). This is sometimes referred to as "inversion" in choreography studies (Blom and Chaplin, 1982, p. 102). A plane of reflection symmetry (the dashed line) passes through the shape in Figure IIID-2A and a shape has been reflected to produce a new variation in Figure IIID-2B.

Convergent and divergent eye movements are simple examples of bilateral reflection symmetry by the kinesthetic perceptual-motor system. When a visual focal point is moving closer the eyes will rotate towards each other (convergence) and when the focal point is moving away the eyes will rotate away from each other (divergence) (Hallett, 1986). In both cases the movement of either eye is a right/left reflection of the other.

Reflections can occur across a plane of reflection symmetry in any orientation, however bilateral right/left reflections across the median plane are the most typical. Children often make bilateral right/left reflection errors when learning to write (Bernstein, 1984, p. 108). It is typically suggested that the dominance of bilateral reflection symmetry in human cognition is related to the bilateral symmetry present within the human body (Rock, 1973, pp. 19-20). Corballis and Beale (1970) review this general tendency in children, adults and other animals to have confusions between right and left and conclude that this may be accounted for by the right/left symmetry of the nervous system. A perfectly symmetrical machine could not tell right from left, thus, the ability to distinguish left from right is indicative of an asymmetry within the system.

A "switched-limb" condition has been used in spatial positioning tasks in which the movement and final location are learned with one arm and then recalled with the other arm. The switched arm may recall the final location with the same direction of movement (body transfer only), or with the opposite direction of movement (body transfer and left/right reflection). In many cases recall of the final location is just as accurate in the same or reflected direction of movement. These results have been used to support the location code for the mental representation of the kinesphere (Larish et al., 1979; Larish and Stelmach, 1982; Stelmach and Larish, 1980; Wallace, 1977; see IIIB.12).

A common effect associated with reflection symmetry and body transfers is when a kinespheric form is transferred to the other body-half then Subjects will spontaneously also perform a right/left reflection of the form. This is typical in dance classes when students perform a movement routine on "the other side". Laban also observed this effect:

> [A person] understands his mirror-like symmetrical movements of left and right sides [of the body] to be identical, although their inclinations are completely different. When someone follows [a particular pathway] with the right arm . . . and is asked to repeat the same movement with the left arm, he will not follow the same trace-form, but [instead will follow] its mirrored form.
> (Laban, 1966, p. 79)

The direction of a rightward movement is different than a leftward movement. However, a rightward movement with the right body-side and a leftward movement with the left body-side both produce similar bodily sensations of widening in the torso. The sensation of narrowing when moving across one's body versus widening when moving away from the medial plane appear to be more significant for the mental representation of movement than the left/right structure of the form. Because of these problems with right and left, some authors refer to kinesthetic forms as widening/narrowing or inwards/outwards rather than right and left (Laban, 1966, p. 38).

In addition, the conceptual distinction of right versus left may be arbitrary. In Weyl's (1952) famous work, forms of "screws" and the concepts of "right" and "left" are scrutinised in the context of geometry, physics, biology, chemistry, and astronomy (pp. 16-38). In all cases no objective basis is found for distinguishing right from left but that "the inner structure of space does not permit us, except by arbitrary choice, to distinguish a left from a right screw" (p. 17). However, it is pointed out that mythical thought in art, magic, and religion consistently separate "rightness" as referring to correctness and truth, from "left-handed" as referring to evil (from the Latin *sinister*; on the left).

In the case of printed words right/left or up/down reflections make the word harder to recognise than rotations (Kolers, 1968; Kolers and Perkins, 1969a; 1969b) and so the mental representation of these forms can be considered to be reflection-specific. However, other stimuli such as inkblots can be recognised better with a right/left or an up/down reflection than if they are rotated 90° (Rock, 1973, pp. 98-100). These figures contain a structure which appears relatively similar when reflected, but dissimilar when rotated and so their mental representation can be considered to be reflection-free.

IIID.27 Rotational Symmetry.

Rotation refers to turning a form around an axis to a new orientation and is defined as:

> A circular motion of a configuration about a given point or line, without a change in shape. . . . A transformation in which the coordinate axes are rotated by a fixed angle about the origin. (Collins, 1986)

For example, an axis of rotational symmetry (indicated by a dot) can be identified perpendicular to the page and passing through the shape in Figure IIID-3A . The shape can be rotated around this axis and appear identical before a full rotation has occurred. The shape in Figure IIID-3B has been transformed by rotation (and translation to a new place).

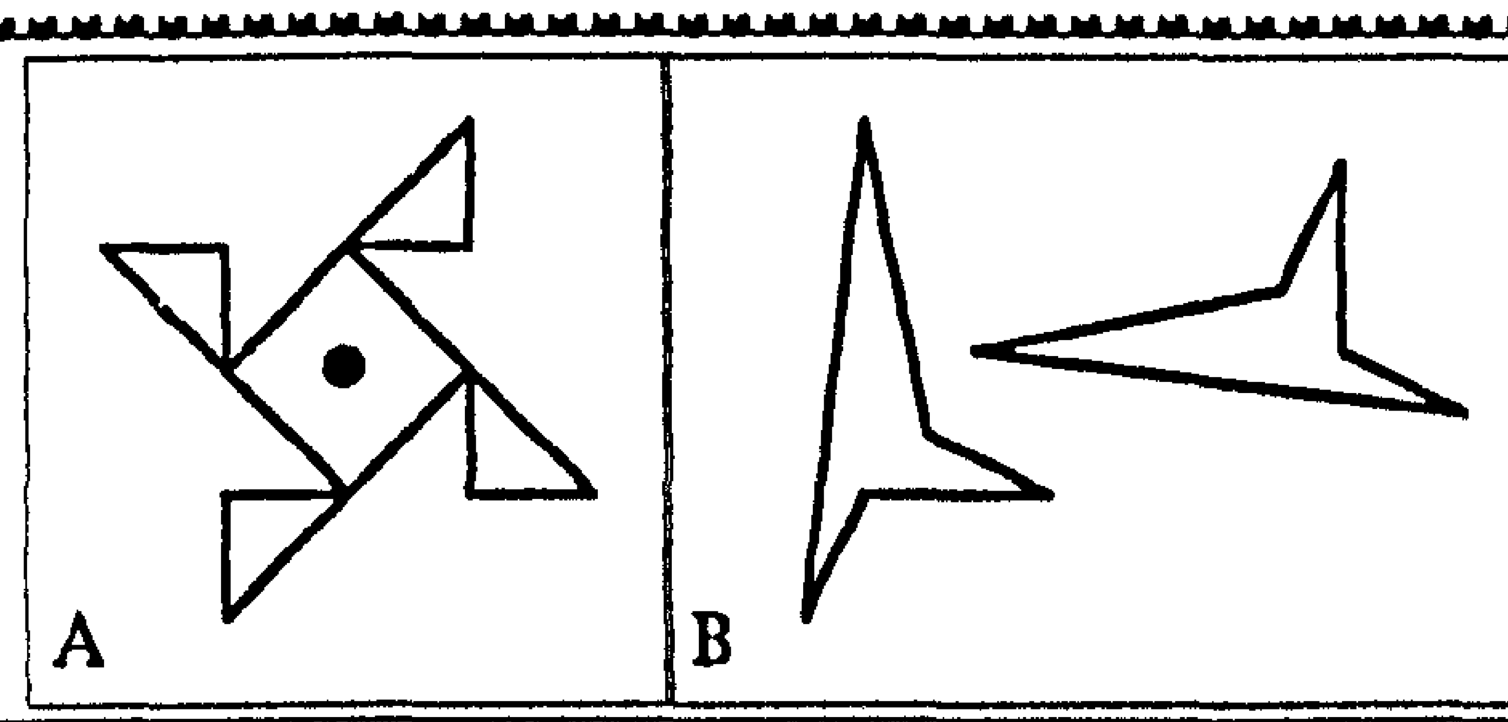

Figure IIID-3. Rotational symmetry within a shape (A), and a rotated version of a shape (B).

In their classic article Shepard and Metzler (1971) identified a linear relation between the time required to compare two figures and the degree to which they are in different orientations. It is concluded that the increased time is required to mentally rotate one of the figures into the same orientation as the other figure where their shapes can be compared.

Further characteristics of mental rotation have been probed (Cooper and Shepard, 1984; Kosslyn, 1980, pp. 305-329). The time required to compare two figures in different orientations can be shortened by informing Subjects about their orientations beforehand (Cooper and Shepard, 1973). The time that Subjects require for this imagery preparation also increases linearly with the amount of mental rotation required (Cooper, 1975; Cooper and Podgorny, 1976). The linear relation between difference in orientation of two figures and the and time required to compare their shapes is sometimes constant regardless of their complexity (Cooper, 1975; Cooper and Podgorny, 1976) but the mental rotation time is also relative to the amount of practice with the stimuli, the type of complexity, and the type of comparison task (Barfield and Salvendy, 1987; Bethell-Fox and Shepard, 1988; Pylyshyn, 1979).

Mental rotation effects also occurred for congenitally blind Subjects who compared the shapes of figures through tactual (kinesthetic) perception (Carpenter and Eisenberg, 1978; Marmour and Zaback, 1976). This indicates that mental rotation is an abstract spatial process independent from any particular sensory modality.

Kinespheric forms may sometimes be readily rotated. For example, turning a hand crank forward (from the top) in the medial plane can be perceived as "familiar in that the movement is a natural extension of winding or cranking in the frontal plane" (Glencross, 1973b, p. 215). In this case the winding cyclic movement of the arm-hand remains essentially identical whether it is oriented in the medial, frontal, or any other plane.

A rotational transformation commonly occurring in ballet is known as "*En Croix*" ("in the shape of a cross") (Grant, 1982, p. 36) in which a kinespheric form (eg. an extension of the leg) is executed towards the front of the body, then to the side, and finally is executed towards the back of the body. Any kinespheric form can be rotated relative to the room simply by changing the (exocentric) orientation of the body.

In many cases spatial forms may be recognisable or producible only in certain orientations. This indicates an orientation-specific representation. The classic example is a four-sided equilateral, equiangular polygon which is referred to as a "diamond" in one orientation and a "square" when in another orientation. In the classic work by Rock (1973) this example and others are reviewed in which visual forms are readily recognised only in their typical orientations. When a form is not in its typical orientation then a process of "correction" (p. 49) occurs where the form is mentally rotated until it can be recognised.

Orientation-specificity also occurs for kinespheric forms. For example, kinesthetic (tactual) perception of objects which were learned in a fixed orientation and tactual perception of familiar objects usually experienced in a particular orientation were difficult to recognise when their orientation was changed (Rock, 1973, pp. 34-36)

Written letters and figures also may have an orientation-specific representation. For example, Bernstein (1984) notes that "it is extremely difficult to draw figures upside down with a pencil" (p. 107), and that while children often make right/left reflection errors while learning to write that "they never turn the letter upside down" (p. 108). Another example is found in the sport of American baseball. The speciality of the pitcher is to throw the ball extremely accurately over "home-base". However, when the pitcher (rarely) throws the ball in a different direction it can often be inaccurate. A pitcher's kinesthetic-motor knowledge is often specific to the single orientation in which the vast majority of practice has been undertaken. Baseball announcer Ron Fairly has commented about this:

> Why is it that a pitcher can stand on the mound and make pitch after pitch so perfect all day long, but let him throw it in any other direction and they don't know where it's going. (Fairly, 1995)

Levine and Colleagues (1982) probed evidence for an "orientation corollary" which posits that at any particular time the mental representation of a spatial environment ("cognitive map") has a specific orientation (p. 168). Their Subjects learned a pathway on a $50cm^2$ card by visual-motor observation or (blindfolded) arm-hand movement. In all cases the card remained in a single orientation throughout learning. Subjects then transformed this path into a locomotor-space by walking through the room (enlarging, body transfer, and translation). Occasionally a "contraligned" condition forced Subjects to recall the pathway in an orientation rotated 180° from how it had been learned. This forced a mental rotation of the pathway and recall was much more difficult (p. 172) indicating that Subjects had learned an orientation specific representation of the path.

Orientation-specificity appears to be the outcome of learning the spatial information from a single orientation, whereas orientation-freedom can develop when the space is explored from many different perspectives. Learning a room-sized path (100cm x 350cm) by seeing paper-sized maps of the path in a single orientation led to (blindfolded) direction judgements (using an apparatus to point between locations along the path) which were most accurate when made facing a particular orientation (orientation-specific). However, when the path is learned by seeing it or walking (blindfolded) along the path (which introduces multiple facings of the body) then direction judgements are equally accurate from any orientation (orientation-free) (Presson and Hazelrigg, 1984). Walking forward or backward along the path (requiring multiple facings) led to more orientation-freedom in direction judgements than learning the path by walking along it and maintaining a constant room facing (Presson et al., 1987). Therefore, multiple orientations during learning appear to produce representations which can freely rotated.

Orientation-specificity and orientation-freedom can also be identified in the time required for mental rotation. More time is required to decide if three U. S. A. states are in the correct arrangement the further away they are from their typical north/south orientation. It is assumed that the states must be mentally rotated into their typical orientation before the decision can be made. An identical effect was found for arrangements of buildings which had been learned from maps. This orientation-specific effect may occur since maps are usually read and learned from a single orientation. Conversely, the reaction time required to decide if three buildings from a familiar campus are in their correct arrangement was not affected by the orientation in which the buildings were presented. This orientation-free effect may occur since buildings on a campus are usually learned by actual locomotion which includes many changes of orientation (Evans and Pezdek, 1980).

Hintzman and Colleagues (1981) used various environments in which Subjects imagined themselves in the centre of a circle and facing one of eight surrounding locations. Another location is indicated and the Subject judges which direction this "target" would be from themselves if they were facing in the imagined "orientation" (by moving a stylus in the appropriate direction from the centre to the periphery of a small, 9 cm diameter, circle). When the orientation and target were indicated by an arrow and a light on a visual display then the typical mental rotation effect occurred; the further the imagined orientation away from straight ahead, the longer the reaction time to judge the direction.

However, Hintzman and Colleagues (1981) also indicated the orientation and target in other ways. In one set-up the locations of drawings were learned in a small ($2.5m^2$) room where Subjects were free to swivel in a chair into all orientations. In another set-up the locations of drawings were learned which were mounted on an octagon and rotated (for viewing from all angles) in the frontal plane. The drawings in both set-ups served to indicate the imagined orientation and the target towards which direction judgements are to be made. In these cases there was no mental rotation effect. The time required to judge the direction toward a target was identical regardless which orientation the Subject imagines facing. All facings were equally free to be used since the environment had been learned from many orientations. However, when the drawings in the room were learned from only one orientation; or eight U. S. A. cities were used as locations (typically learned from a map in one orientation); then mental rotation effects occurred, indicating an orientation-specific representation.

Subjects as young as five years old can accurately align a "sighting tube" in the direction towards four locations in a large well known room (≈ 30' x 50') regardless of the orientation they are facing (orientation-free). Adults are able to combine this rotational transformation together with imagining oneself to be standing at a different place in the room, or imagining that the entire room was rotated. This indicates that a high degree of free transformations are possible in a well learned environment and well developed Subjects (Hardwick et al., 1976).

This research has indicated that multiple orientations experienced during learning lead to an orientation-free mental representation. As a spatial environment is explored from many orientations, its mental representation becomes more and more orientation-free.

IIID.28 Retrogradation.

When a sequential spatial form (pathway) is learned from beginning-to-end, it might then be recalled from end-to-beginning. The order in which the path was learned might be termed the "original order" and the retracing of one's motions in reverse can be referred to as "retrograde". The concept of retrograde is not typically included within symmetry studies but it can be identified as a usable transformation, is listed as a choreographic device (Blom and Chaplin, 1982, p. 102) and is also used in music to refer to a melody which is played backwards (Collins, 1986).

Retrograde transformations are sometimes used in spatial cognitive and motor control studies. One difference between forward or backward hand cranking (Glencross, 1973b) is that they are retrogrades of each other. Subjects could recall pathways with arm-hand movements or locomotor movements equally accurately in their original or retrograde orders (Levine et al., 1982, pp. 164, 166, 169).

IIID.30 Specifying Symmetry Operations in Spatial Cognition Research

A complete and explicit understanding of symmetrical transformations can provide a clearer analysis of transformations which are required in spatial cognitive tasks. As spatial cognition research has become more complex so have the transformations required by the spatial tasks.

For example, in visual imagery experiments by Attneave and Farrar (1977) the transformations can be defined according to egocentric and exocentric symmetries. Control Subjects were not required to perform any transformations relative to egocentric or exocentric space. Other Subjects either rotated the body together with the visual image in exocentric space (equivalent to no transformations in egocentric space) or rotated the body and translated the image through exocentric space (equivalent to an image rotation in egocentric space).

In some cases the exact movement directions and end locations of switched-limb spatial positioning tasks (Larish et al., 1979) or mental transformations required in cognitive map tasks (Hardwick et al., 1976) are not clearly described. These spatial transformations need to be explicitly stated in an agreed upon language to encourage clarity in discussions of spatial cognition.

Other problems with terminology are evident. Stelmach and Larish (1980; Larish and Stelmach, 1982) write about "limb orientation" within a switched-limb spatial positioning task. This use of "orientation" fails to identify that the only thing being tested is recall of the location of the limb's distal end (the locus of the handle on the positioning apparatus). For a single limb the orientation may (but not necessarily) be the same each time the location of the distal end is recalled. But when different limbs recall the same location of the distal end, the orientation of the two limbs will necessarily be different. The limb's orientation, which can be transformed by rotation, needs to be distinguished from the distal end locus, which can be transformed by translation.

Describing the turning of a hand-crank as either "forward" or "backward" within the medial plane (Glencross, 1973b; 1975) contains an implicit assumption of forward or backward *from the top* of the crank. Either direction of cranking has both a forward and a backward component. One direction turns forward from the top of the crank and backward from the bottom, and vice versa for the other direction. A similar assumption occurs in the instructions to turn a knob or screw towards the right or towards the left (eg. "lefty-loosey, righty-tighty"*). The implicit assumption is left or right *from the top*. In the interests of precision these implicit assumptions should be explicitly stated.

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* A traditional rhyming mnemonic used to remember which direction to loosen or tighten a knob or screw. Told to the Author in Eugene, Oregon by Kim Christensen.

IIID.40 Explicit Studies of Symmetry in Dance

As discussed above, there is not a standard language for describing kinesthetic spatial symmetry transformations and these are often not explicit in spatial cognition research. This same gap in the knowledge can be found in dance studies. The types of symmetry outlined above can serve as a basis for clarifying the conception of symmetry operations in dance.

Wechsler (1990) gives a brief introduction to symmetry in dance with a few examples of body poses analysed according to "point groups", "line groups", and "plane groups" with translation, reflection, and rotation symmetries. The concept of "approximate symmetry" is introduced according to which symmetries are identified across body parts in an approximate way, for example, the two legs as an upwards/downwards reflection of the two arms.

In a review of the movement theories of Francois Delsarte (1811-1871) Shawn (1954, pp. 33-35) recounts the "Three Great Orders of Movement" consisting of oppositions, parallelisms, and successions. "Oppositions are defined as any two parts of the body moving in opposite directions simultaneously" and so are identical to reflection symmetry together with body transfer. "Parallelisms are defined as two parts of the body moving simultaneously in the same direction" and so are identical to translation symmetry together with body transfer. "Successions are defined as any movement passing through the entire body, or any part of the body, which moves each muscle, bone, and joint *as it comes to it*" (italics his). This appears to be identical to a movement being transferred across a series of adjacent body parts.

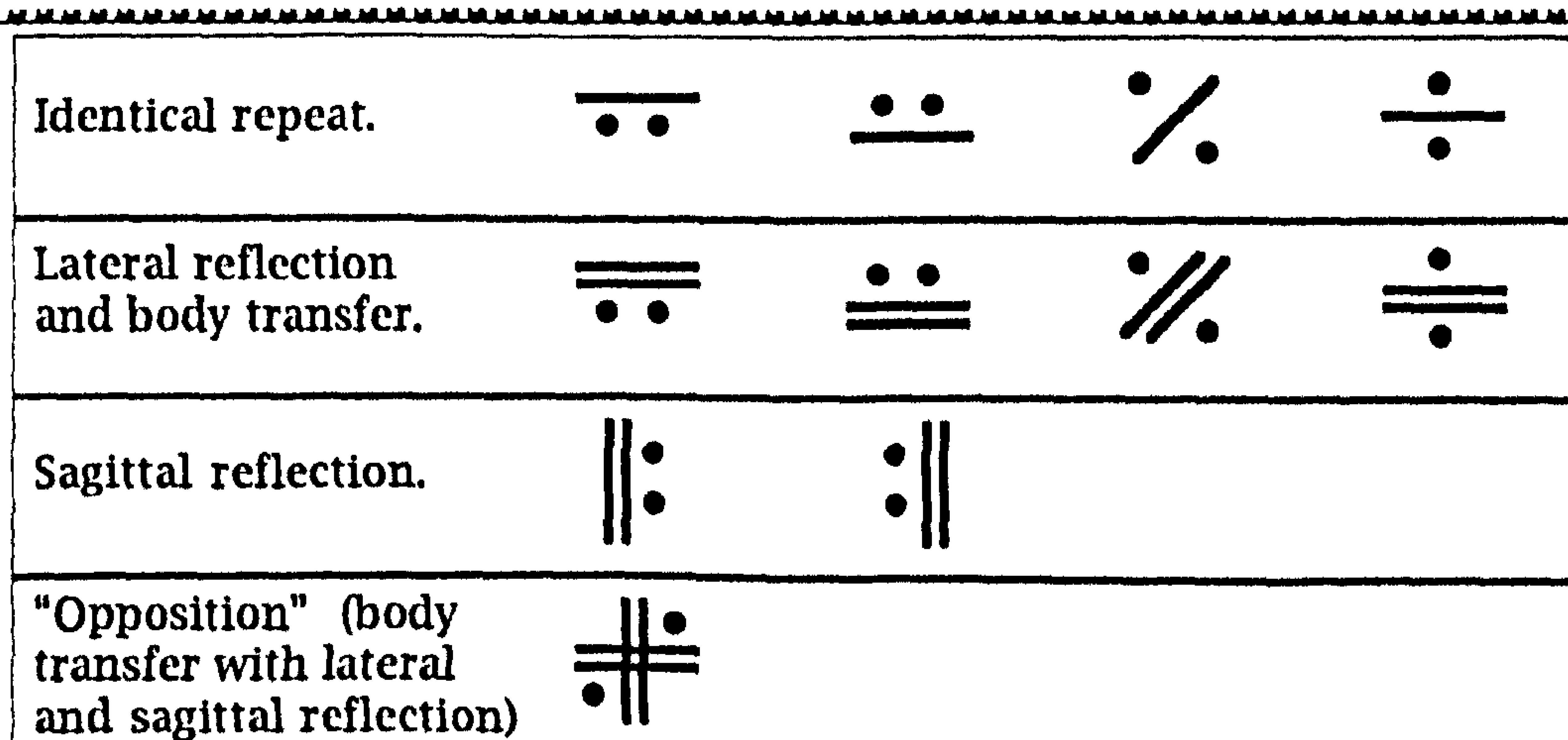
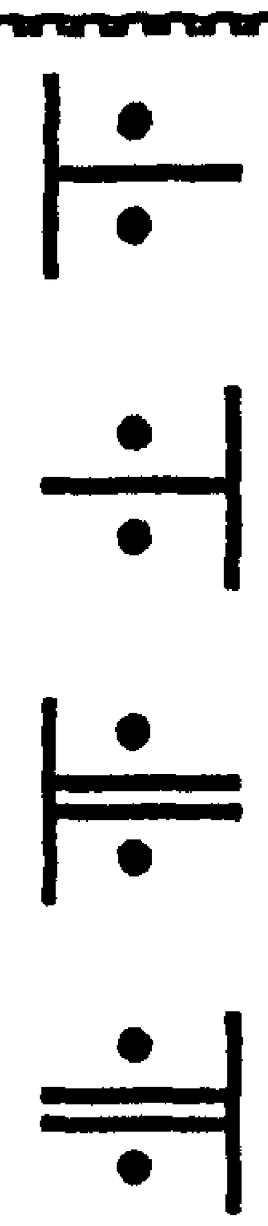


Figure IIID-4. Labanotation symbols for reflection symmetries combined with body transfer (Hutchinson, 1970, pp. 346-359).

In their choreography textbook, Blom and Chaplin (1982) consider "symmetry" only as referring to right/left reflection symmetry (pp. 38-41). Later they list a variety of "ways to manipulate a motif" (pp. 102-104). These include "repetition" which consists of a translation symmetry across time, and possibly also to a new place in space; "retrograde" which is identical to the retrograde transformation discussed here; "inversion" which refers to an up/down reflection symmetry, and; "size" which is identical to size scaling discussed here.

A few specialised symmetries are used in Labanotation (Hutchinson, 1970) which have corresponding notation symbols (Fig. IIID-4). The symbol for an identical repeat of a previous movement is adopted from musical notation. Doubling the line in the symbol indicates "'the other side' . . . a laterally symmetrical repeat" (pp. 346, 354, 357) (an option not found in music) which consists of the typical right/left body transfer together with a right/left reflection (see IIID.26). The symbol for "sagittal symmetry" specifies a reflection where all forward directions become backwards and vice versa (but without any body transfer) (pp. 354, 358). The lateral and sagittal symmetries can also be combined into a single "oppositional symmetry" symbol (eg. used when two people face each other in ballroom dancing) (p. 354, 359).



Rotational symmetry; to the front, left, and back.

Rotational symmetry; to the front, right, and back.

Rotational symmetry; to the front, left, back, and to the left again.

Rotational symmetry; to the front, right, back, and to the right again.

Figure IIID-5. Labanotation symbols for rotational symmetries (Hutchinson, 1970, p. 351).

Symbols have also been developed to specify ballet "*En Croix*" repeats (Hutchinson, 1970, p. 351). In these rotational symmetries a movement is performed to the front of the body, to the side, and then to the back (see IIID.27). A modification to the symbol is introduced to indicate that the movement is then performed again to the side (as often occurs in ballet exercises) (Fig. IIID-5). These symbols were developed to specify this rotational symmetry around the vertical axis in ballet and consequently they are not easily adapted for rotational symmetries around other axes.

IIID.50 Symmetry within Choreutics

Symmetrical transformations of kinespheric forms are fundamental to choreutics. The terminology used is often variable, but an implicit knowledge of symmetries is embodied within the choreutic scales.

Preston-Dunlop (1980, p. 182; 1984, p. x) uses "transposition" to refer to reflection symmetries. The term "harmonic opposite" (1984, p. viii) is also used to refer to a reflection across all three dimensions. Ullmann (1966) uses the notion of a "transposed" movement to refer to a movement translated to a new place (p. 146) or translated and also reduced in size (p. 172). The notion of an "inverted" movement is also used to refer to a retrograde (p. 165).

Laban (1966) uses "degrees of extension" to refer to size scaling transformations in which a spatial form can be performed in a "shrinking and growing kinesphere . . . [which] makes it possible to describe innumerable variations of trace-forms" (pp. 41-42). Later this size scaling is referred to as "transposing a trace-form" (p. 113).

Laban (1966) also describes how one can "transform" a dynamic sequence (eg. a sequence of movement qualities such as punching, gliding, and slashing) by "enlarging and transferring" it to create a spatial sequence (p. 60). This dynamic/spatial transformation is not encompassed within the conception of symmetry transformations presented here.

Choreutic "scales" and "rings" are composed of symmetric divisions of three-dimensional space and a large number have been illustrated and notated (Preston-Dunlop, 1984). Because of this symmetry choreutic practice can be considered to be exercises in producing and transforming a variety of symmetrical divisions of space.

At the basis of Laban's (1966) conception of spatial "scales" is that they are derived from body movements which strive to maintain equilibrium. These often create symmetrical patterns and so are considered to be "harmonious":

> A most important way of attaining what we call equilibrium is found in the so-called movements of opposition. When one side of the body tends to go into one direction, the other side will almost automatically tend towards the contrary direction. We feel the loss of equilibrium and produce, often involuntarily, motions to re-establish balance. . . .

> The wish to establish equilibrium through symmetric movements is the simplest manifestation of what we call harmony; the aim of this is . . . to achieve a unity of form, a wholeness, a completeness. (Laban, 1966, pp. 89-90)

Laban noted the frequency relations among visual and audio vibrations as a model for identifying harmony in bodily movement:

> Relations of vibrations expressed in primary numbers give our senses an impression of balance which we call harmony. For instance, the octave in music has the relation 1:2 which means that the vibrations of the high octave are twice as many as the lower one. There is also a numerical relationship between the primary colours of red, blue and yellow and it is the purpose of this investigation to point out the possibility of discovering similar relations in the trace-forms of movement. (Laban, 1966, p. 29)

Symmetrical movements to re-establish balance do not exhibit a simple reflection symmetry but a sequence of asymmetrical movements which, as a whole, complete a symmetry. Laban (1966, p. 90) refers to this as "Equilibrium through asymmetric movements", that is, many choreutic scales consist of "asymmetric movements which must necessarily be completed by other asymmetric tensions or moves" to arrive at an overall symmetrical pattern.

This description by Laban is identical to the concept of "dynamic equilibrium" within kinesiological studies in which each movement serves as a balancing reaction to the last movement:

> After an unbalancing movement is perceived, some motion is initiated to counterbalance it and move the centre of gravity of the body back over the supporting base. Typically, this countermovement is too great, producing an unbalancing movement in the opposite direction. This calls again for detection and countermovement. As the process is repeated, oscillation occurs. (Rasch and Burke, 1978, p. 102)

Laban's conception of dynamic equilibrium is rooted in the plastic nature of space in which balancing movements must counteract the tendencies toward three dimensions simultaneously:

> The three-dimensionality (plasticity) of our body requires that each true equilibrium placement shall be tensioned in three directions over the supporting vertical. The most stable condition is given if the three swinging body-quarters [ie. three limbs] are each directed into one [of the three] dimensions. (Laban, 1926, p. 17)

Mechanical equilibrium is typically measured and graphically depicted in two dimensions but it is understood that this is only to simplify the problem and that equilibrium forces will always be in three dimensions during an actual event (Dempster, 1961; see Appendix XV.11). Likewise, Golani (1986) argues that the full three dimensional plastic attributes of body motion patterns need to be considered rather than the planar analysis typically found in motor control studies. A conceptual planar analysis can never fully depict actual plastic body motions.

Laban (1926) states this within the "law of countermovement" in which the movement to maintain equilibrium consists of "moving towards a *nearly* opposite spatial-direction" (p. 18 [italics mine]). In terms of the choreutic scales the initial move and the following countermovement are described as a "preparation-swing" which occurs before each "primary direction" and that "in fact this preparation-swing lies in a completely particular specific direction and *not* exactly opposite the primary direction" (p. 29 [italics mine]). This plastic conception of body movement results in choreutic scales which continually transition from one dimension to another.

Similarly, Preston-Dunlop (1989) states that in a spatial scale "you go up so that you may go down". Bartenieff and Lewis (1980, p. 29) also describe how scales "are not mere lines of different design written into space; [but that] they reflect the condensations and expansions of body-muscle-spatial patterns". In accordance with dynamic equilibrium patterns "The sequence of the scale is ordered for the easiest shifting from one direction to another".

Because of these exercises in symmetrical patterns of dynamic equilibrium, choreutic scales are sometimes thought of as a "prescriptive" system of movement training. The three-dimensional symmetrical patterns within the "scales and rings are thought to give practice over the whole range of spatial possibility", and for choreutics, this is a "practical test of validity" (Salter, 1977, p. 138).

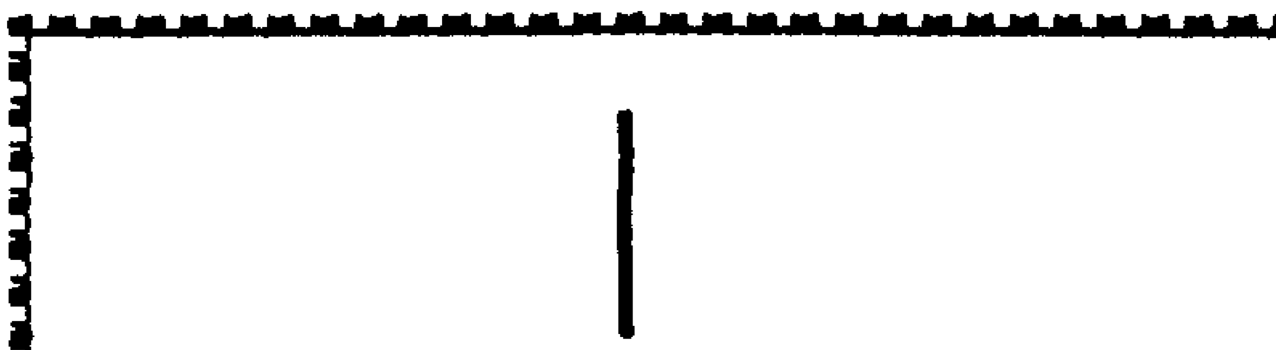


Figure IIID-6. Proposed symbol for an "item", spatial form, path, pose, tension, projection, etc.; a line, or "action stroke" in any orientation).

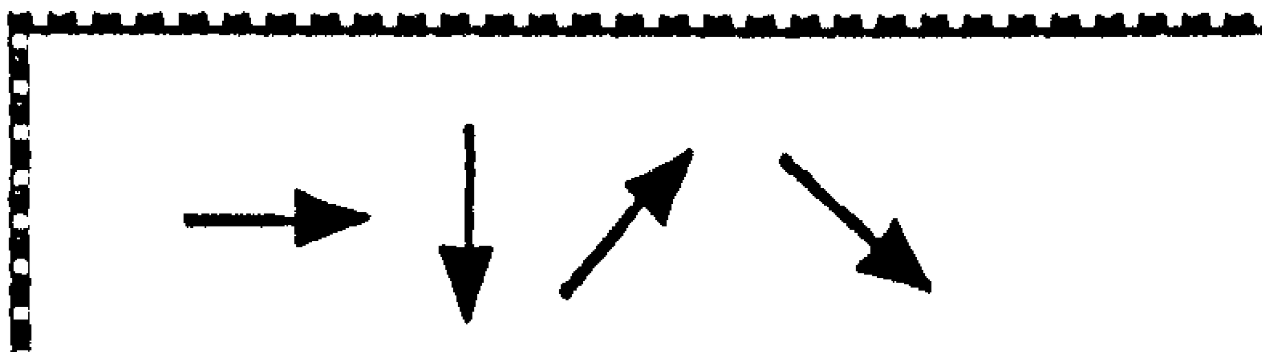


Figure IIID-7. Proposed general symbol for "symmetry"; an arrow in any orientation.

Some of the principal choreutic scales are identical to symmetric solutions for Sir W. R. Hamilton's "The Icosian Game" (invented around 1850) which set up a problem of traversing through a given set of polyhedral corners, visiting each corner only once, and ending at the same point at which you began (Hankins, 1980, pp. 339-343; O'Donnell, 1983). Hamilton used a dodecahedron (20 corners, 30 edges) but any polyhedra could be used. This is similar to a geometrical problem presented earlier by Leonard Euler (around 1750) about "whether it was possible to take a walk in the town of Koenigsberg in such a way as to cross every bridge in it once and only once" and to return home at the end (back to the original starting place) (Ball, 1905, p. 167). The bridges become the places to be traversed once and only once while moving through the city.

Choreutic symmetry can be distinguished within a sequence and between different sequences. Within each scale or ring the sequence of movements create a symmetrical pattern and so the entire shape of the scale or ring exhibits (for example) axes of rotational symmetry and planes of reflection symmetry. In addition, each scale, ring, or shorter sequence within a scale, is distinguished in one orientation and then reflected and rotated into all possible orientations. The symmetry within and between choreutic scales and rings has been described and graphically represented in many places (Laban, 1966, pp. 68-82; Preston-Dunlop, 1984; Ullmann, 1966, pp. 152-170). However, because of the complexity of three-dimensional symmetry and the variety of terminology used, descriptions of symmetry relationships among the scales and rings has not been integrated into a complete picture.

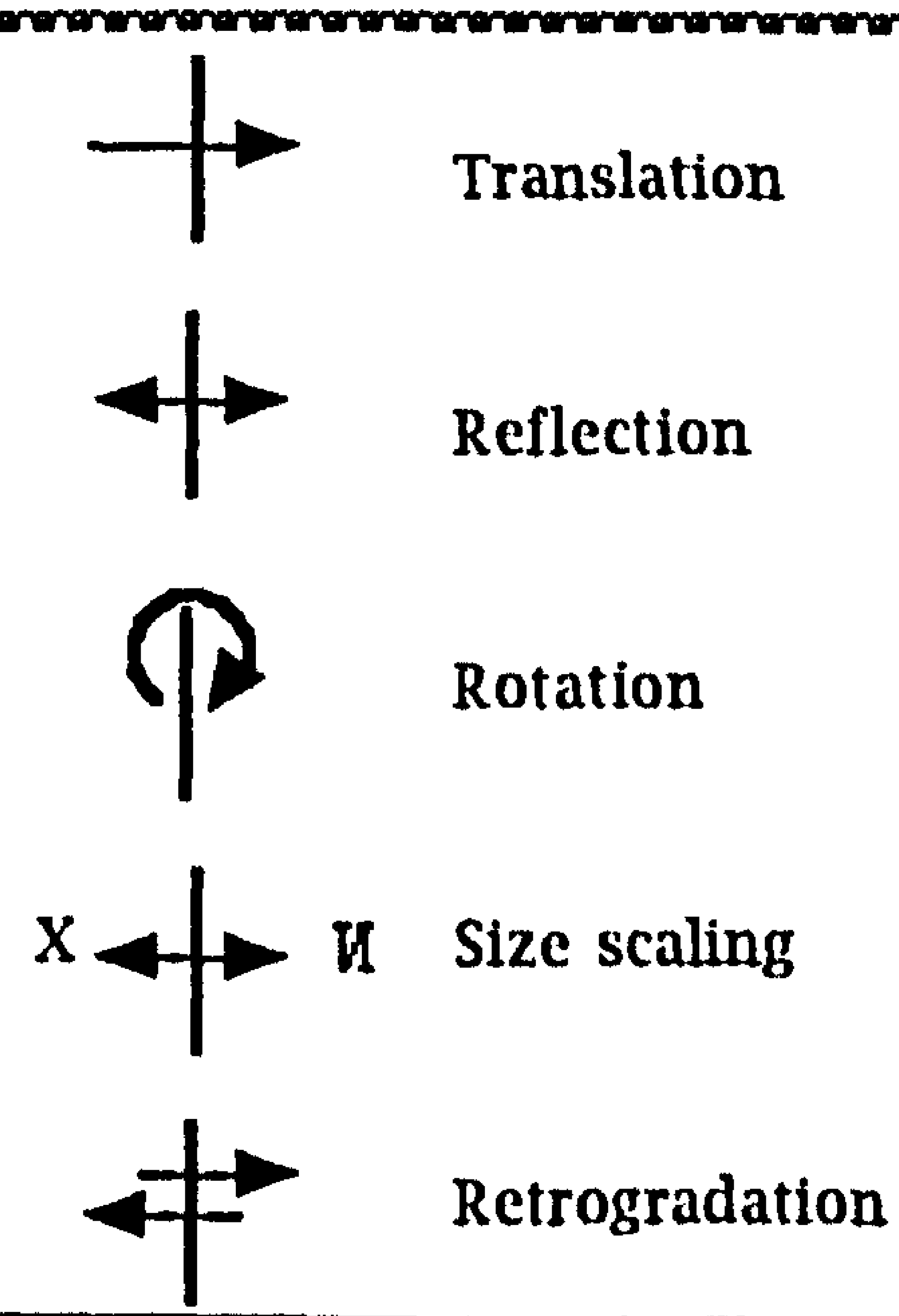


Figure IIID-8. Proposed symbols for symmetry transformations (all symbols can be written in any orientation that feels appropriate to the user).

IIID.60 Proposed Notation Symbols for Symmetrical Transformations

Notation symbols are devised here to aid in concisely and explicitly analysing symmetries present in spatial cognitive tasks, dance and choreography transformations, and choreutic scales. These symmetry symbols may be more cumbersome for certain applications (cf. *en croix* in Fig. IIID-5 versus Fig. IIID-13) but they are designed for broad and encompassing application rather than to only represent a few special symmetries. These symbols are pictographic, their figures visually resemble the symmetries they represent. They might therefore be more easily used by the dancer or lay person than a more computational abstract representation (eg. letter abbreviations or numbers).

A single stroke can be used as the basic symbol for an "item" (Fig. IIID-6). This might be thought of as similar to the "action stroke", referring to "any action" in Labanotation motif writing (Hutchinson, 1970, p. 24; Preston-Dunlop, 1969, p. 6). The stroke might also be conceived as the salient axis of a figure or object which is likely to be used as the primary axis in its mental representation (Marr, 1980; Marr and Nishihara, 1978; see IVB.26). An arrow pointing in any direction is taken as a general symbol for symmetry (Fig. IIID-7). The arrow implies the action of transformation whereby new variations of a form are generated. The action stroke and the symbol for symmetry are combined to indicate the different types of symmetry (body transfer is considered to be a type of translation) (Fig. IIID-8).

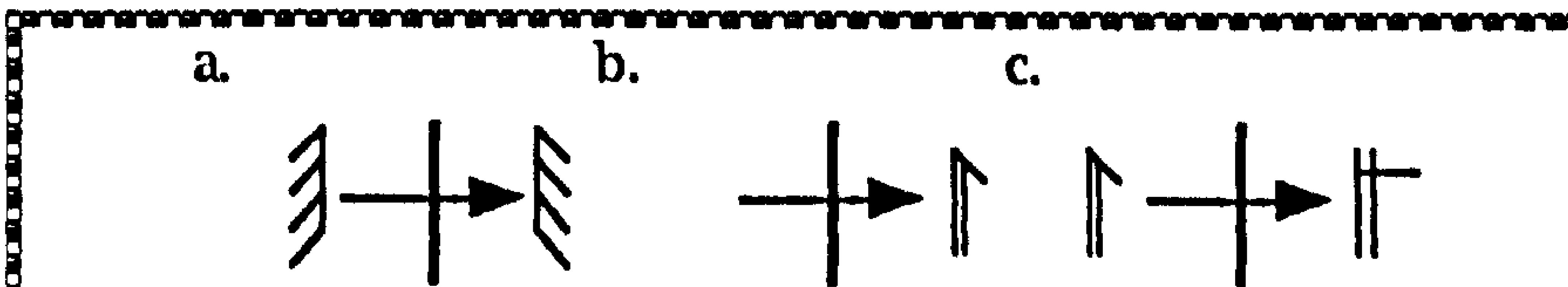


Figure IIID-9. Notation for body transference (with Labanotation body-part symbols): a) transfer from the left hand to the right hand; b) transfer from anywhere to the right arm; c) transfer from the right arm to the right leg.

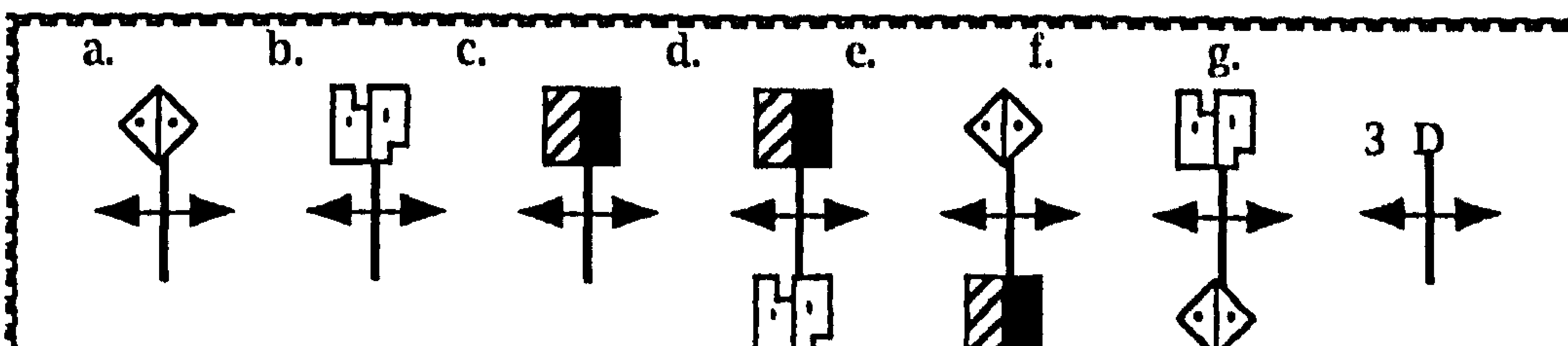


Figure IIID-10. Notation symbols for specific reflections which reverse one-dimension (a., b., c.), two-dimensions (d., e., f.,) or all three dimensions (g.) (borrowing from Labanotation).

The symmetry symbols can be used in a general way or can be made more specific by adding Labanotation symbols. Body transfers can be notated as a translation symmetry across body-parts (Fig. IIID-9). Symbols for reflection symmetry can indicate the dimensional components which are reversed in the reflection

(Fig. IIID-10). Either reduction or enlargement can be indicated in size scaling (Fig. IIID-11). The axis of rotational symmetry can be indicated on either end of the action stroke (Fig. IIID-12). In all cases the symbols might be written in any orientation, and the arrow in any direction, that feels appropriate to the situation.

Figure IIID-11. Notation symbols for specific reducing or enlarging size scaling (borrowing from Labanotation).

Figure IIID-12. Notation symbols for rotational transformations around specific central axes.

Notation symbols can help make symmetry transformations explicit. Each $^{1}/_{4}$ rotation of a kinespheric form in a ballet *en croix* can be indicated as a rotary transformation around the vertical axis (Fig. IIID-13). The transformation in which dancers "mark" the movement with their forearm-hand and then perform it with their leg can be notated as a body transfer with accompanying enlargement (Fig. IIID-14).

Figure IIID-13. Symmetry notation for a 1/4 rotation in *en croix*.

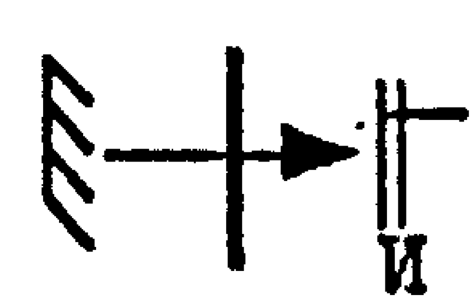


Figure IIID-14. Symmetry notation for transfer from the hand to the leg with enlargement.

The "A-scale" (Dell, 1972, p. 14; Preston-Dunlop, 1984, p. 67) can be taken as an example of symmetry within choreutic scales. Comparable symmetries can be identified in other scales. Bar-lines are used in Figure IIID-15 to indicate the amount of the scale which is transformed. The amount of the scale which is indicated within the first segment (indicated by the bar-lines) is transformed into the amount of the scale in the following segment. Within the A-scale a "steeple" can be identified in which the second movement is a retrograde and a $^{1}/_{5}$ rotation transformation of the first movement (Fig. IIID-15A). This steeple is then transformed into the next steeple by a retrograde and a $^2/_5$ rotation transformation (Fig. IIID-15B). This entire sequence of two steeples is then transformed by a $^1/_3$ rotation transformation to derive the second third of the scale, and rotated again to derive the final third of the scale (Fig. IIID-15C). Alternatively, the second half of the scale (containing three steeples) consists of a three-dimensional reflection of the first half (Fig. IIID-15D).

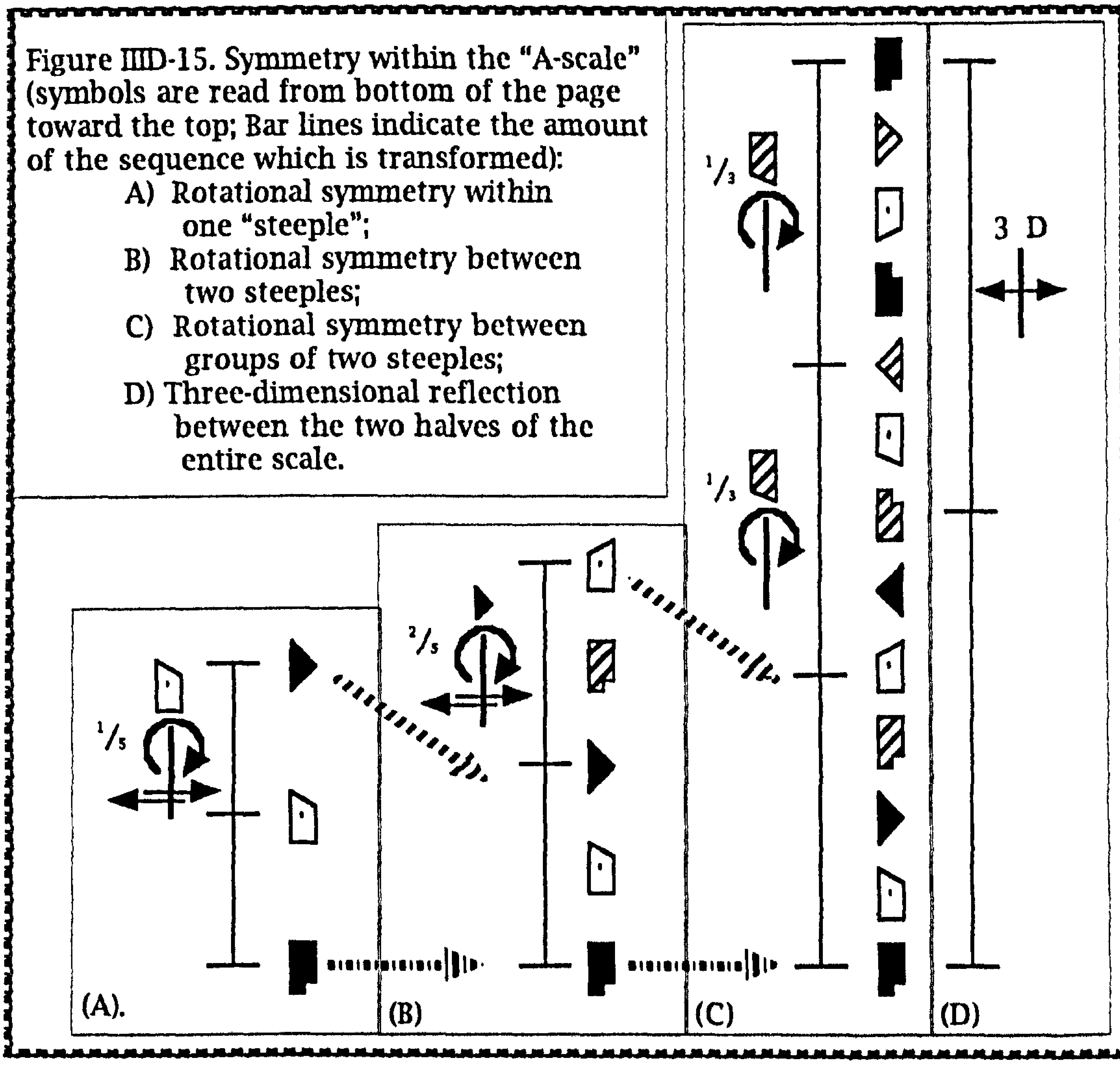


Figure IIID-15. Symmetry within the "A-scale" (symbols are read from bottom of the page toward the top; Bar lines indicate the amount of the sequence which is transformed):
A) Rotational symmetry within one "steeple";
B) Rotational symmetry between two steeples;
C) Rotational symmetry between groups of two steeples;
D) Three-dimensional reflection between the two halves of the entire scale.

IIID.70 Conclusions: Symmetrical Transformations

A variety of symmetrical transformations are used within spatial cognition and motor tasks. This ability to perform symmetrical operations is critical for effective everyday use of spatial knowledge (eg. when reading a map which is not in alignment with the actual physical environment). Varieties of symmetry are identified here. Choreutic "scales" are composed of paths and poses with three-dimensional symmetry which are described identically to spatial patterns used while maintaining dynamic equilibrium in three dimensions. The mental conception and physical execution of choreutic scales can be considered to be cognitive and bodily practice in symmetrical transformations and varieties of dynamic equilibrium adjustments.

IV. REEVALUATING CHOREUTICS

In Section III. psychological validity was provided for the choreutic conception of kinesthetic space since its cognitive structures for the mental representation of kinesthetic spatial knowledge have also been well developed in spatial cognition and motor control research. These include how spatial information is defined relative to a reference system; kinesthetic spatial knowledge is based on a mental code of elemental locations; higher-order networks of locations are collected into map-like images; and many symmetrical operations can be performed. Close similarities were especially identified between choreutic polyhedral-shaped cognitive maps of the reachspace and the "trajectory formation" model of motor control.

Section IV. reevaluates two components of choreutics more closely. In Section IVA a prototype/deflection hypothesis is identified in choreutics which posits that space is conceived according to dimensional and diagonal prototypes while actual body movement occurs along "deflected" directions. Similar spatial prototypes are identified in visual spatial cognition and the conceptual structure of ballet. A kinesiological analysis supports the bodily tendency towards deflections, and this concurs with ergonomic measurements of the shape of the kinesphere. Various choreutic deflections are reviewed and it is seen as a diagonally-conceived technique as opposed to the dimensionally-conceived technique of ballet. An experiment then attempts to identify prototypical reference points in kinesthetic spatial cognition.

In Section IVB. various categories of kinespheric form are identified which can contribute to the need of defining classes of kinesthetic spatial information in psychology and dance studies. These are reevaluated according to perceptual processes and kinesiology. The primitive element of body poses is the straight body segment with individual segments conceptually organised into higher-order groupings. The primitive element of body paths is the curved stroke between positions of agonist/antagonist equilibrium. Curved strokes can be joined into higher-order sequences according to anatomical constraints. Choreutic topological forms deflected across various kinespheric nets are analogous to Bernstein's (1984, p. 109) conception of the "net of the motor field . . . as oscillating like a cobweb in the wind". An experiment demonstrates that kinesthetic spatial information is organised into cognitive categories and that choreutic material and Labanotation symbols can be advantageously used in experimental research.

IVA. Prototype / Deflection Hypothesis

A hypothesis can be identified in choreutics which posits that dimensional and diagonal orientations serve as conceptual prototypes of pure directional stability and pure directional mobility respectively, while actual body movements occur as "deflections" between the idealistic pure dimensions and pure diagonals, that is, mixtures of stability and mobility. Considerable support for this prototype/deflection hypothesis can be found within kinesiological and spatial cognition studies.

IVA.10 "Directions" and Direction Symbols

In order to evaluate the prototype/deflection hypothesis, the choreutic system of kinespheric directions needs reviewing. Before "directions" are reviewed, some preliminary distinctions should first be made. "Direction" will be taken as referring to the orientation of a directional line. When the directional line passes through centre then a point on the line may be considered a directional point. All lines in the same orientation are considered to be in the same direction.

IVA.11 Directional Lines versus Directional Points.

"Direction" can be defined as a line; "the course or line along which a person or thing moves, points, or lies" or also as a point; "the place towards which a person or thing is directed" (Collins, 1986). For example, if a person is asked which "direction" they are going, they might reply in terms of their final destination (eg. to the store, to the kitchen), or they might reply in terms of their line of progression (eg. down main street, westward). The "directions" north and south consist of a heading towards a directional point while the directions west and east consist of a heading along any one of many parallel directional lines.

IVA.12 Limb Orientation versus Line of Motion.

This distinction between a directional line versus a directional point has been an underlying factor throughout the development of choreutics and Labanotation. Limb movements can be notated according to the limb position (directional point) or according to the line of motion from one position to the next (directional line). Gertrud Snell-Friedburg (1979) recalls that while working with Laban during the development of Labanotation in the 1920s "a question occurred again and again -- should the [notation] signs . . . show the movement in the *direction* [the line of motion] or the *final goal*, the position achieved" (p. 12 [italics hers]). Preston-Dunlop and Lahusen (1990) also discuss the problem which Laban "tried to solve was how to write [lines of] motion, not only positions passed through, a task which proved to be extraordinarily difficult" (p. 25).

Some of Laban's (1926) early notations represented lines of limb-motion rather than positions moved to (see IVA.14). This idea carried through into early introductions of modern Labanotation where the "direction symbols" (see IVA.13) are said to be "motion characters" which indicate the "directions of movement" and "complex movement actions" (Laban, 1975b, pp. 29-30; also Preston-Dunlop, 1969, p. 26), or that "progression is expressed by the direction signs" (Knust, 1979a, p. 1). In other places it was made explicit that, in reference to limb movements, the direction symbols indicate the limb's position, that is, the orientation of a directional line from the limb's proximal to distal ends. Limb positions are represented as "directional-points" (Laban, 1966, p. 21) and limb "movement is the transition from one point to the next", or one "directional destination" to the next (Hutchinson, 1970, pp. 15, 29; also Hutchinson-Guest, 1983, p. 61).

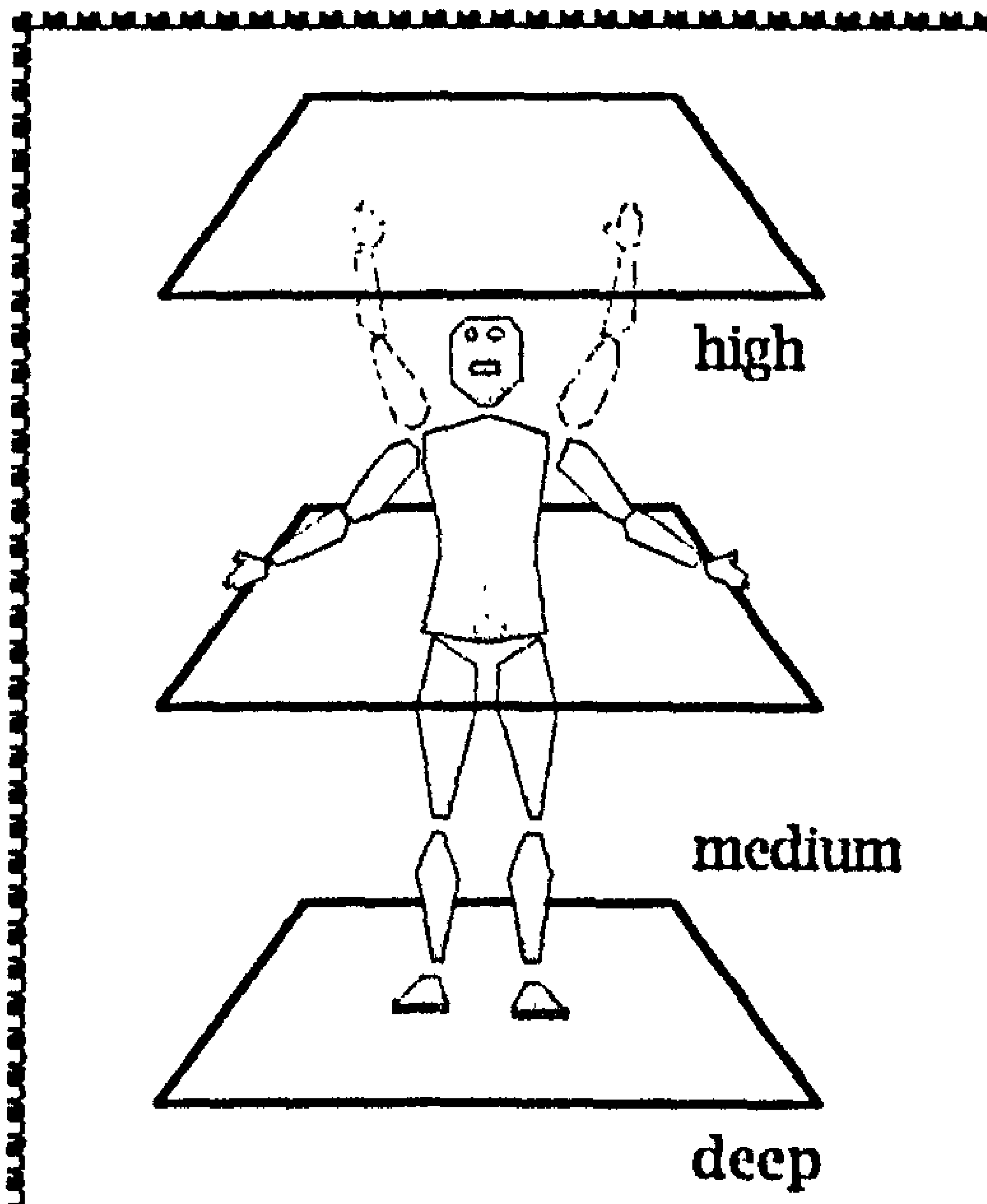


Figure IVA-1. Three levels (from Bartenieff and Lewis, 1980, p. 27).

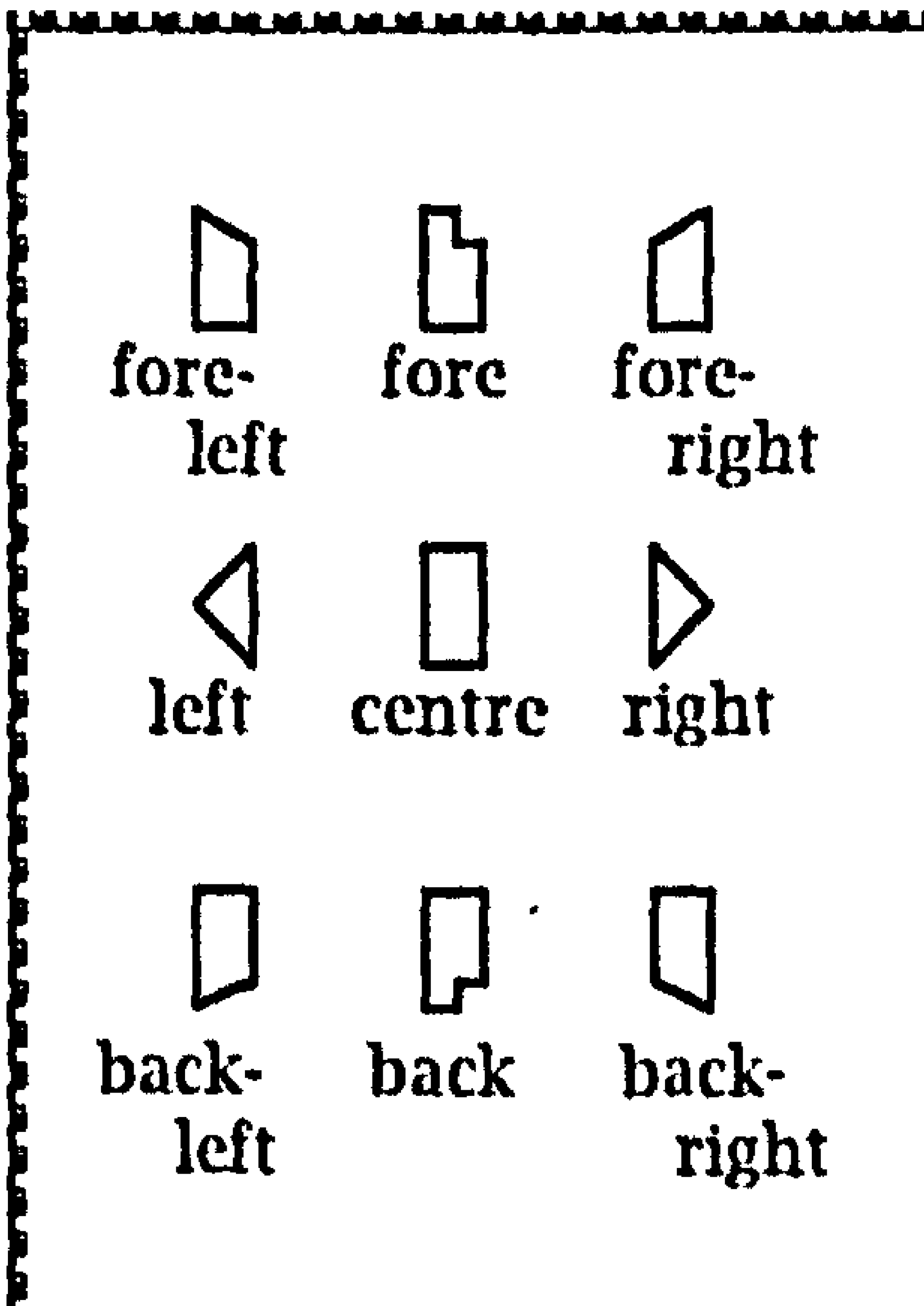


Figure IVA-2. Shapes of symbols for nine directions in each level.

The "direction" of a limb's orientation should be distinguished from the "direction" of the limb's motion. The arm may begin in one direction (its initial orientation) and then move into a different direction (its new orientation). A "line of motion" is used here to refer to the curved or straight path of the limb's centre of gravity (or any anatomical point) as it moves from one limb orientation to the next. One "direction" refers to the limb orientation. The other "direction" refers to the line of motion of the limb's centre of gravity from one position to the next.

IVA.13 Labanotation Direction Symbols.

A set of "direction symbols" has been developed in Labanotation and choreutics (Hutchinson, 1970, p. 24; Laban, 1966, p. 12) which can be used to indicate limb-motion or self-motion. In reference to limb motion, a direction symbol indicates the orientation of the line between the proximal and distal points of a particular skeletal linkage (regardless of the degree of joint angles within the linkage) (Hutchinson, 1970, pp. 164-170; Preston-Dunlop, 1969, p. 60). That is, "the direction signs indicate the direction towards which the limbs must *incline*" (Knust, 1979a, p. 14 [italics his]).

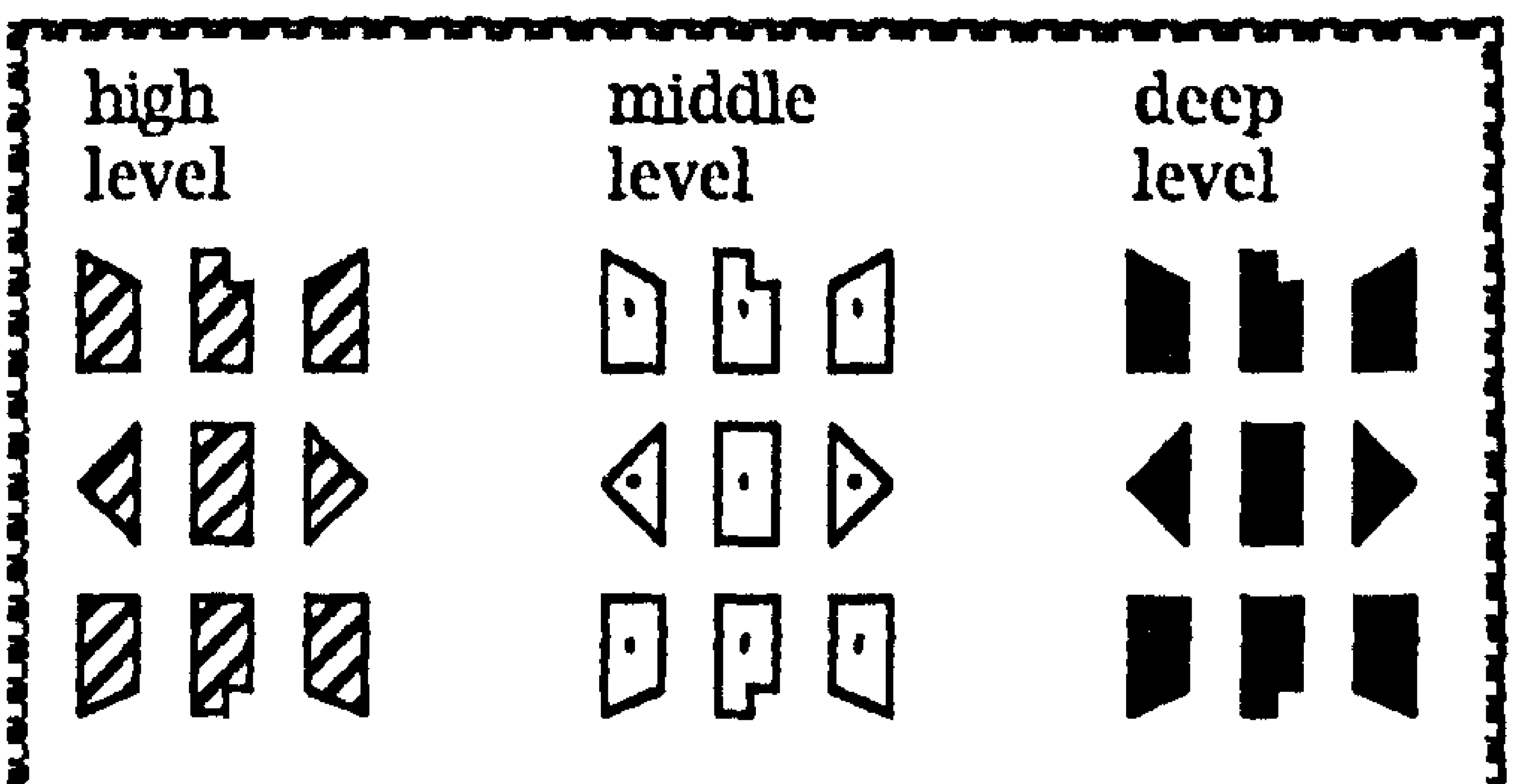


Figure IVA-3. Direction symbols.

The orthography of the Labanotation direction symbols is based on three levels (high, medium, deep) (Fig. IVA-1) and nine points at each level (fore, fore-right, right, right-back, back, left-back, left, left-fore, and centre). Each symbol for the nine points at each level has its own particular shape (Fig. IVA-2). The level is indicated by whether the symbol is striped (high level), has a dot (medium level), or is blackened in (deep level); this yields a total of 27 direction symbols* (Fig. IVA-3). Further details about the meaning of the direction symbols are given below (IVA.20).

What is implicit in the indication of limb motions and positions with a direction symbol is its relationship with the centre ( ). The "direction" of a limb position represented by each symbol is the orientation of a directional line which passes through centre. For example, a directional point (eg.) really refers to the directional line between two locations (•••).

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* It could be said that there are 33 direction symbols since the symbols for fore and back are also written as right/left reflections (Hutchinson, 1970, pp, 24-26). This variation in the fore/back direction symbols indicates whether the right or left body-side is executing the movement but the indication of direction is identical. For rough motifs this distinction between the two forward symbols or the two backward symbols is not critical.

In regards to limb positions and movements, a direction symbol specifies a limb's orientation. The limb's line of motion is specified by using two direction symbols, that is, "the transition from one point to the next" (Hutchinson, 1970, p. 29). Other notation systems developed in dance (Eshkol and Wachmann, 1958, p. 53) and in motor control (Bernstein, 1984, p. 117) have also represented limb positions as an orientation of a distal to a proximal joint, with limb motions (pathway) implied as transitions from one position to the next. Laban (1966) makes use of three dots following a direction symbol to indicate "the continuity of the movement" (p. 22). Thus (in reference to limb positions) the direction symbols represent locations of a limb's distal end relative to "centre" and the dots represent the line of motion (of the centre of gravity or an anatomical point) between two locations (Fig. IVA-4).

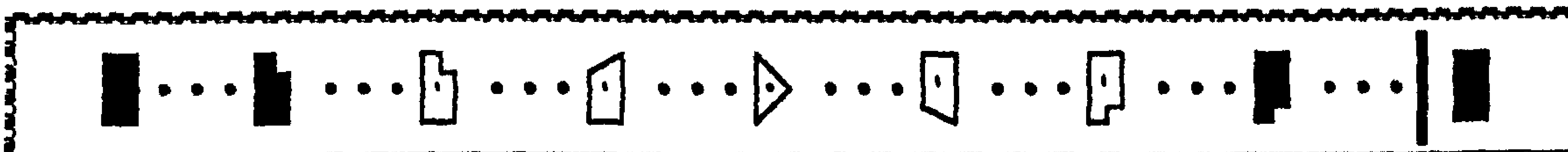

Figure IVA-4. Dots as motion between two directional-points (Laban, 1966, p. 22).

IVA.14 Vector Symbols from "Choreographie" (Laban, 1926).

Another group of symbols used during the early development of Labanotation and published in Choreographie (Laban, 1926, pp. 20-21, 35, 44-45, 47, 50-53, 72) appear to be used to specify the direction of a limb's line of motion regardless of the limb's orientation (Fig. IVA-5). These are referred to here as "vector-symbols" since they specify the direction of motion but not any particular locations. An analysis supporting this vector-like interpretation of Laban's (1926) notations is provided in Appendix IX and translations of the vector symbols into Labanotation direction symbols are presented below (IVA.20).

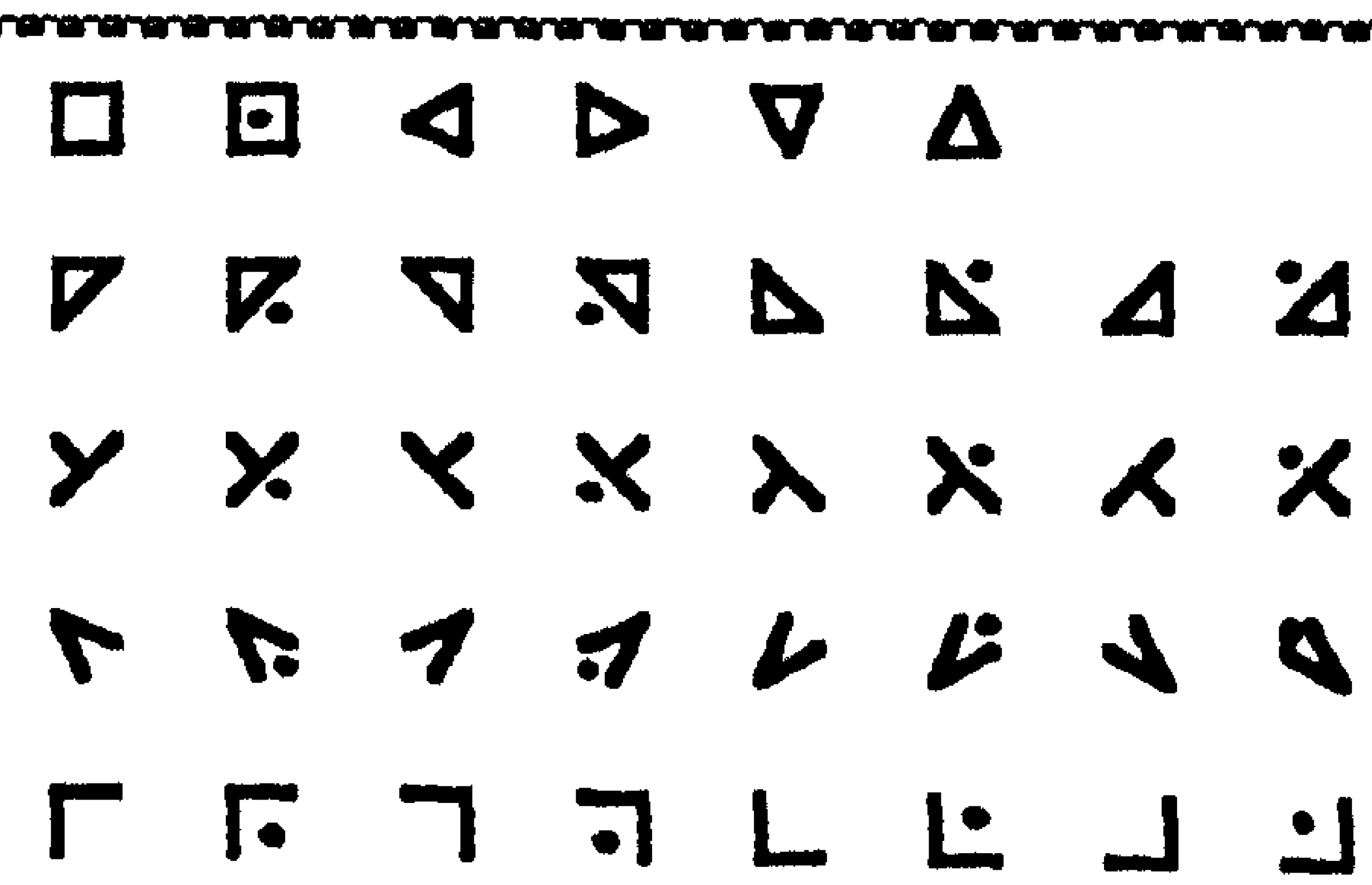

Figure IVA-5. Vector symbols (Laban, 1926).

Other vector-like notations were also developed. Laban (1966, pp. 125-130) outlines "free-inclination symbols" or "free space lines" consisting of a direction-symbol together with a small letter to indicate the "deflection" (Fig. IVA-6) (for discussion of "deflection" see IVA.24). The notion of "free" refers to how the symbols can be used to specify the direction of a limb's line of motion regardless of the positions and locations of the body-parts (ie. locus-free). Laban mentions that this type of notation is "an old dream in this field of [choreutic] research" but which is left for the "future development of kinetography" (p. 125) This suggests the early work developing the vector-symbols (Laban, 1926) which were later abandoned in favor of the (conceptually simpler) locus-based direction symbols.

Hutchinson-Guest (1983, p. 261) developed an analogous notation referred to as "direction of the progression" used to notate the "path of a gesture". This notation consists of an arrow contained within a direction symbol (Fig. IVA-7). None of these vector-type notations have received any noticeable usage which may attest to the greater difficulty of conceptualising the orientation of a limb's line of motion versus its orientation. Similar notations such as the "motion toward" or "motion away" symbols (Hutchinson-Guest, 1983, p. xxiv; Preston-Dunlop, 1969, p. 54) (Fig. IVA-8) indicate motion but this is motion towards a particular point and does not specify the orientation of the line of motion.

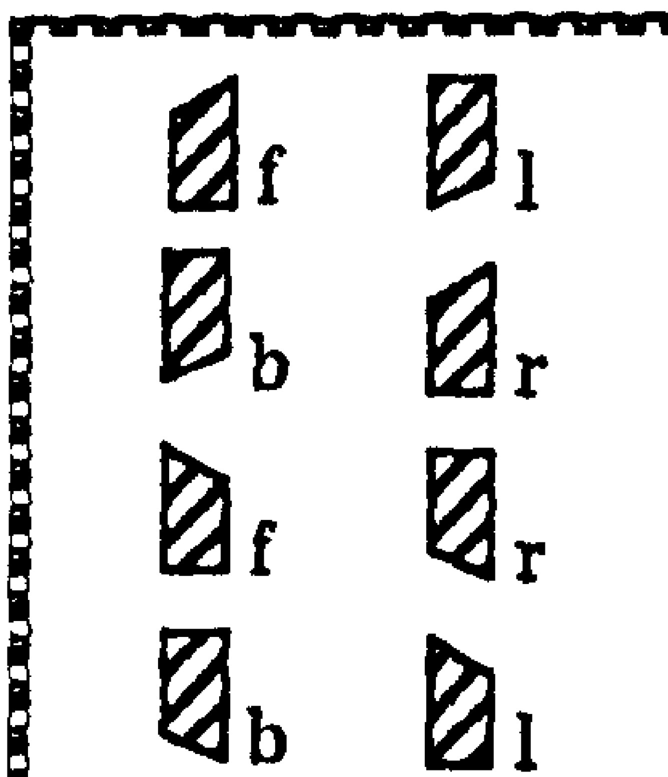

Figure IVA-6. Free inclination symbols (adapted from Laban, 1966, p. 127).

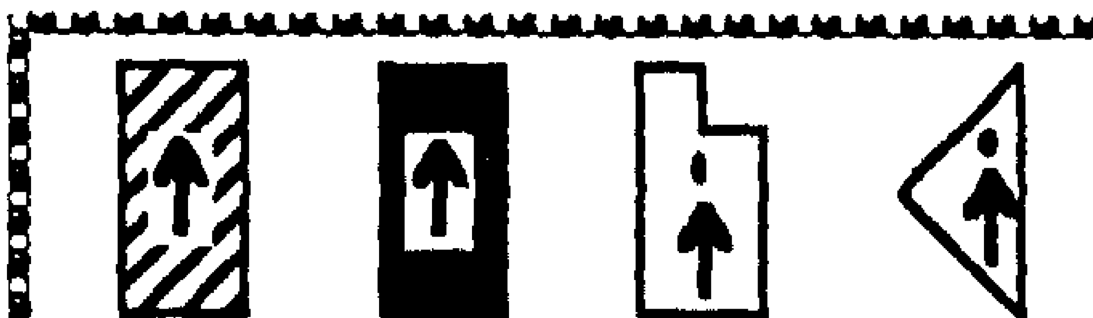
Figure IVA-7. Direction of the progression symbols (adapted from Hutchinson-Guest, 1983, p. 261).

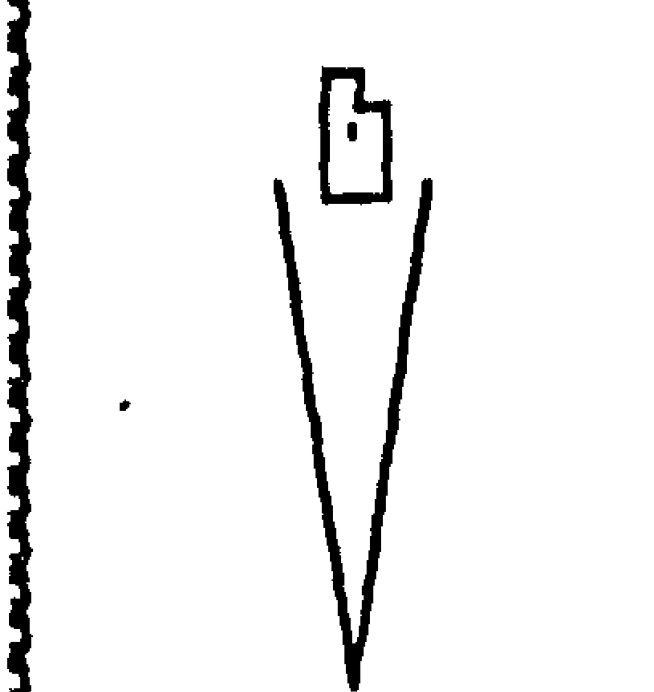
Figure IVA-8. Notation for motion, approaching a particular point (see text).

IVA.15 Equality of Parallel Directions.

When two lines are parallel they are considered to be in the same "direction", that is, all parallel lines will have the same measure of their inclination, or "slope" (Munem and Foulis, 1986, p. 139). For example, all lines pointing westward will be parallel and will be considered to be oriented in the same direction.

This equality of parallel directions is utilised in choreutics. For example, Ullmann (1966) describes how "Dimensional, diagonal and deflected directions have the same directional value in both central and [parallel] non-central movements" (p. 147) and that when peripheral lines are parallel to transverse lines "they do not constitute new directional inclinations, but are the same as those of the transversals only transposed further away from the centre of the kinesphere" (p. 172).

IVA.20 "Directions" as Conceived in Choreutics

In order to reevaluate the prototype/deflection hypothesis it is necessary to first review the categories and orientations of "directions" as conceived in choreutics. These consist of directional lines which are joined together to form conceptual kinespheric networks (see IIIC.30).

IVA.21 Undifferentiated Spherical Conception of Space.

The most basic conception of space is as a sphere. This "imaginary sphere" is conceived as a "sphere around the body whose periphery can be reached by easily extended limbs" and is termed the "kinesphere" (Laban, 1966, p. 10; see IIB.38).

A sphere is undifferentiated except for its centre and its periphery. A distinction is made between 1) lines which lie along the edges of the kinesphere, 2) lines which pass through the kinesphere and intersect its centre and 3) lines which pass through the kinesphere but do not intersect its centre (Laban, 1966, p. 68). These are referred to as "peripheral", "central", and "transverse"* respectively (Bartenieff and Lewis, 1980, p. 107; Preston-Dunlop, 1984, p. viii).

There are no other landmarks or orientation points available within this generalised spherical spatial conception. Thus, for greater definition of areas, zones, and directions in space, the sphere must be divided into distinct parts.

IVA.22 Dimensions.

IVA.22a Three dimensions.

The fundamental directions used in all types of spatial conception and also within choreutics are the three dimensions (referred to here as lateral, vertical, and

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* It is evident from Laban's (1966, p. 68) discussion that dimensions, diagonals, and diameters are different from "'transversals'" or peripheral "surface lines". This distinction is not maintained here because in many cases transverse lines or peripheral lines are parallel to a dimension or a diameter and all parallel lines are considered to be in the same "direction". This necessitates using the terms "peripheral dimension" and "transversal dimension" (as opposed to a "transversal inclination") (eg. Ullmann, 1966, pp. 165-166, 181-184). In this paper the terms "central", "peripheral" and "transverse" are used to describe the relationship to centre of any direction. Thus, a "dimension" is not necessarily different from a "transversal".

sagittal*) which correspond to the Cartesian x, y, and z axes. Laban (1966, p. 11) refers to the three dimensions as the "basic elements of orientation" and that the solid object which contains the three dimensions and is "easiest to visualize, is the cube". Thus, the cubic, dimensional conception of space is envisaged as the simplest, most prototypical, division of the sphere into differentiated regions.

> The spheric form of the kinesphere is simplified [differentiated] by our cubic conception of space. We recognize the cube inside the kinesphere as being representative of the most important space directions. (Laban, 1966, p. 18)

Laban (1966) goes on to describe how the three dimensions are evident within the structure and function of the human body. The "simple one-dimensional vertical" is described as the "fundamental structural extension of the body" (p. 18), that is, the body's structure is extended along this dimension more than any other. The lateral dimension or the "bilateral extension" is considered to be the "second extension which we feel [which] originates from the bilateral organisation of our body, caused by the mirror-like structure of the left and right sides" (p. 18). The sagittal dimension is mostly evident in the function rather than the structure of the body. This "third dimension becomes apparent only when moving . . . when stepping or reaching and grasping, and manipulating objects" (p. 19).

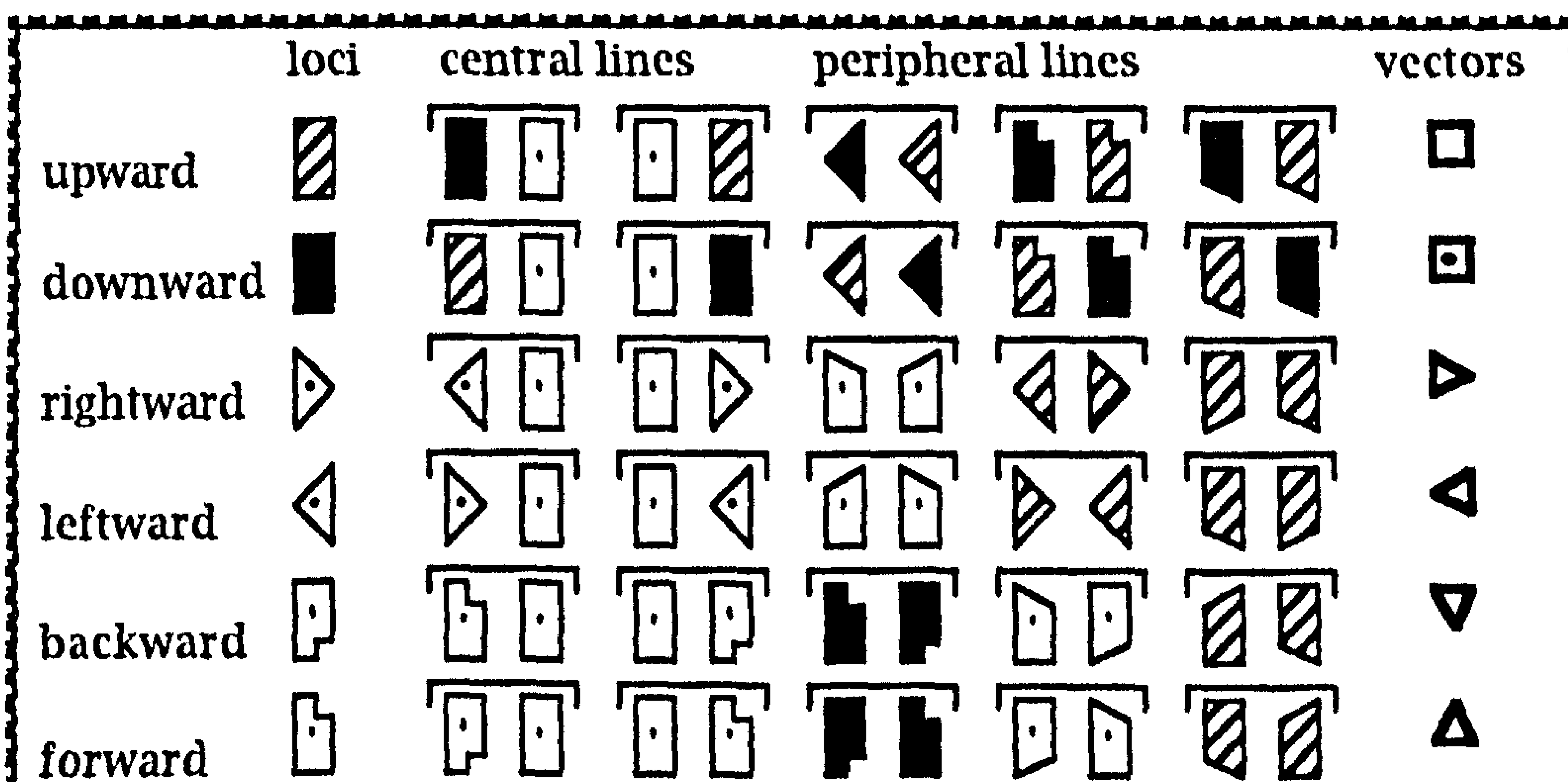

Table IV-1. Examples of dimensional notations (symbols in brackets read from left to right).

"Each 'dimension' has two directions" and these are referred to as the "'dimensional directions'" (Laban, 1966, pp. 11, 14). Various terminology can be used

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* To avoid confusion it is desirable that different names be used for the dimensions versus the Cartesian planes. The dimensions are referred to here as "vertical", "lateral", and "sagittal" while the Cartesian planes are referred to as "frontal", "medial", and "horizontal" (see Appendix VIII).

for the dimensional directions (eg. deep, low, down, and downward can all refer to the same direction). They will be referred to here as upward, downward, rightward, leftward, forward, and backward. Dimensional directions can be notated in various ways. Table IV-1 lists some possibilities for notating limb paths and poses as dimensional points with a single direction symbol, as dimensional lines of motion with pairs of direction symbols, and as the line of limb motion (regardless of particular positions) with vector symbols.

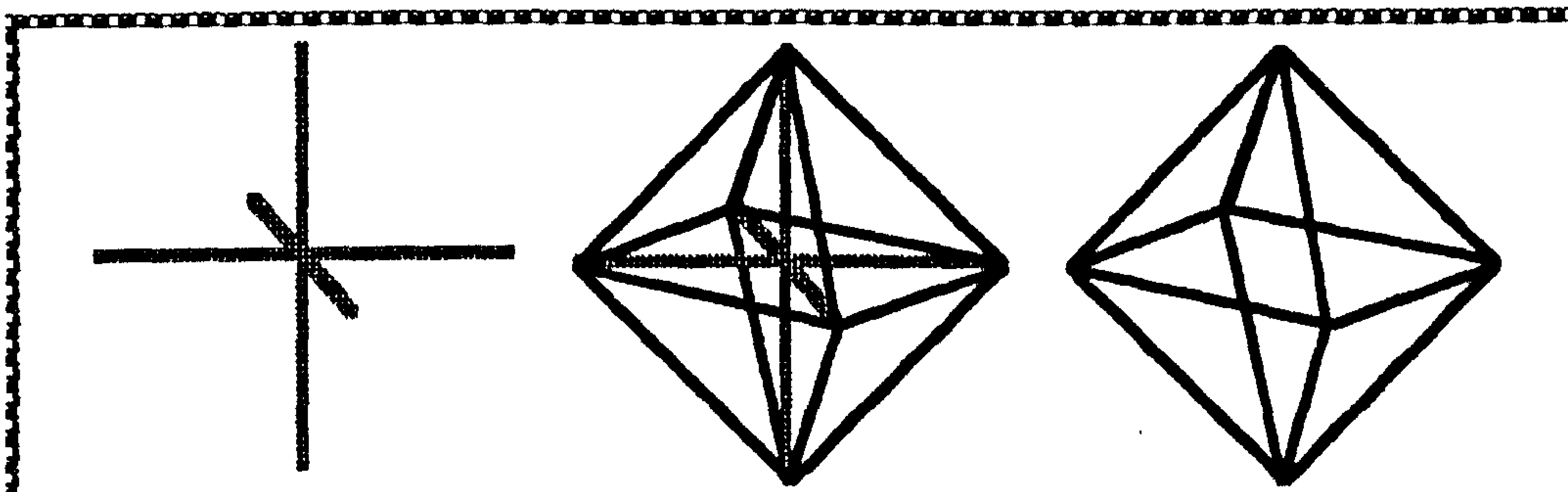


Figure IVA-9. End-points of the dimensional cross form an octahedron.

IVA.22b Dimensional Cross and Octahedral Network.

When the three dimensions are arranged to intersect at the centre of the kinesphere Laban (1966) refers to them collectively as the "dimensional cross" (pp. 13-16). This is identical with the Cartesian cross when it is aligned with the body's anatomy. When the end-points of the dimensional cross are connected, they form an octahedral-shaped kinespheric network (p. 103) (Fig. IVA-9).

IVA.23 Diagonals.

IVA.23a Pure diagonal directions.

The concept of "diagonal" has a specific meaning in choreutics. Laban (1966) describes each of the diagonals* as "a kind of axis" between the three dimensions such that a diagonal is "surrounded by three dimensions" (p. 11). Therefore, a "pure diagonal" is described as a "space-direction which stresses all three dimensions equally strongly" (Ullmann, 1966, pp. 143-144; also Bodmer, 1979, p. 14) and refers to how a diagonal line is oriented at a 45° angle to each of the three dimensions. This means that a choreutic pure diagonal does not lie within any of the Cartesian planes. This specific definition of "diagonal" in choreutics is different than its usage in modern-day Labanotation, in common dance terminology, or its typical definition in

* Rarely, Laban (1966) refers to pure diagonals as "'diagonal inclinations'" (p. 15) but the term "inclination" is usually used in choreutics in a more specialised sense and this will be maintained here (see IVA.25).

every-day language.

In Labanotation the term "diagonal" is used to refer to directions which "lie exactly between forward and side directions . . . or between backward and side directions . . . and not for a gesture which is slanting upward or downward" (Hutchinson, 1970, p. 25). Thus, the right-forward, left-forward, right-backward, and left-backward directions in the horizontal plane are considered to be "diagonals". Laban (1966, p. 13) refers to these four horizontal planar directions, together with the choreutic diagonals, collectively as "oblique directions" whereas Hutchinson (1970, p. 25) uses the term "oblique" to refer only to the up/down slanting of the choreutic diagonals.

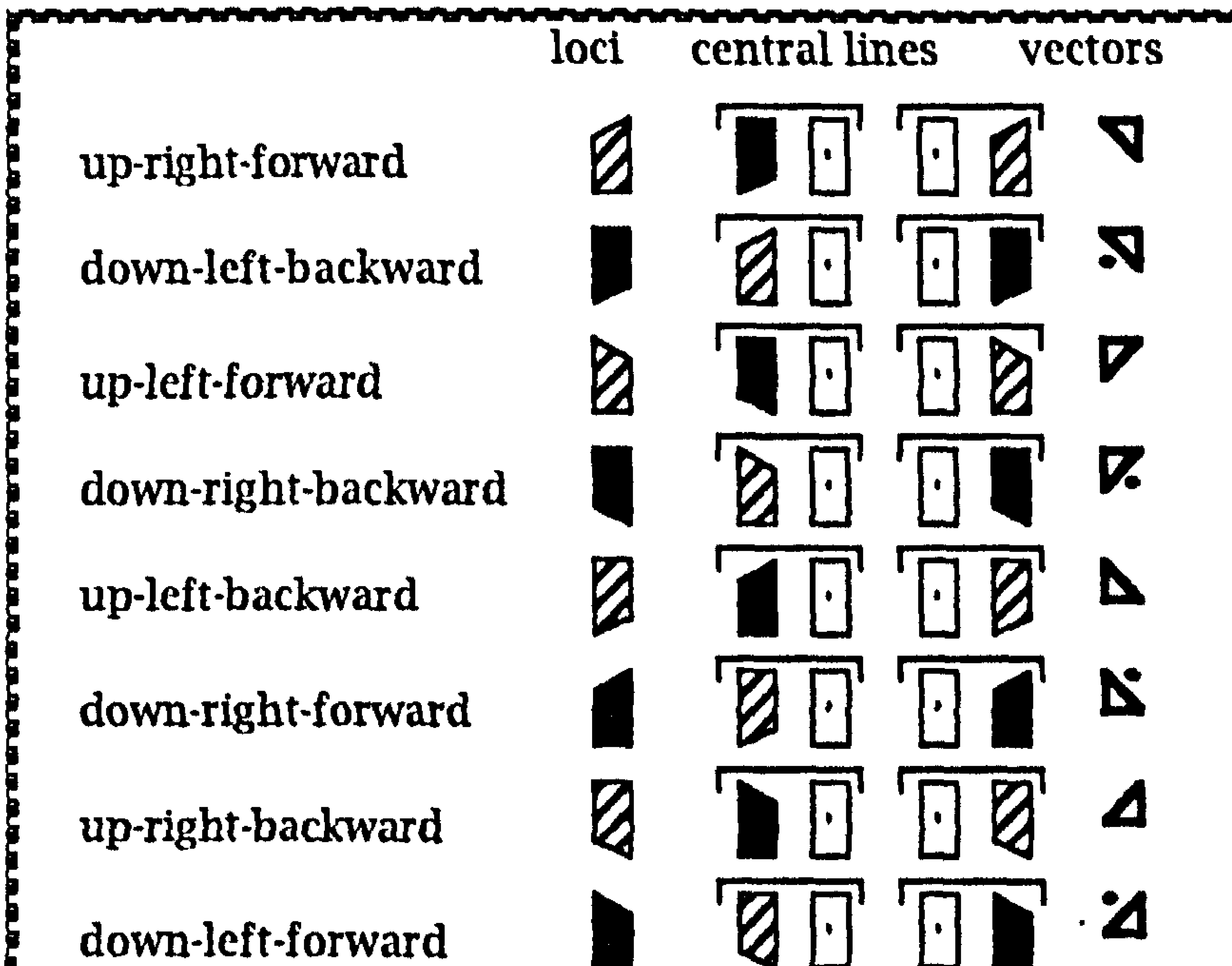


Table IV-2. Examples of diagonal notations (symbols in brackets read from left to right).

In common language (Collins, 1986) and in everyday dance terminology the concept of a "diagonal" refers to any type of oblique slanting, whether it is within a Cartesian plane or not. Likewise, Bodmer (1979, p. 14) uses the term "plane diagonals" to refer to the slanting directions which lie within a Cartesian plane.

Each of the four choreutic pure diagonals can be produced in either of two directions. These eight diagonal directions do not have individual names and so are referred to in terms of their dimensional content. Table IV-2 gives examples of diagonal directions notated as directional points, directional lines and vectors.

IVA.23b Diagonal cross and cubic network.

When the four pure diagonals are arranged to intersect at the centre of the kinesphere Laban (1966) refers to them collectively as the "diagonal cross" (pp. 14, 16). When the end-points of the diagonal cross are joined together they form a cubic-shaped kinespheric network (p. 104) (Fig. IVA-10).

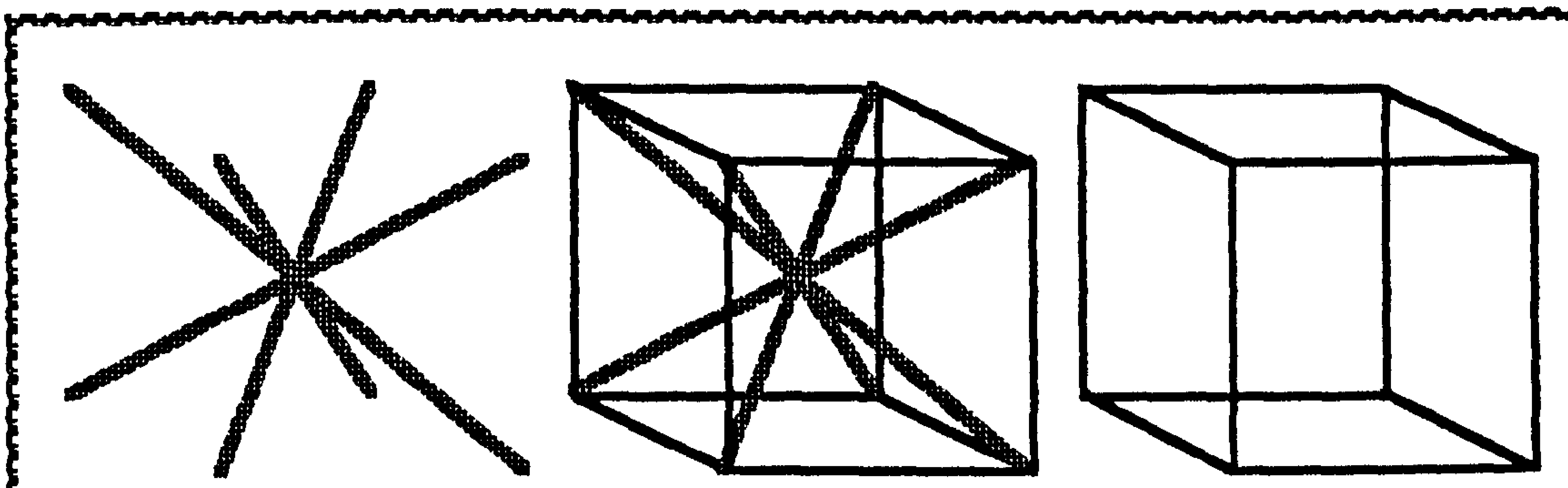


Figure IVA-10. End-points of the diagonal cross form a cube.

IVA.24 "Diameters", Primary Deflections.

The term "diameters" is used in choreutics to refer to directions which are oriented obliquely across one of the Cartesian planes, thus they have also been referred to as "plane diagonals" (Bodmer, 1979, p. 14). The exact orientation of the diametral directions is a principal topic of the prototype/deflection hypothesis (see IVA.40; IVA.82). Because of this importance given to the twelve diametral end-points they are sometimes referred to as "signal-points" (Laban, 1966, pp. 82, 85, 101).

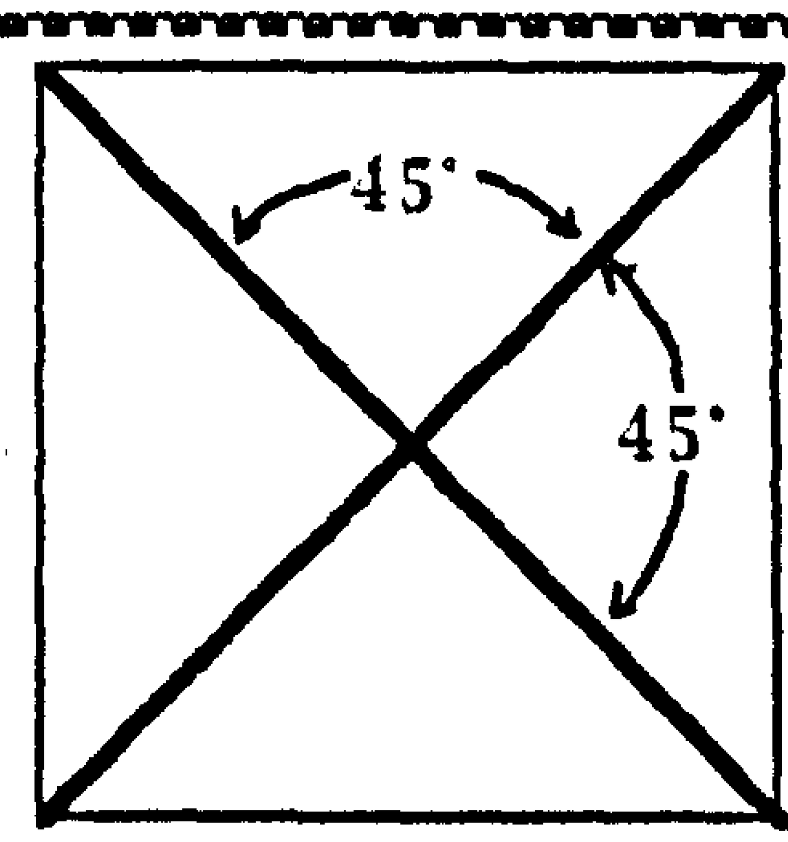


Figure IVA-11. Square plane; ratio between edges, 1:1.

Two orientations of diameters are commonly used in the choreutic conception. "Primary deflected diameters" are oriented relative to a cuboctahedral network, and "modified diameters" are oriented relative to an icosahedral network.

IVA.24a Primary deflected diameters, Square Cartesian planes.

Laban (1966) describes one group of diameters as "axes which lie between two diagonals and two dimensions" and so are considered "to be 'deflected' from the dimensions or from the diagonals" (p. 11) and so are referred to as "deflected directions", "diametral inclinations" or "primary deflected inclinations"* (pp. 15-16). The primary deflected diametral directions are each conceived to be oriented at a 45° angle from each of the two dimensions within a Cartesian plane. When the end-points of the primary deflected diameters within the same Cartesian plane are connected they create a square-shaped plane (Fig. IVA-11).

IVA.24b Modified diameters. Rectangle Cartesian planes.

As part of the prototype/deflection hypothesis (see IVA.40) the orientation of the diameters is conceived to be shifted slightly and these are referred to as "modified diameters" (Laban, 1966, pp. 101-102). The frontal planar diameters deflect toward the vertical dimension, the horizontal planar diameters deflect toward the lateral dimension, and the medial planar diameters deflect towards the sagittal dimension. As a result "the pull of one of the dimensions in each plane is dominant over the other" (Bartenieff and Lewis 1980, p. 32). The proximity of diametral directional points to the dimensions is notated in Table IV-3.

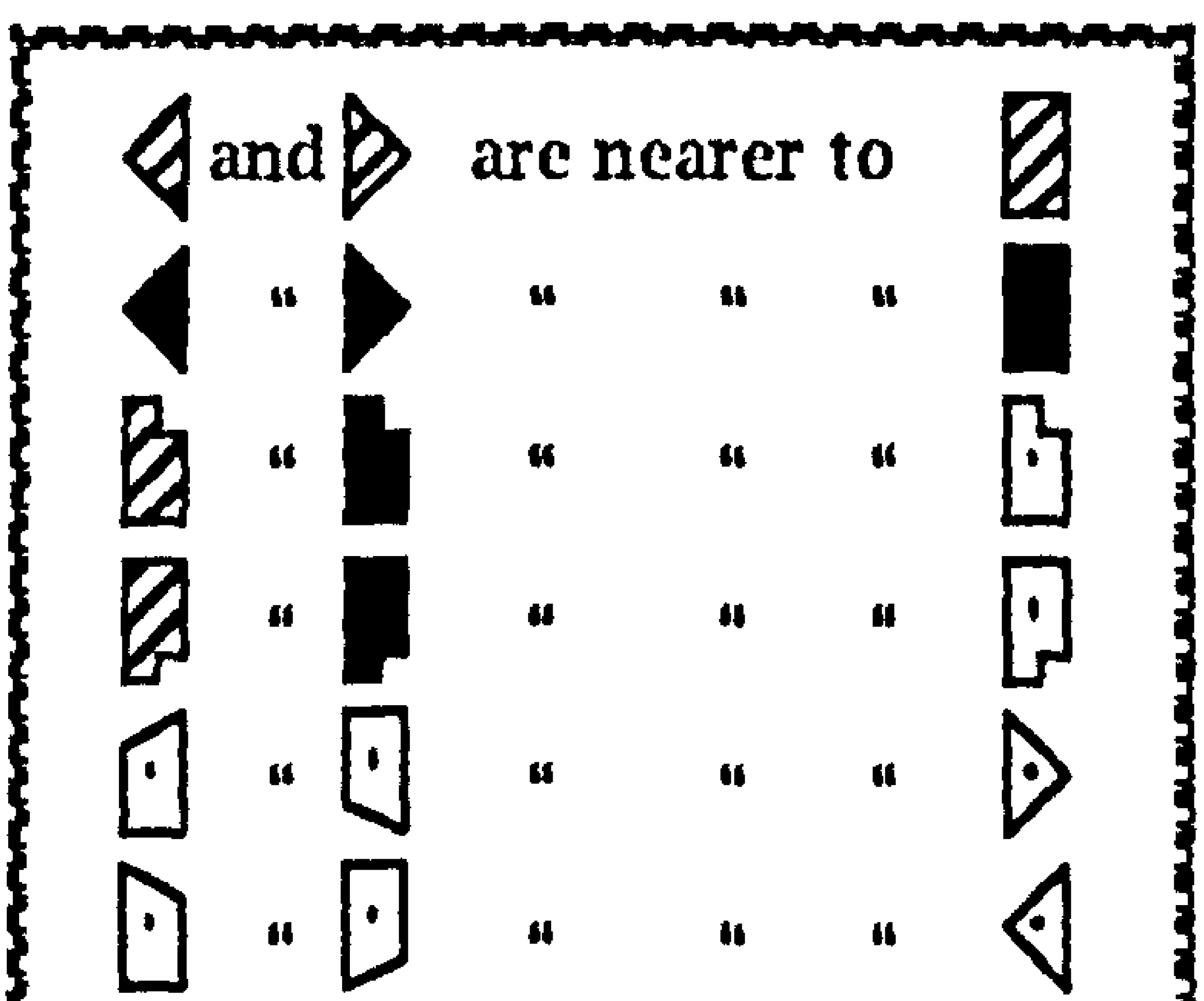


Table IV-3. Modified diameter end-points (adapted from Laban, 1966, p. 105).

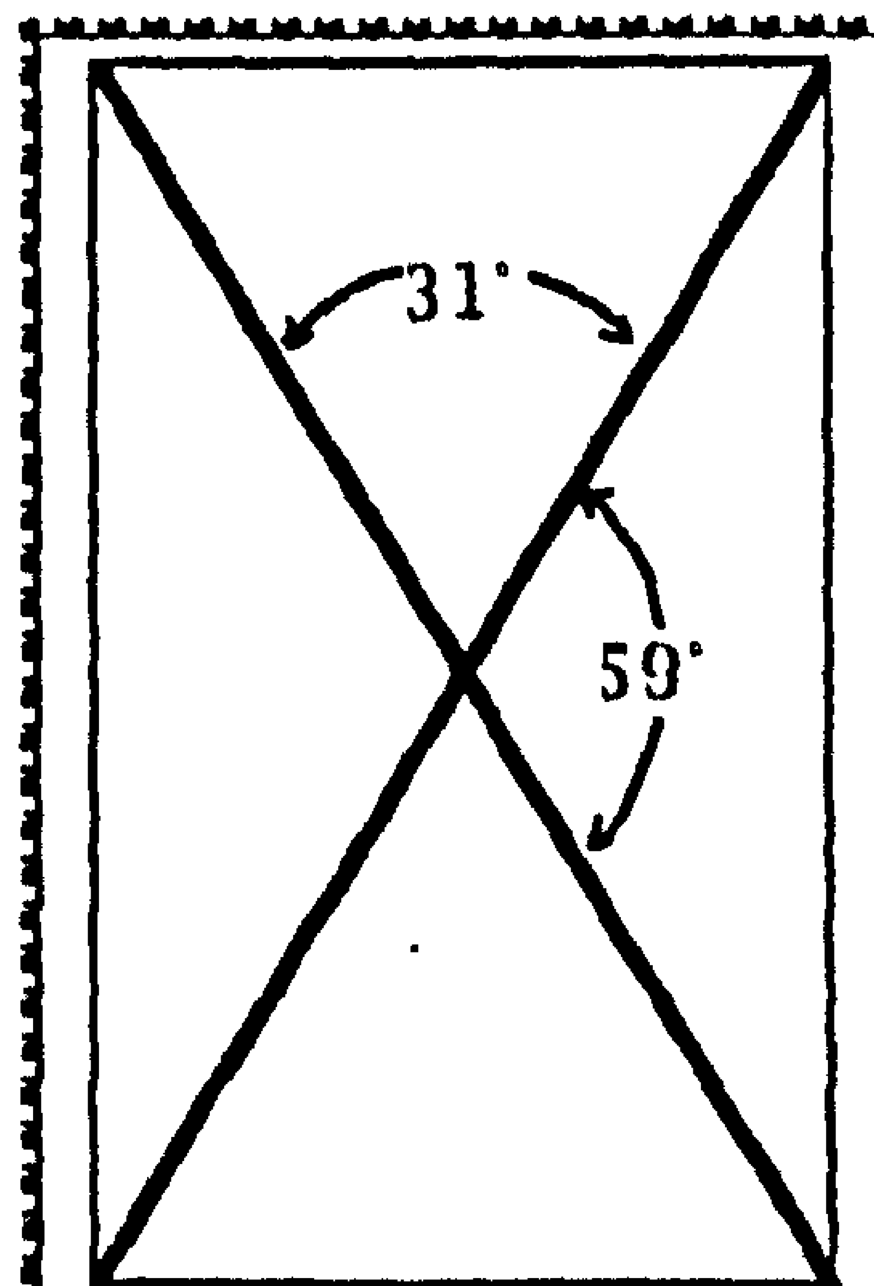


Figure IVA-12. Rectangular plane; Edge ratio $\frac{1+\sqrt{5}}{2} : 1$ (≈ 1.618 : 1)

The modified diameters are oriented at an approximate 31° angle to one dimension and 59° to the other dimension (for details, see Appendix X). If the end-points of the modified diameters are connected they create a rectangle-shaped Cartesian plane (Fig. IVA-12) which has the proportions of the "golden section".

* Rarely, Laban (1966) refers to diameters as "'diametral inclinations'" (p. 16) but the term "inclination" is usually used in choreutics in a more specialised sense and this will be maintained here (see IVA.25).

Sometimes the orientation of the modified diameters is conceived as resulting from a division of each of the dimensions (rather than a shifting of the diameters) (Laban, 1926, pp. 22-23; Preston-Dunlop, 1984, pp. 21-22; Ullmann, 1955, pp. 29-31; 1966, pp. 139-142; 1971, pp. 18-21). According to this conception "The three dimensions [each] have a double consequence" (Laban, 1926, p. 22) resulting in a "split of the one dimensional" and so "the dimensions are not felt by the body as lines but as planes" (Ullmann, 1966, p. 141). Accordingly, the planes created by modified diameters are sometimes referred to as "dimensional planes" in which one dimension is the "primary one" and the other dimension in the plane is the "secondary one" (Laban, 1926, p. 23; Ullmann, 1966, p. 142). The vertical dimension is conceived to widen slightly into the frontal plane, the lateral dimension bulges slightly into the horizontal plane, the the sagittal dimension extends into the medial plane (for description see IVA.82).

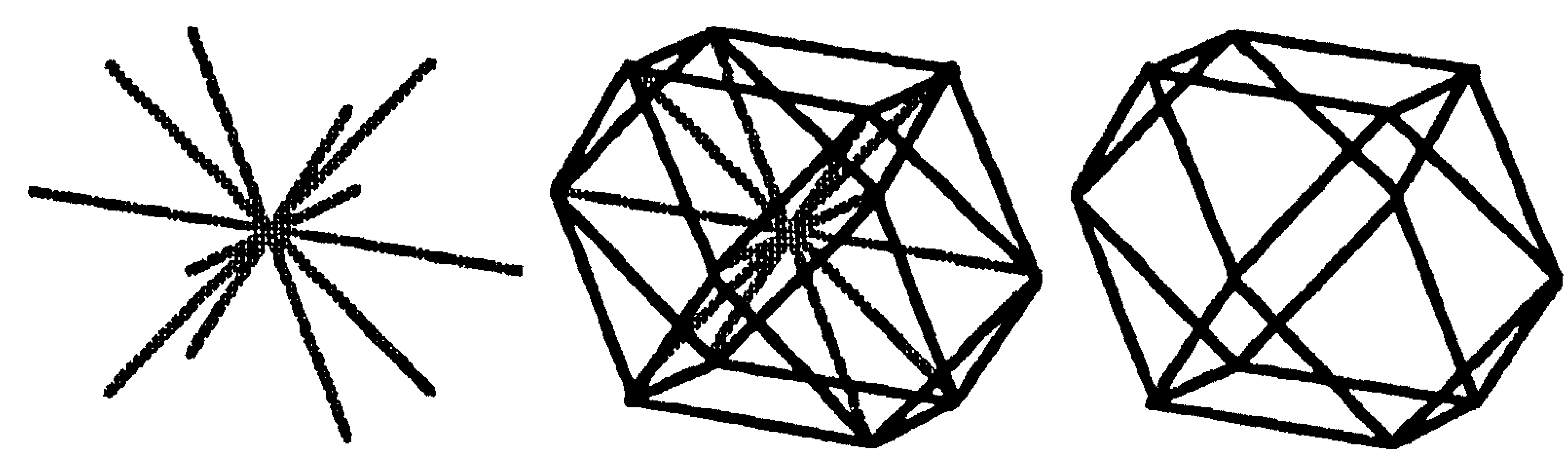


Figure IVA-13. End-points of primary deflected diameters form a cuboctahedron

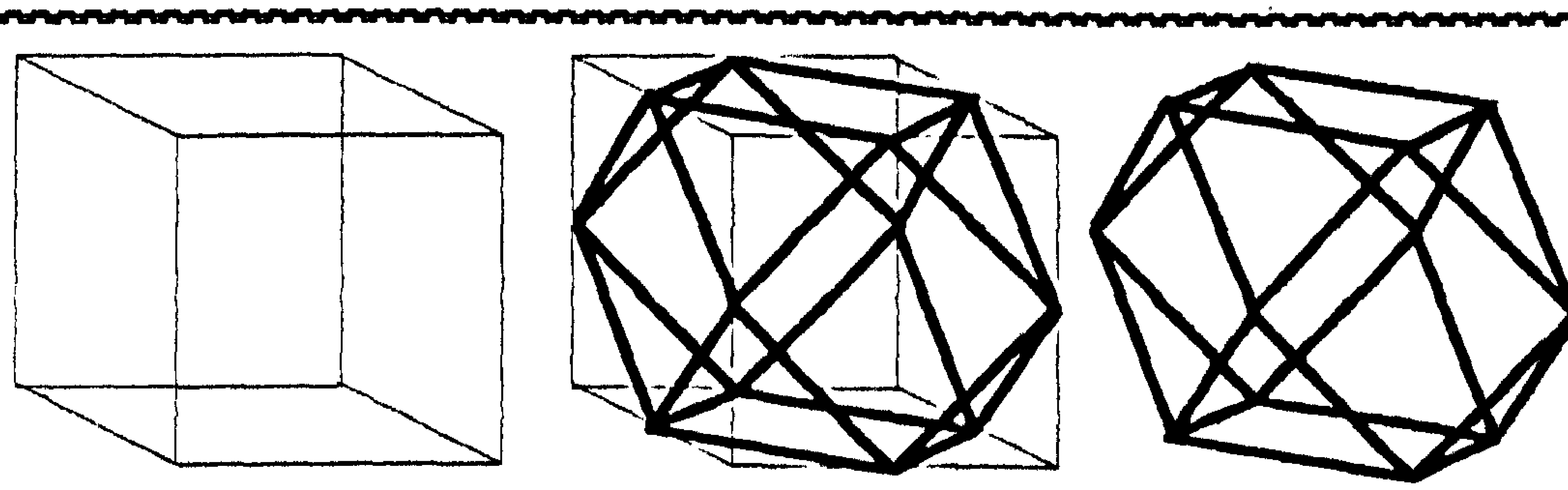


Figure IVA-14. Cuboctahedron derived by joining the cubic edge mid-points.

IVA.24c Diametral crosses. Polyhedral networks .

There are six diameters (two diameters within each Cartesian plane). When these are arranged to intersect at the centre of the kinesphere they can be referred to collectively as the "diametral cross" (Laban, 1966, pp. 15-16). When the end-points of the primary deflected diametral cross are joined together they form a cuboctahedral-shaped kinespheric network (Laban, 1966 p. 104) (Fig. IVA.13). This cuboctahedron net can be conceptually simplified by regarding it as derived from a cube (Fig. IVA.14) and so primary deflections might be referred to as cubic diameters, or as cuboctahedral diameters. When the ends of the modified diametral cross are joined together they form an icosahedral-shaped kinespheric network (Fig. IVA.15). These can be referred to as icosahedral diameters.

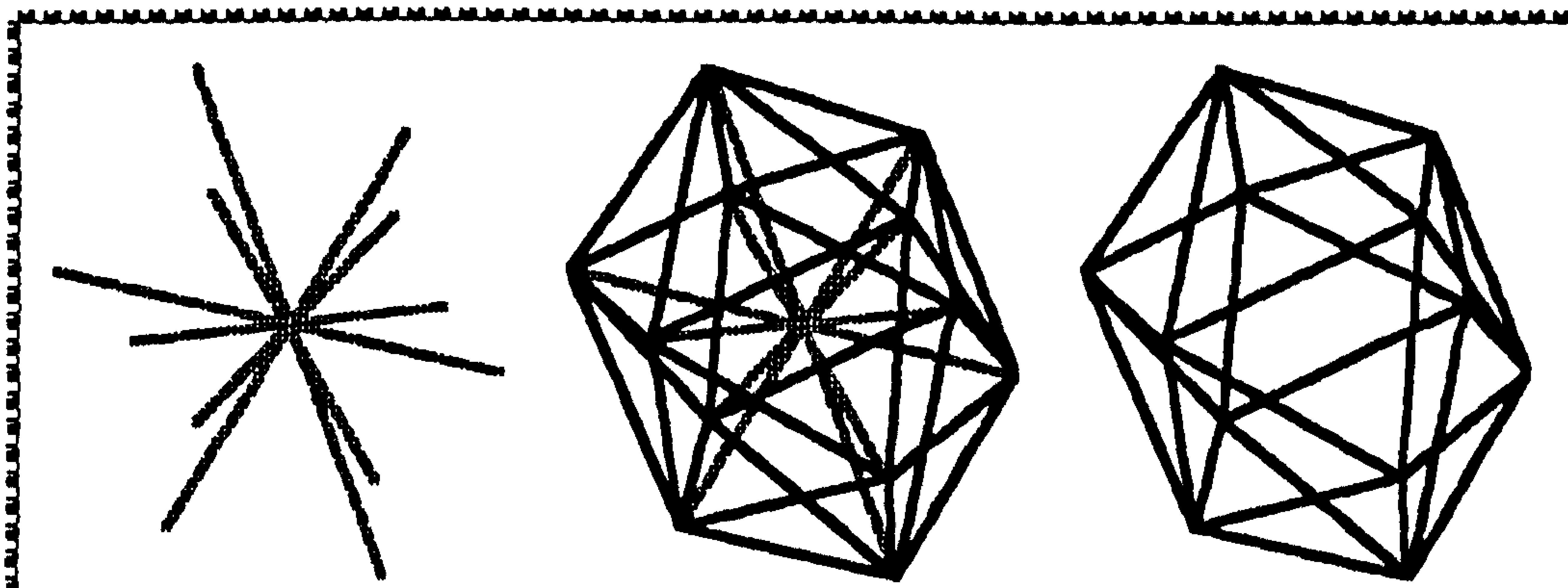


Figure IVA-15. End-points of modified diameters form an icosahedron.

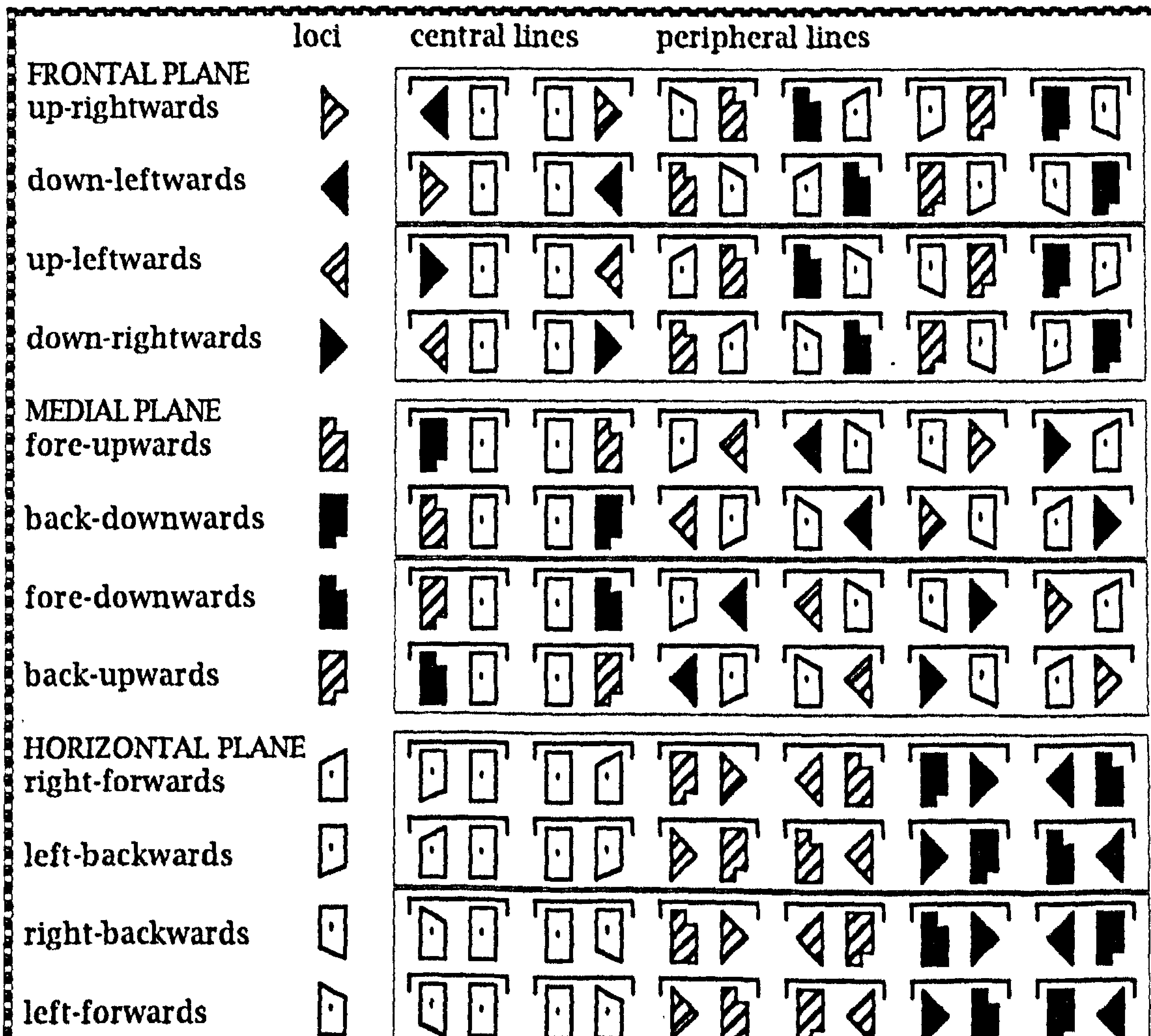


Table IV-4. Notations of cuboctahedral diametral directions.
(symbols in brackets read from left to right).

IVA.24d Notation of diametral directions.

Each of the six diameters can be produced in either of two directions. This yields a total of twelve diametral directions. The diameters are referred to in terms of their dimensional content. The primary dimension in an icosahedral diametral direction can be indicated by underlining (following Laban, 1966, p. 102).

Examples of notations for cuboctahedral diametral points and diametral lines are given in Table IV-4. Peripheral lines in the cuboctahedral net are parallel to the central directional lines and so are included as examples of the same diametral direction.

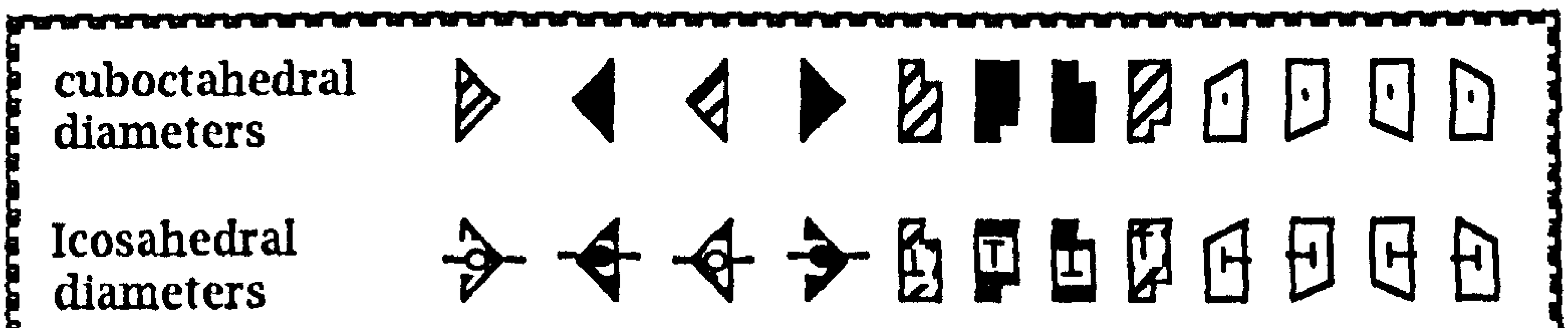


Table IV-5. Labanotation symbols for cuboctahedral and icosahedral diametral points.

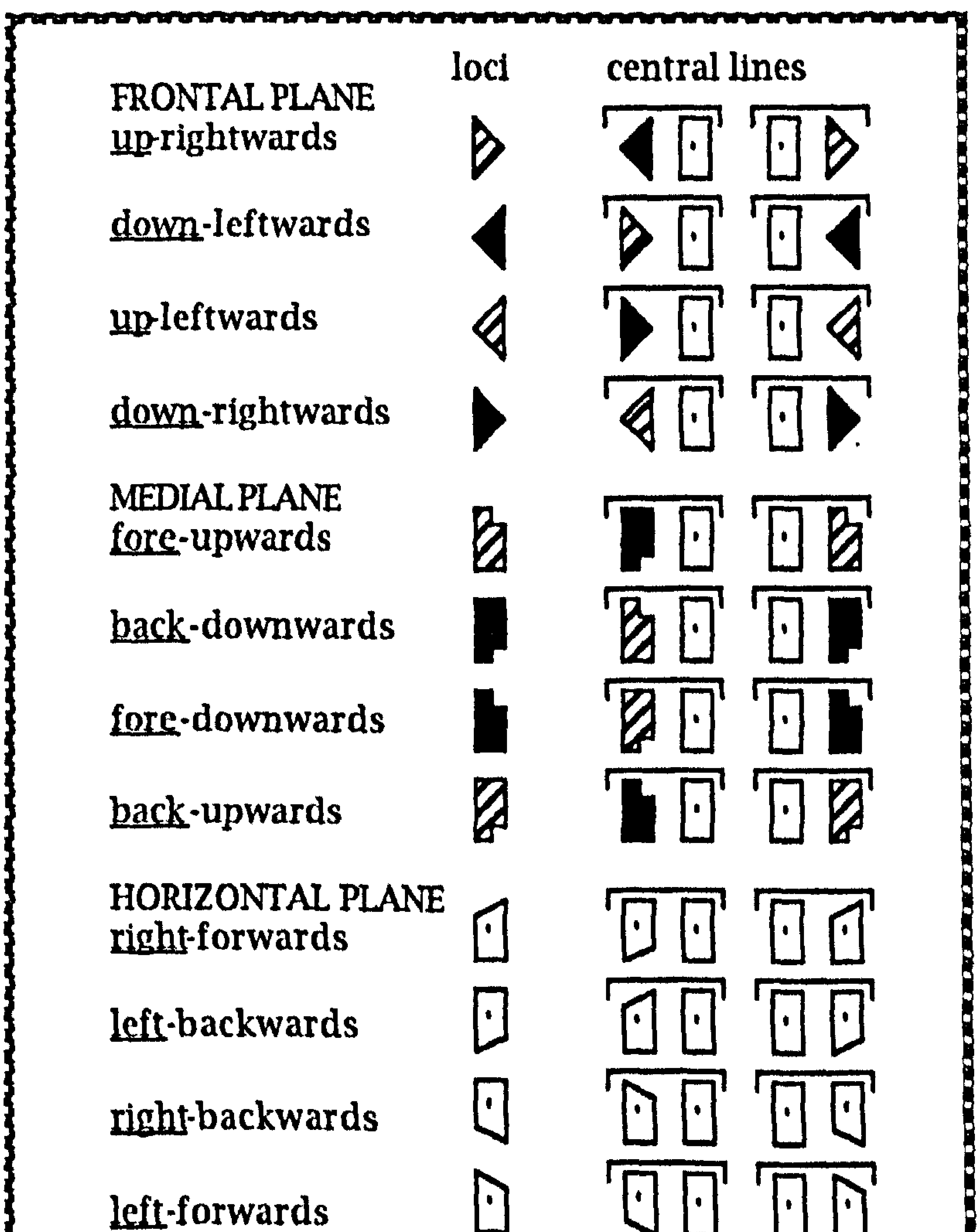


Table IV-6. Notations of icosahedral diameters (symbols in brackets read from left to right).

Labanotation direction symbols indicate cuboctahedral diametral directions (ie. 45°) (Hutchinson, 1970, p. 25). However, in choreutic texts (Preston-Dunlop, 1984) and in common practice, the Labanotation direction symbols are also used to indicate icosahedral diametral directions (Laban, 1966, pp. 104-105). Icosahedral diametral directions could be correctly notated with Labanotation "third way points" (Hutchinson, 1970, p. 439) (Table IV-5). However, in interests of simplicity the same direction symbols are typically used for both types of diameters and this will be followed here. Icosahedral diameters can be specified by using a special "icosahedron" symbol (eg. Maletic, 1950), or this can be indicated verbally in the description of the notation. Examples of notations for icosahedral diameters are given in Table IV-6. In contrast to the cuboctahedron, peripheral lines in the icosahedral net are "tertiary deflections" (see IVA.25c) and are not parallel to the central diameters.

IVA.25 "Inclinations", Secondary and Tertiary Deflections .

Diameters were conceived as "primary deflections" (see IVA.24a) in which a dimension tilts to a certain degree within a Cartesian plane. Secondary and tertiary deflections are also conceived as intermediary directions between dimensions and diagonals. These directions do not lie within or parallel to a Cartesian plane, nor is it parallel to a diagonal, but will "always connect two end-points of two different diameters" (Laban 1966, p. 68). These are referred to as secondary (cuboctahedral) and tertiary (icosahedral) deflected directions. Since these play a special role in choreutics they are referred to collectively as "inclinations".*

Laban explains that an inclination could be conceived as either a dimensionally-

* In rare cases pure diagonals or diameters have also been referred to as "inclinations" in order "to denote a digression from the . . . dimensional cross" (Laban, 1966, pp. 15, 16). This is closest to the dictionary definition of "inclination" as "the degree of deviation from . . . a horizontal or vertical plane" (Collins, 1986), that is, any non-dimensional line. However, in choreutic practice the term "inclination" has become specialised to refer to a direction which is deflected from a diagonal toward one of the dimensions (Dell, 1972, p. 11; Preston-Dunlop, 1984, p. ix; Ullmann, 1966, p. 145; 1971, p. 17) and this definition is used here.

"Transversal" is sometimes used synonymously with "inclination" (Dell, 1972, pp. 11-12; Ullmann, 1966, p. 152; 1971, p. 25). This equivalence is rejected here since "central inclinations" and "peripheral inclinations" can occur which are not transverse and a "transversal dimension" may occur which is not an inclination (Salter, 1977, p. 134; Ullmann, 1966, pp. 147, 165, 173, 184).

Inclinations could also be referred to collectively as "deflections" since they are deflected from a diagonal and a dimension. The notion of "deflection" is kept distinct here as a reorientation process, for example diameters can also be considered to be deflected from dimensions.

deflected-diagonal or a diagonally-deflected-dimension but that the former is conceptually easier:

> There appear two possibilities: To put forward either a diagonal deflected through a close-by dimensional, or alternatively, a dimensional deflected through one of the closest diagonals. Since to us the dimensional-concepts are more familiar, we shall relate the positional-inclinations to these. (Laban, 1926, p. 13)

IVA.25a Flat, steep, and suspended inclinations.

The directions of the secondary and tertiary deflections is defined according to their dimensional content. When an inclinational line is oriented primarily along one of the dimensions then it can be called a deflection of that dimension (and the closest diagonal). The three possible dimensional deflections are referred to as "flat" (lateral deflection), "steep" (vertical deflection), or "suspended"# (sagittal deflection) (Bartenieff and Lewis, 1980, p. 40). Each of the four diagonals can be deflected by either the lateral, vertical, or sagittal dimension yielding a total of 12 inclinations.

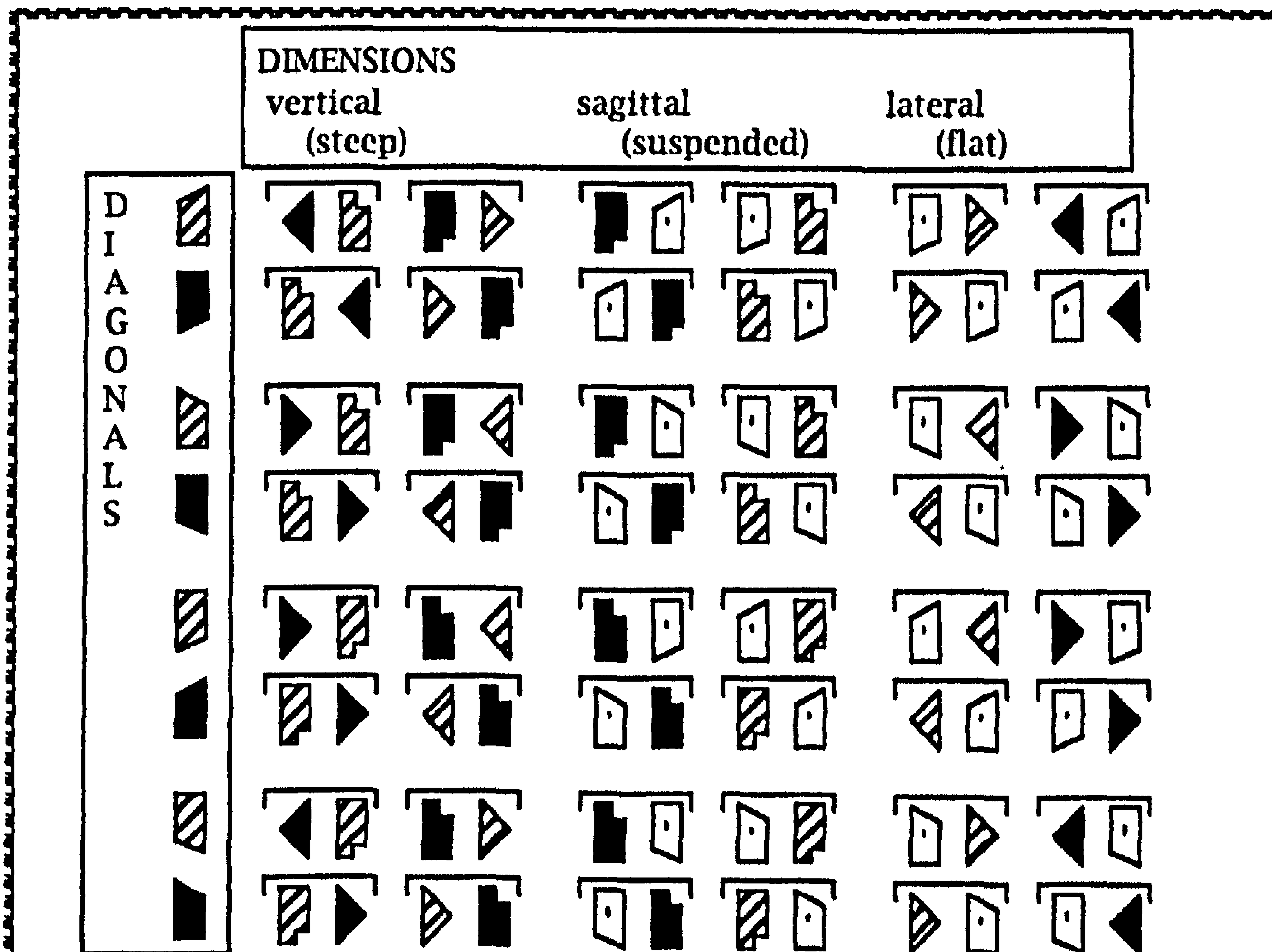


Table IV-7. Cuboctahedral dimensional/diagonal deflections (inclinations) (symbols in brackets read from left to right).

The English term "flowing" was chosen by Laban (eg. 1966, p. 74) for a sagittal deflection but "suspended" will be used here (following Bartenieff and Lewis, 1980, p. 40) so as not to create confusion with Laban's conception of the movement's "effort" quality referred to as "flow" (Laban and Lawrence, 1947). The original German term, "*schwebende*" (Laban, 1926, p. 44), from *Schwebe*, refers to a quality of hanging, hovering, floating, suspense (Collins, 1969).

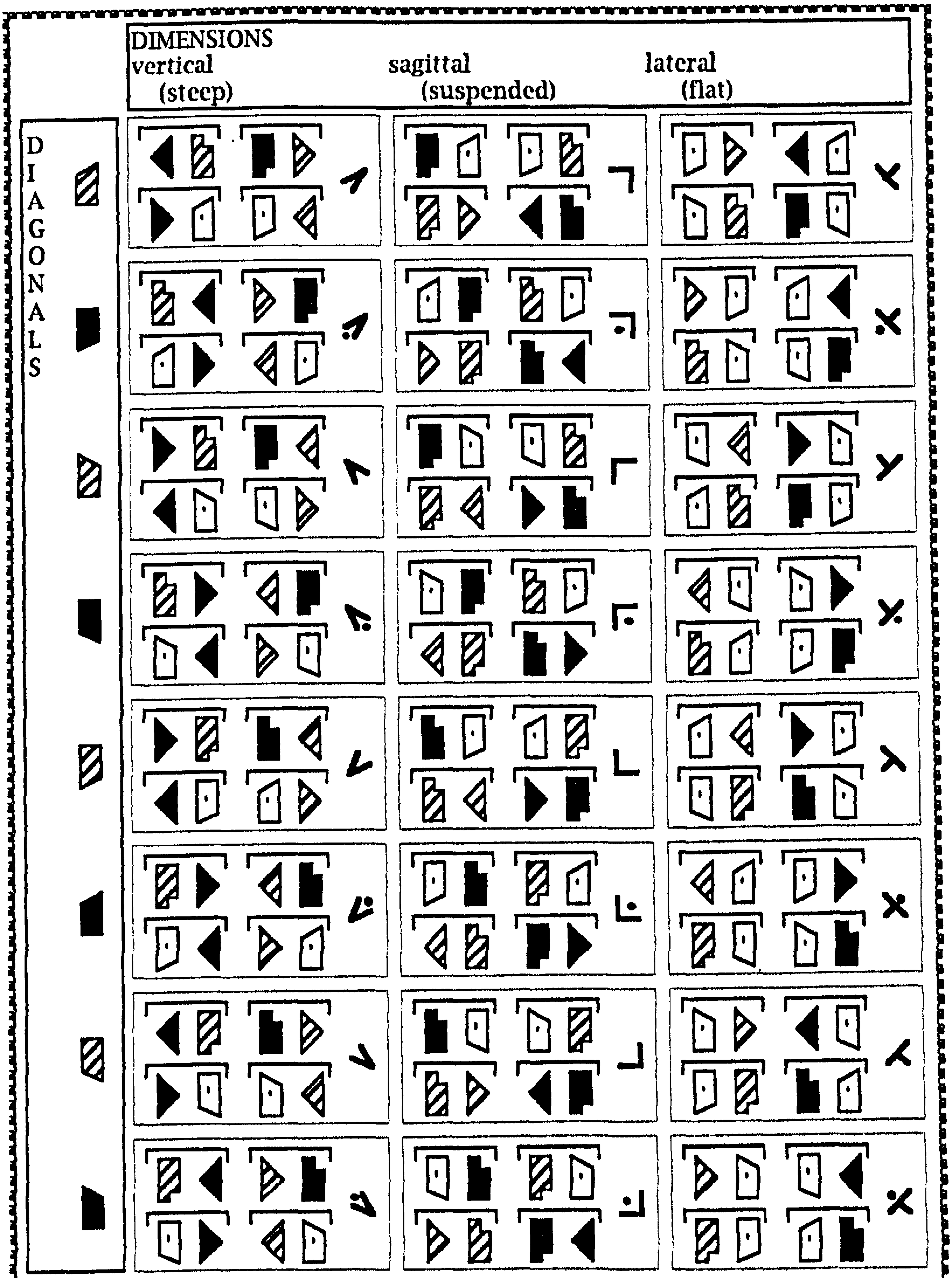


Table IV-8. Dimensional / diagonal tertiary deflections; Icosahedral inclinations (transverse and peripheral); Vector symbols.
(Symbols in brackets read from left to right.)

IVA.25b Secondary deflections. Cuboctahedral inclinations.

Laban (1966) considers inclinations within a cuboctahedral network* to be

* It is clear that Laban's (1966, p. 68 et seq.) discussion is in reference to a cuboctahedral network since he refers to its "24 surface-lines" (the icosahedron has 30) and the many parallel relationships reviewed between the central diameters and peripheral directions are true for the cuboctahedron but not the icosahedron.

"'secondary deflections'" (p. 68) or as "secondary deflected inclinations" (p. 73). A total of 24 transverse lines can be constructed by linking pairs of loci within a cuboctahedral network. These can be grouped into 12 pairs of parallel lines, each pair being in the same direction (and so the same inclination). This yields 12 possible inclinations within the cuboctahedral network (Laban, 1966, p. 73). Each inclination can be executed in two directions, thus yielding a total of 24 secondary deflected directions. Examples of the secondary deflections are notated in Table IV-7. Inclinations in the cuboctahedral net are transverse. Peripheral lines in the cuboctahedral net are parallel to the diameters and so are primary deflections (see IVA.24d).

IVA.25c Tertiary deflections, Icosahedral inclinations .

"The inclinations in the icosahedron are [referred to as] 'tertiary deflections' from the diagonals and dimensions", as "tertiary deflected diagonals" (Ullmann, 1966, pp. 145-146), or sometimes as "modified diagonals" (Bartenieff and Lewis, 1980, p. 33; Dell, 1972, p. 11).

A total of 30 transverse lines can be constructed by linking pairs of loci within an icosahedral network. These can be grouped into 15 pairs of parallel lines, each pair being oriented along the same direction. These 15 directions can then be grouped into 3 transverse dimensions and 12 transverse inclinations. This yields 12 possible inclinations within the icosahedral network. Each inclination can be produced in two directions, thus yielding a total of 24 possible tertiary deflected directions. Examples of the tertiary deflections are notated in Table IV-8. Peripheral lines in the icosahedral net are parallel to the transverse inclinations and so are also considered to be tertiary deflections. Vector symbols can also be used to notate tertiary deflections without regards to specific locations.

IVA.25d Slopes of secondary and tertiary deflections .

A fundamental difference between cuboctahedral inclinations (secondary deflections) and icosahedral inclinations (tertiary deflections) is that they have different slopes, or a "different degree of inclination" (Ullmann, 1966, p. 145).

The slope of a line is typically calculated within a single plane as:

$$\text{slope} = \{\text{rise/run}\}$$

This gives a "numerical measure of the inclination or steepness of the line" (Munem and Foulis, 1986, p. 137). This formula for the slope in two-dimensions can be expanded to three-dimensions by including an additional "run", thus:

3-D slope = {vertical rise / lateral run / sagittal run}

This can be used to compare the slopes of cuboctahedral versus icosahedral inclinations. The steep deflection of the diagonal up-right-forward can be considered as an example. The slope of the cuboctahedral inclination (secondary deflection) is: {2/1/1}; whereas the slope of the icosahedral inclination (tertiary deflection) is approximately: {2.6/1/1.6} (Table IV-9).

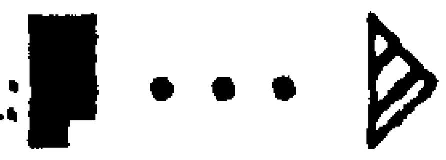
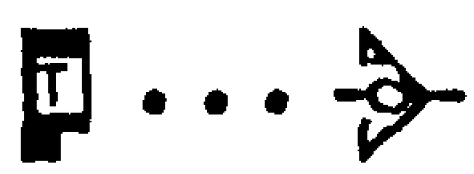
Cuboctahedral:		slope = { 2/1/1 }
Icosahedral:		slope = {2.6/1/1.6}

Table IV-9. Steep deflections of diagonal up-right-forward.

Both slopes have the largest proportion of vertical rise which identifies them as steep deflections. The lateral run and the sagittal run are equal in the cuboctahedral inclination whereas the lateral run is smaller than the sagittal run in the icosahedral inclination. These three uneven components of the slope of an icosahedral inclination are described as the "uneven stress on three spatial tensions" (Dell, 1972, p. 10), as "three unequal spatial pulls" (Bartenieff and Lewis, 1980, p. 38), as "primary, secondary, [and] tertiary spatial tendencies"[*] (pp. 92-93) and so as "extremely" , "somewhat", or "scarcely" "outspoken"[#] (Laban, 1926, pp. 25-26).

IVA.30 Prototype (Schema) Theory in Psychology

IVA.31 General Statements.

A psychological theory has been well developed which posits that memory representations consist of prototypes and variations (deflections) of a prototype. This prototype or "schema theory"[ç] has been used to account for memory effects with non-spatial stimuli (eg. stories, members of categories, music), and spatial

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* These primary, secondary, and tertiary spatial components of an icosahedral inclination should not be confused with the primary, secondary, and tertiary deflections.

\# The German "*ausgespragt*", translated as "outspoken".

ç Some researchers use the term "schema" (Edmonds et al., 1966a; 1966b; Evans, 1967; Schmidt, 1975), others use the term "prototype" (Neumann, 1974; 1977; Strange et al., 1970) and some use the two terms interchangeably (Posner, 1969; Posner and Keele, 1968; 1970). Generally, a "prototype" refers to the most usual example, or typical features of a class of items, and "schema" includes the prototype plus the range of parameters used to derive variations of that prototype (Edmonds and Evans, 1966a; Franks and Bransford, 1971).

stimuli (eg. drawings, visual scenes) and also for the overall memory of bodily movements (see below).

Bartlett (1932) was one of the first modern psychologists to popularise the notion that items are not remembered in terms of particular features but are abstracted into prototypes which are representative of important attributes shared by members within a particular category of items. Individual members of the category are identified by noting their variation away from the prototype. Bartlett (1932, pp. 199-202) referred to this abstracted prototypical memory representation as a "schema" and asserted that body movements are not stored in memory as individual items but that similar movements are organised together into a unitary prototype. The notion of schematic representations was also applied to an overall theory of motor learning by Schmidt (1975; 1976; 1982) which is described as "currently [the] dominant psychological theory of motor learning" (Jordan and Rosenbaum, 1989, p. 753).

The prototype structure of memory representation provides a degree of cognitive economy since a single prototype and small set of variable parameters can represent a large group of actual items. This problem of limited memory capacity can be referred to as the "storage problem" which must be addressed by theories of motor learning (Cummings and Caprarola, 1986, p. 51). Memory representation as a prototype and deflections reduces the demand on memory capacity. "The schema would be stored only once and each stimulus or instance would be stored by noting only those aspects which deviated from the schema" (Evans, 1967).

A prototype structure of memory representation also allows new, never before experienced items to be recognised or produced by judging the degree to which they fit together with, or deviate from, existing prototypes. The ability to recognise and respond to new, never before experienced stimulations can be referred to as the "novelty problem" which must also be addressed by theories of motor learning (Cummings and Caprarola, 1986, p. 51). For example, Bartlett (1932, p. 202) and Schmidt (1975, p. 230) argue that in a tennis or a cricket game a stroke is never an exact repeat of a previous stroke, neither is it an absolutely new stroke, but it is a product of all the past experiences of similar strokes. Novel movements can be executed and recognised which are not exact duplicates of past movements, but are derived by creating variations of prototypical movements stored in memory. In the psychological literature this process of deriving variations of a prototype has been referred to as "corrections" (Evans, 1967), "distortions" (Posner and Keele, 1970), "deviance", "structural changes", "transformations" (Franks and Bransford, 1971) and "deviations" (Evans, 1967; Evans and Edmonds, 1966; Rosch, 1975a).

IVA.32 Psychological Effects Indicative of Prototypes .

Certain experimental effects have been identified which indicate that the items in question are mentally represented as prototypes and deflections.

IVA.32a Prototypes perceived and recalled fastest .

Items which are prototypical of a class of items will be perceived, categorised, and recalled faster than items which are less prototypical. This has been found for verbal semantic categories (Loftus, 1973; Rips et al., 1973; Wilkins, 1971), colours (Berlin and Kay, 1969; Rosch, 1973; Rosch-Heider, 1972), numbers (Armstrong et al., 1983), abstract visual shapes (Posner, 1969, p. 65; Posner and Keele, 1968), geometric forms (Rosch, 1973), random dot patterns and body stick-figures (Rosch et al., 1976), actions within an event or "script" (Barsalou and Swell, 1985; Galambos and Rips, 1982), and the angle from which an object is best viewed (Palmer et al., 1981).

IVA.32b Prototypes learned first.

Items which are most prototypical of a category will be learned before other less prototypical items. This has been found for colours (Rosch, 1973), the semantic meaning of a verbal paragraph or story (Anderson and Pichert, 1978; Bower, 1976; Bransford and Franks, 1971; Bransford et al., 1972), geometric forms (Rosch, 1973), random dot patterns, and body stick-figures (Rosch et al., 1976).

IVA.32c Prototypes recalled first .

Items which are most prototypical of a category of items will be recalled before other items which are less typical. This has been found for verbal semantic categories (Battig and Montague, 1969; Bousfield and Sedgewick, 1944), random dot patterns and body stick-figures (Rosch et al., 1976), and the angle from which an object is first imagined to be viewed (Palmer et al., 1981).

IVA.32d Prototypes recalled more accurately .

Items which are more prototypical of a category will be recalled better (ie. more often, with greater accuracy) than items which are less prototypical. This has been found for colours (Rosch-Heider, 1972), actions within an event or "script" (Lichtenstein and Brewer, 1980), objects and their locations in a visual scene (Mandler and Parker, 1976; Mandler and Ritchey, 1977; Mandler and Stein, 1974; Von Wright et al., 1975), and positions of chess pieces (Chase and Simon, 1973; Goldin, 1978; Holding and Reynolds, 1982).

IVA.32e Prototypes serve as reference points.

Items which are prototypical of a class of items serve as reference points for other less prototypical items. For example, a less prototypical item is conceived to be "almost like" a prototype, rather than the prototype being conceived as "almost like" a non-prototype. This has been found for patterns of dots and angles between line segments (Wertheimer, 1923, pp. 78-79), colours, line orientations and numbers (Rosch, 1975a) and locations in a well-known town (Sadalla et al., 1980). Reference points in the kinesphere were experimentally probed as part of this research (see IVA.110).

IVA.32f Perceptual/memory bias toward the prototype.

The most characteristic effect is that prototypical items tend to be perceived/remembered even if they were never actually experienced. When learning a new set of items Subjects will later believe they have seen a prototypical item when in fact they had not. When Subjects are presented with a well-known category or context this creates expectations that prototypical items will be present. This expectation encourages perceptual bias in which actual items may be perceived to be more similar to the prototype than they actually are.

This bias toward the prototype has been found for stories (Anderson and Pichert, 1978; Bartlett, 1932, pp. 83-85), colours (Medin and Shoben, 1988), abstract visual or kinesthetically traced shapes (Franks and Bransford, 1971; Lee, 1985; Neumann, 1977; Solso and Raynis, 1979), patterns of dots (Posner and Keele, 1968; 1970; Strange et al., 1970), an ambiguous letter within a word (Eysenck and Keane, 1990, p. 50; Smyth et al., 1987, p. 7), indecipherable sounds within an auditory sentence (Warren and Warren, 1970), the meaning of a word within a particular context (Anderson and Ortony, 1975; Barclay et al., 1974; Light and Carter-Sobell, 1970), the significance of body movements within a particular context (Poizner, 1983), actions within an event or "script" (Abbott et al., 1985; Bower et al., 1979; Bower and Clark-Meyers, 1980; Schank and Abelson, 1977; Walker and Yekovich, 1984), the identity and locations of objects in realistic visual scenes (Brewer and Treyens, 1981; Friedman, 1979; Labov, 1973; Mandler and Parker, 1976; Palmer, 1975), line drawings of objects

(Bartlett, 1932, pp. 178-183), locations of dots within a circle (Huttenlocher et al., 1991), orientation of line segments (Weintraub and Virsu, 1971; 1972), orientation of arm positions (Clark and Burgess, 1984), and orientation or angle of geographical directions (Byrne, 1979; Moar, 1978; Moar and Bower, 1983; Ross et al., 1970).

IVA.40 Prototype / Deflection Hypothesis in Choreutics

A prototype/deflection hypothesis can be identified within the choreutic conception which posits that the spatial aspect of bodily movements and positions are mentally conceived in terms of easily imagined dimensional and diagonal prototypical directions whereas actual body movements occur as deflections of the dimensions and diagonals, referred to as "inclinations". Considerable support can be found for this hypothesis in cognitive research and kinesiological analysis.

IVA.41 General Statements.

The prototype/deflection hypothesis in choreutics has not been concisely stated but is alluded to in various places where dimensions and diagonals are considered to be mental prototypes while deflected "inclinations" occur in actual body movement:

> Because the body limits the fulfillment of perfect three-dimensional shapes that pure diagonals would offer, most three-dimensional shapes are created through *modified* diagonals . . . These *are* available to the body. (Bartenieff and Lewis, 1980, p. 33)

> The principles of choreutics can easily be developed by taking the cube as the basis of our spatial orientation. The conception of the cube as a basis is not a compromise but a fundamental principle [ie. conceptual prototype] of our orientation in space. In practice, harmonious movement of living beings is of a fluid and curving nature which can be more clearly symbolized by a scaffolding [ie. kinespheric network] closer to a spheric shape [ie. the icosahedron]. (Laban, 1966, p. 101)

> The [spatial] order within a cube -- when looked upon purely as a space form without relationship to the body or its uses -- is easily comprehended because of the right angles and equal edges. [However] If we relate our moving body to this [cubic] order we shall at first meet with some difficulties. (Ullmann, 1966, p. 139)

The "difficulties" arise since actual body movements do not conform to the shape of a cube. Bartenieff and Lewis (1980, pp. 89-91) report that pure dimensional oriented movements, pure diagonal oriented movements, or movements purely within one of the Cartesian planes "rarely appear in pure form" but that they sometimes may be observed in small isolated gestures. Instead of dimensions or diagonals it is observed that actual body movements occur along inclinations:

> Such inclinations of the pathways of our gestures which have combined directional values [ie. primary, secondary, tertiary spatial components] are very frequent. In fact they are the rule rather than the exception. (Ullmann, 1971, p. 17)

> One of the essential discoveries which arose from the study of movement is that of the crystalline structure of man's movement possibilities. I found this out very early . . . that people, in spite of their differences of race and civilization, had something in common in their movement patterns. This was most obvious in the expressions of emotional excitement. I observed that in these patterns certain points in space around the body were specially stressed. In joining these points, I arrived at a regular crystal form . . . an icosahedron . . .
>
> Man is inclined to follow the connecting lines of the twelve corner points of an icosahedron with his movements in traveling as it were along an invisible network of paths. (Laban, 1951, pp. 10-11)

It is evident that Laban "found this out very early" since in his early work (Laban, 1926) the notation system (vector symbols; see IVA.14) consisted only of pure dimensions, pure diagonals, and inclinations. It appears that Laban considered these directions to be sufficient to represent the various spatial patterns of body movement. The vector symbols provide the prototypes (dimensions and diagonals) and the deflections (inclinations).

The later specification of primary deflections (diameters) and secondary deflections (cuboctahedral inclinations) distinguished intermediary stages in the gradual process of deflection through primary, secondary, and tertiary deflections (see IVA.20). Each deflection represents body movement which is more and more natural or organic. For example, the rectangular (icosahedral) planes are considered more organic than the dimensions, and the inclinations are considered more organic than the planes:

> Whilst the human body is not capable of making a purely one-dimensional movement, it can move, although in a rather restricted and hampered way, in the above mentioned [dimensional] planes. (Ullmann, 1966, p. 141)

> In considering man's natural way of moving we have so far stated that: (a) purely one-dimensional movement never occurs; (b) two-dimensional [planar] movement is possible but does not really correspond to the potential of human movement . . . (Ullmann, 1966, p. 143)

Laban (1966, p. 90) appears to describe how the mental conception of dimensions and diagonals arises from the cognitive analytical "role of the outside observer" and the resultant "certain rigidity of thinking". While in contrast to this the physical actuality of deflected movements arises from the "bodily perspective" with "a more dynamic view of reality" in which "we should try to feel it [movement] sympathetically from within".

Different terms have been used to describe the process of deflection in choreutics. For example, Ullmann (1966) refers to how a pure diagonal is "influenced by" a pure dimension (p. 145) to create a "flat deviation of the diagonal" (p. 147), whereas she later lists these as "deflections" (p. 148). In another place Ullmann (1971) writes about "deriving" an inclination from a dimension and a diagonal (p. 17) or the "transformation" consisting of "replacing" a dimensional movement with an inclination (p. 22). An inclination is a "'harmonic mean'" between a pure dimension and a pure diagonal (Bodmer, 1979, p. 18) such that the diagonal is "modified" (Bartenieff and Lewis, 1980, p. 43) and occurs as flat, steep, and suspended "variations" of a diagonal (Dell, 1972, p. 10). If a distinction is intended between deflecting, deviating, deriving, varying, transforming, modifying, or replacing it is not consistent in the literature. These all appear to refer to the same process of producing physical variations of the dimensional and diagonal conceptual prototypes.

IVA.42 Dimensions and Diagonals as Spatial Prototypes.

In all types of spatial conception, and also choreutics, the dimensions are considered to be the most prototypical directions. Laban (1966) referred to them as the "basic elements of orientation" and so the solid object which is "easiest to visualize, is the cube" (p. 11). At another place he indicates that the dimensional cross is to be considered as the "norm" and other directions to be a "digression from the given norm" (p. 15 [footnote]). This further indicates the dimensions as the prototypical directions with other directions as variations or digressions from the prototype. Or the three dimensions and the four diagonals are referred to as the "seven fundamental cross-sections of space" , and their deflections into the twelve diameters as the "twelve cross-sections which are tempered" (p. 118). The dimensions are also described as the "orthogonal axes", the "simplest frame of reference" and so are the most "basic" for the conception of space (Salter, 1977, p. 129). Thus, the cubic conception of space with the dimensional orientation of its edges is the simplest, most prototypical, easiest to conceive, division of space into definable regions:

> The spheric form of the kinesphere is simplified [differentiated] by our cubic conception of space. We recognize the cube inside the kinesphere as being representative of the most important space directions. (Laban, 1966, p. 18)

IVA.43 Dimensions and Diagonals as Dynamic Prototypes .

The dimensions, together with the pure diagonals, are also conceived to be representative of prototypical dynamics referred to as stability and mobility (or liability*). Laban (1966) characterises movements oriented along Cartesian dimensions as being "stable and always connected with the perpendicular support". This is in contrast to movements oriented along pure diagonal directions "which have a tendency to real mobility, bring the body into situations which lack the perpendicular support . . . [thus] our body flies or falls" (p. 88). And so "The two contrasting fundamentals on which all choreutic harmony is based are the dimensional tension and the diagonal tension" (p. 44)

> [The] dimensions, seem to have in themselves certain equilibrating qualities . . . a feeling of stability. This means that dimensions are primarily used in stabilising movement, in leading it to relative rest, to poses or pauses. (Laban, 1966, p. 90)

> Movements following space diagonals give . . . a feeling of growing disequilibrium, or of losing balance. . . . Real mobility is, therefore, almost always produced by the diagonal qualities . . . (Laban, 1966, p. 90)

This is equivalent to the "first principal of body mechanics" which states that "As long as the line of gravity remains inside the base of support the body is stable; if it falls outside of the base, the balance is lost" (Rasch and Burke, 1978, p. 98). Laban and Ullmann state the choreutic prototype/deflection hypothesis according to these prototypes of stability and mobility:

> Since every movement is a composite of stabilising and mobilising tendencies, and since neither pure stability nor pure mobility exist, it will be the deflected or mixed inclinations [ie. mixture of dimensions and diagonals] which are the more apt to reflect trace-forms of living matter. (Laban, 1966, p. 90)

> . . . the deflected directions are those directions which, in contrast to the stable dimensions and to the labile diagonals, are used by the body most naturally and therefore the most frequently. In these deflected directions stability and lability complement each other in such a way that continuation of movement is possible through the diagonal element whilst the dimensional element retains its stabilising influence. The deflected directions in the icosahedron . . . are easily felt because they correspond to the directions natural to the moving body. (Ullmann, 1966, p. 145)

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* In Europe "liability" is typically used while "mobility" is more typical in America. Preston-Dunlop (1996) reports that mobility was used in a more basic way; "in Laban's practice he used lability for diagonal mobility and stability for dimensional mobility". However, other reviewers of Laban's work consider mobility and lability to be used synonymously (Maletic, 1987, pp. 52-53). This distinction does not appear to be critical to this thesis and the term "mobility" will be (arbitrarily) used here.

> The two contrasting fundamentals on which all choreutic harmony is based are the dimensional tension and the diagonal tension. Basic sequences can be built up on these two principles. Such scales, being based on natural movement which corresponds to the structure of the body, may be called "natural sequences" in space. (Laban, 1966, p. 45)

> [Harmonious movement scales can be determined] when relating the structure and function of the human body to the three-dimensional property of space. Two such movement scales are the "dimensional" and the "diagonal" scales, each of which consists of an ordered sequence of movements based on the fundamental conditions of stability in the three-dimensional scale, and of mobility in the four-diagonal scale. There are also other [inclinational] scales in which the movement sequence depends upon the inter-action of these two states. (Ullmann, 1971, p. 1)

IVA.44 Choreutic Education Organised According to Prototypes.

The structure of choreutic education reveals an implicit organisation according to prototypes. One of the effects indicative of a prototype memory representation is that items which are most prototypical are learned first (see IVA.32b). Textbooks on choreutic education are arranged in this same way in which dimensions and diagonals are introduced before other directions (Laban, 1926; 1966, pp. 13-14; Preston-Dunlop, 1984, pp. 25-26; Ullmann, 1971) and it is recommended that they be practiced and learned before proceeding on to the other deflected directions (Bartenieff and Lewis, 1980, p. 38). The sequence or "scale"* of dimensional directions is also referred to as "the first scale" (Preston-Dunlop, 1984, p. 25) or as the "simplest of the scales" (Bartenieff and Lewis, 1980, p. 29). The sequence of diagonal directions is referred to as "a basic choreutic form" (Preston-Dunlop, 1984, p. 26) and sequences of deflected directions are described as "increasingly complex" (Bartenieff and Lewis, 1980, p. 29).

IVA.45 Directional Prototypes in Labanotation.

Evidence for the prototypicality of dimensions and pure diagonals and (correspondingly) of 90° and 45° angles in conceptions of body movement is also found in the conceptual structure of Labanotation. Directions are expressed by direction symbols (Hutchinson, 1970, p. 24 et seq.) and also with corresponding "position pins" (or "relationship pins") (p. 434 et seq.) which can be used to specify the degree of turning in place (pp. 94-95), degree of traveling in a circle (pp. 186-192), the directional relationship between the two feet (pp. 62-64), as "front signs" which

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* Certain sequences of directions are referred to as "scales", analogous to musical scales they are considered to be "natural sequences of movements . . . determined by the anatomical structure of our body" (Laban, 1966, p. 37). They are typically symmetrical patterns which progress through all variations of a particular type of direction (see IIID.60).

indicate the direction of facing in the room (pp. 104-107), or the signs for specific areas in the room (p. 182). All of these directional symbols are based on dimensional directions and 45° angled planar diagonals (ie. diameters). Other less typical deflected directions can only be specified by deriving them from halfway points or third-way points between the prototypical directions (Hutchinson, 1970, pp. 437-440). Thus, the less-typical directions/angles are conceptually derived according to their relationship to the prototypes.

IVA.50 Prototypical Angles and Orientations in Spatial Cognition

All spatial directions are not treated equally. This character of "having different physical properties in different directions" is referred to as "anisotropy" (Collins, 1986). This unequal responding to different spatial directions is indicative of perceptual/memory organisation.

IVA.51 Directional Prototypes in Language.

Cognitive prototypes are evidenced by the specialised terms which have developed in the English language for spatial directions, while deflections (non-prototypes) are referred to according to their relationship to the prototypes. Spatial anisotropy is evident in that dimensions are given the greatest specificity, diagonals are given less, and intermediary deflections are given the least.

Each dimension has been given a specialised name (eg. vertical, lateral, sagittal; see Appendix VIII), each of the two directions within each dimension has also received a special name (eg. up/down, right/left, fore/back), and the group of three dimensions taken together has been designated as the Cartesian cross which are used as the basis of geometric coordinate systems. Dimensions are also sometimes referred to as the "cardinal axes" (eg. Weintraub and Visru, 1971; 1972) containing the "cardinal points" (north, south, east, west) which indicate the "fundamentally important" or "principal" directions (Collins, 1986).

All other directional orientations besides the dimensions are referred to collectively with terms such as "diagonal", "oblique", "slanted", or "tilted" which do not specify any particular orientation other than "not-dimensional". The particular orientation can only be specified according to the dimensional content of planar diagonals (eg. diagonal right-forward; diagonal up-leftward) or cubic diagonals (eg. diagonal up-right-forwards; diagonal up-left-backwards, etc.). This reveals how the dimensions serve as prototypes with other directions conceived according to their dimensional components.

Specialised terminology has also developed to refer to the most prototypical planes and prototypical angles. The three planes which contain the dimensions are referred to collectively as "Cartesian planes" or "cardinal planes" (Rasch and Burke, 1978, p. 97) and have also been distinguished by the specialised terms "frontal", "medial", and "horizontal" (various other terms are also used; see Appendix VIII). The terms "right angle" (90°), and "straight angle" (180°) refer to specific sized prototypical angles. Other less prototypical angles are referred to collectively as "acute" (any angle between 0°-90°) or "obtuse" (any angle between 90°-180°). Thus, the less prototypical angles are conceived according to their relationship to the prototypes.

IVA.52 Directional Prototypes in the "Oblique Effect".

A perceptual effect has been identified in which vertically or laterally oriented lines are visually perceived better than lines oriented diagonally (45°). This spatial anisotropy, known as the "oblique effect", has been identified in humans and other animals as higher detection thresholds, slower response, less accurate duplication, and longer training periods required to learn a selective response for oblique compared to vertical or lateral stimuli (Appelle, 1972; Attneave and Olson, 1967; Attneave and Reid, 1968; Matin and Drivas, 1979). Neural electrical recordings have demonstrated that this "neural anisotropy" occurs at some post-retinal processing stage (Maffei and Cambell, 1970). The oblique effect may occur relative to either the exocentric (gravitational) vertical, or egocentric (retinal) vertical, thus it is a cognitive phenomenon dependent on the voluntarily adopted system of reference, rather than being attributable to characteristics of the visual receptors (Attneave and Olson, 1967; Attneave and Reid, 1968).

The oblique effect is similar to effects indicative of prototypes in which prototypical items are learned first and categorised quicker than less prototypical items (see IVA.32) Thus, the oblique effect reveals a neural basis for the conception of greater prototypicality of dimensional oriented directions.

Two prominent theories for the origin of the oblique effect are based in the Nature-versus-Nurture debate (Camisa et al., 1977). The "nurture" view posits that the oblique effect arises from early visual experience of predominately vertical and lateral architectural stimuli which effect neural development. Thus, vertical and lateral lines are experienced as more prototypical of the real-world environment than oblique lines.

This is evidenced in findings of "neural plasticity", that is, neural responses are not predetermined by genetics but are molded by the stimuli experiences which an organism is exposed to during development (Hirsch and Spinelli, 1970; Pettigrew and Freeman, 1973). This is supported by Annis and Frost's (1973) findings of an absence of the oblique effect in Native-American Cree Indians who had been raised within the oblique structures of tee-pee shelters.

In contrast, the "nature" view posits that the oblique effect is a genetically determined character of visual perception. This is supported by Leventhal and Hirsch's (1975) findings of limits on neural plasticity; even with solely oblique visual stimuli during development, 71% of cats' visual cortex cells respond selectively to horizontal and vertical stimuli, but only 29% respond to obliques. Leehey and Colleagues (1975) also found that children as young as six-weeks old fixate on vertical or horizontal grids rather than oblique grids 75% of the time. This would be too young for neural plasticity to have already caused an effect.

IVA.53 Perceptual Bias Toward Vertical and Horizontal Orientations.

It is commonly found that Subjects perceive and remember orientations to be more dimensional than they actually are. This is indicative of dimensions serving as cognitive prototypes (see IVA.32f). In one type of task Subjects were presented with two converging line segments on a sheet of paper and asked to place a dot at the point where the lines would intersect if they were extended. Results were interpreted according to misperceptions of the slope of the line segments. The general trend indicated that "tilted lines tend to appear as either more horizontal or more vertical . . . than they actually are", that is "perceptual tilts [of the line] toward the nearer cardinal axis of the visual field" (Weintraub and Virsu, 1971, p. 7). These results led to the development of "the principal of assimilation toward a cardinal viewing axis", that is "A line segment appears perceptually tilted toward the more closely aligned axis either the horizontal or vertical" (Weintraub and Virsu, 1972, pp. 277, 282). Similar results were found by Bouma and Andriessen (1968) where the prototypical vertical and horizontal are considered to be "anchor orientations".

The perceptual tilt of lines toward the vertical or lateral dimensions may be an example of perceptual/memory "heuristics" (ie. a general "rule of thumb"; Collins, 1986). Tversky (1981) suggested that heuristics "may be adopted to facilitate encoding and retrieval of the spatial orientations and locations of figures" (p. 410).

Two possible heuristics are outlined. In a rotation heuristic "the natural axes induced by a figure and the axes of its frame of reference converge", thus "figures that are slightly tilted will be remembered as more vertical or horizontal than they [actually] were". In an alignment heuristic "arrays of figures will be remembered as more lined up, more orderly, than they [actually] were" (p. 410).

Tversky (1981) found that Subjects recalled directions between locations in small neighborhoods, cities, countries, continents, and make-believe maps as being aligned closer to the vertical or lateral dimensions (north/south or east/west) than they actually are. Moar (1978, p. 92) found a similar effect in that Subjects recall the long axis of Great Britain as running north/south (vertical dimension) rather than its actual alignment of (roughly) a 20° incline towards the southeast/northwest.

Rosch (1975a) presented Subjects with pairs of line segments ranging from 0° (horizontal) to 152° in an attempt to discern whether vertical, horizontal and diagonal orientations serve as reference points for other orientations. Subjects inserted the lines within blanks of a "linguistic 'hedge'" (eg. "____ is essentially ____") or within a semi-circular grid at a distance which represented the perceived similarity between the two orientations. These tests were hypothesized to reveal whether the vertical, horizontal, and 45° diagonal orientations serve as reference-points for other orientations (for details see IVA.111). Results in the sentence-completion task indicated that vertical, horizontal and diagonal orientations all served as reference points for other orientations. In the grid task only the vertical and horizontal orientations were indicated as reference points.

These results of bias toward a dimensional or diagonal orientation are entirely consistent with the choreutic prototype/deflection hypothesis. This grid task (Rosch, 1975a) was used in this thesis to probe whether reference point effects would also be found for kinesthetic spatial orientations (see IVA.110).

IVA.54 Prototypical Angles.

Angles are also perceived and remembered to be more similar to prototypical angles than they actually are. Perception and memory of angles is inseparable from the perception and memory of line orientations since an orientation is defined by its angle relative to a reference line. Thus, the perception of an angle between two lines can also be interpreted as the perception of the orientation of the lines and vice versa (Weintraub and Virsu, 1971; 1972).

Byrne (1979) asked Subjects to draw the intersections between pairs of roads in a well-known city. In 80% of the cases, angles between roads from 60° to 120° were recalled with no significant difference from 90°. In the other 20% of cases the angles were recalled significantly closer to 90° than to their actual angle. It is concluded that spatial angles are encoded according to a "heuristic that junctions and turns are based on a right angle" (p. 152). That is, the 90° angle is the prototype.

Similar effects were found by Tversky (1981) whose Subjects recalled the intersections of streets in a neighborhood as being closer to 90° than they actually are. Lynch (1960) also found a similar effect in that residents of Boston conceived of its park to be square-shaped, with each of the five corners to be 90° (even though this is an impossibility). And angles between visual line segments are judged to be closer to the 45° or 90° prototypical angles than they actually are (Beery, 1968; Maclean and Stacey, 1971).

Moar and Bower (1983) had Subjects imagine that they were standing at a location in a well-known town and facing a particular direction. They would then draw a line on a piece of paper in the perceived direction towards another location in the town. Actual angles ranging from 50° to 100° were judged to be not significantly different than 90°. They interpret this according to the 90° angle perceptual/memory heuristic. Moar (1978, pp. 203, 299) found a similar bias of angles toward 90° in judgments of directions within a well-known town centre, or directions between locations within a familiar building.

Ross and Colleagues (1970) guided blindfolded Subjects along two edges (18 feet and 20 feet long) of a large triangle (walking on land or swimming under water) and asked them to return to the starting location. The correct 57° turn was overestimated (closer to 90°) by almost all Subjects. Likewise, the Gestalt psychologist Wertheimer (1923) reports that when Subjects see very brief presentations of an angle between two lines that "the observer frequently *sees* a right angle even when objectively a more acute or more obtuse angle is being presented" (p. 79 [italics his]).

All of the tasks described above implicitly include the use of the kinesthetic perceptual-motor system (see IIC.33). In a task which explicitly involves memory for limb position, Subjects recalled the position of their arm in several orientations ranging from 50° below and 50° above the pure sagittal dimension. After a 24 hour retention interval Subjects recalled their arm orientations closer to the sagittal dimensional direction than they were originally (Clark and Burgess, 1984). Thus, memory for arm position was bias toward a dimensional prototype. Wyke (1965) also found that recalling the dimensionally forward arm position is more accurate than recalling arm positions to the right or left of forward.

Tversky (1981) relates these heuristics to the Gestalt principles of common fate and proximity according to which similar and nearby oriented lines will be perceived as lined up with each other. The basis of these perceptual/memory heuristics is that they "distort visual scenes by imposing more order or regularity than actually exists in the scene" (p. 409).

This process is described by the fundamental Gestalt principal of *pragnanz*, literally translated from German as "concise" or "terse" (Collins, 1969), which are defined as "neatly brief" and "expressing much in few words" (Collins, 1986). Koffka (1935, pp. 108-145) and Wertheimer (1923, pp. 79-83) describe *pragnanz* as groupings of stimuli which are the most "good", "regular", "simple", "stable", "logically demanded", with "inner coherence", "inner necessity", and "wholeness". Orientations tend to be perceived or remembered as dimensional, and angles tend to be perceived or remembered as 90° because (in most cases) these are the most ordered, most regular, symmetrical, "good" arrangements of stimuli (see IVB.27).

IVA.55 Balance System of a Figure.

In a landmark analysis of forms in Art, Rudolf Arnheim (1974) draws on an abundance of sources to describe characteristics of visual perception similar to those described by the Gestalt principles. Arnheim discusses how observers never see a visual stimulus in isolation but always perceive it in relationship to the whole surrounding array of stimulation (pp. 10-16). For example, certain directions and locations can be identified within an "empty" square which are the most prototypical, or most regular and "good" (in the Gestalt sense). This can be referred to as the "hidden structure of a square" (p. 10). In the simplest experiment a black disk is placed just slightly away from the centre of the square. This creates a certain perception in the observer:

> The disk . . . is not simply displaced with regard to the center of the square. There is something restless about it. It looks as though it had been at the center and wished to return, or as though it wants to move away even farther. And the disk's relations to the edges of the square are a similar play of attraction and repulsion. (Arnheim, 1974, p. 11)

Arnheim (1974, pp. 12-14) refers to the perceived locations and lines within the "empty" square as the "'induced structure'" or "perceptual inductions" which are derived spontaneously during perception and so are different from conscious interpretations or "logical inferences". An induced structure is perceived which is likened to "lines of force in a magnetic field" with each induced (prototypical) location being analogous to a magnet. Because of this a visual figure (eg. a square) can be described as "empty and not empty at the same time".

A procedure is suggested for probing the prototypical locations and orientations within the induced structure. Arnheim (1974) observes that when an object is placed within a space that there will be a perceived "pull" in which it "tends to strive" according to the balance system (p. 14) such that if an object is only briefly, or not clearly seen, that it will be perceived to be closer to one of the locations of the balance system than it actually was.

> If a disk is placed at various locations within the square, it looks solidly at rest at some points; at others it exhibits a pull in a definite direction; and in others its situation seems unclear and wavering. (Arnheim, 1974, p. 12)

Arnheim (1974) calls this a "reduction of tension" (p. 15) which is identical to the perceptual/memory effect of bias toward a prototype (see IVA.32f). From "informal explorations" Arnheim reports that a black disk appears most "stably settled" when it is at the centre of the square, and if the disk is placed near to one of the square's edges it appears to be "drawn toward" that edge. The centre appears to be the "principal locus of attraction and repulsion". Other structural elements of the square also create induced perceptions, namely; the four corners; the vertical and horizontal lines passing through the centre and bisecting opposite cubic edges; and the two diagonal lines passing through the centre and intersecting opposite cubic corners; that is, the symmetrical axes of the square. Arnheim (1974) refers to these perceived elements within a square as its "structural skeleton" (pp. 12-13) or a "balance system" (p. 15) which is essentially a map of the prototypical locations and orientations spontaneously perceived within a particular spatial form.

Likewise, Arnheim (1974, pp. 14-16) reports on unpublished experiments by Goude and Hjortzberg (1967) in which Subjects were asked to report on their introspective perceptions of whether a black disk (4cm diameter) appeared to strive in particular directions when it was placed in various locations within a square (46cm x 46cm). The disk appeared to move least when it was placed at the centre of the square. When the disk was placed near a symmetrical axis of the square (ie. an imagined vertical, lateral, or diagonal line passing through the centre of the square) then it appeared to move in a direction parallel to the nearby axis.

Similarly, Nelson and Chaiklin (1980) found that dots are recalled closer to the exterior visual border than they actually are (ie. the dots perceptually strive toward the border). Also, Huttenlocher and Colleagues (1991) briefly presented a dot within a circle and asked Subjects to report its location. The dots were recalled as being closer to a position along a diagonal line through the circle than they actually were. They conclude that "Subjects spontaneously impose horizontal and vertical boundaries that divide the circle into quadrants. They misplace dots toward a central (prototypic) location in each quadrant" (p. 352).

Arnheim (1974) uses the phrase "directed tension" to refer to the perceived stress, pull, attraction, or tension between a prototypical location or orientation and a less-typical location or orientation. When a form does not exhibit the prototype then a "tension" is created between the actual form and the prototypical form. Arnheim refers to the prototype as the "norm position" (p. 426) or the "norm image" (p. 429) and the actual form as the "deformation" or the "deviation" (p. 428). As an example Arnheim considers the orientation of the arms of windmills in Dutch landscapes. When they are painted in a vertical/lateral orientation they do not appear to turn and when painted in diagonals (45°) they appear to turn slightly. However when painted in an "asymmetrical, unbalanced" orientation, at an odd angle somewhere between the dimensions and the diagonals (cf. inclinations IVA.25) then they induce the greatest amount of perceived motion (p. 425). This unbalanced position is farthest from the symmetric prototypes (dimensions or diagonals) and thus create the greatest amount of perceived motion as a striving toward the prototypes.

IVA.60 Prototypes and Deflections in Ballet

Evidence for the prototypicality of dimensions and pure diagonals (and correspondingly of 90° and 45° angles) in conceptions of body movement are also found in the conceptual structure of ballet which is based almost entirely on dimensional directions. It is not surprising that ballet is a perfect example of the prototype/deflection hypothesis since Laban (1926, pp. 6-12) explicitly used the ballet model in his conceptual development of choreutics (see IVA.81).

IVA.61 Ballet Facing.

The directional orientation of body facings in ballet, known as the "directions of *épaulement*" or the "eight directions of the body" (Grant, 1982), is conceived according to a square with dimensional orientations directed toward the edge midpoints, and diagonal orientations directed toward the corners (Fig. IVA-16). These directions are commonly presented in ballet manuals as diagonal and dimensional lines through the centre of a square (Bazarova and Mey, 1987, p. 49; Grant, 1982, p. 125; Hammond, 1974, p. 65).

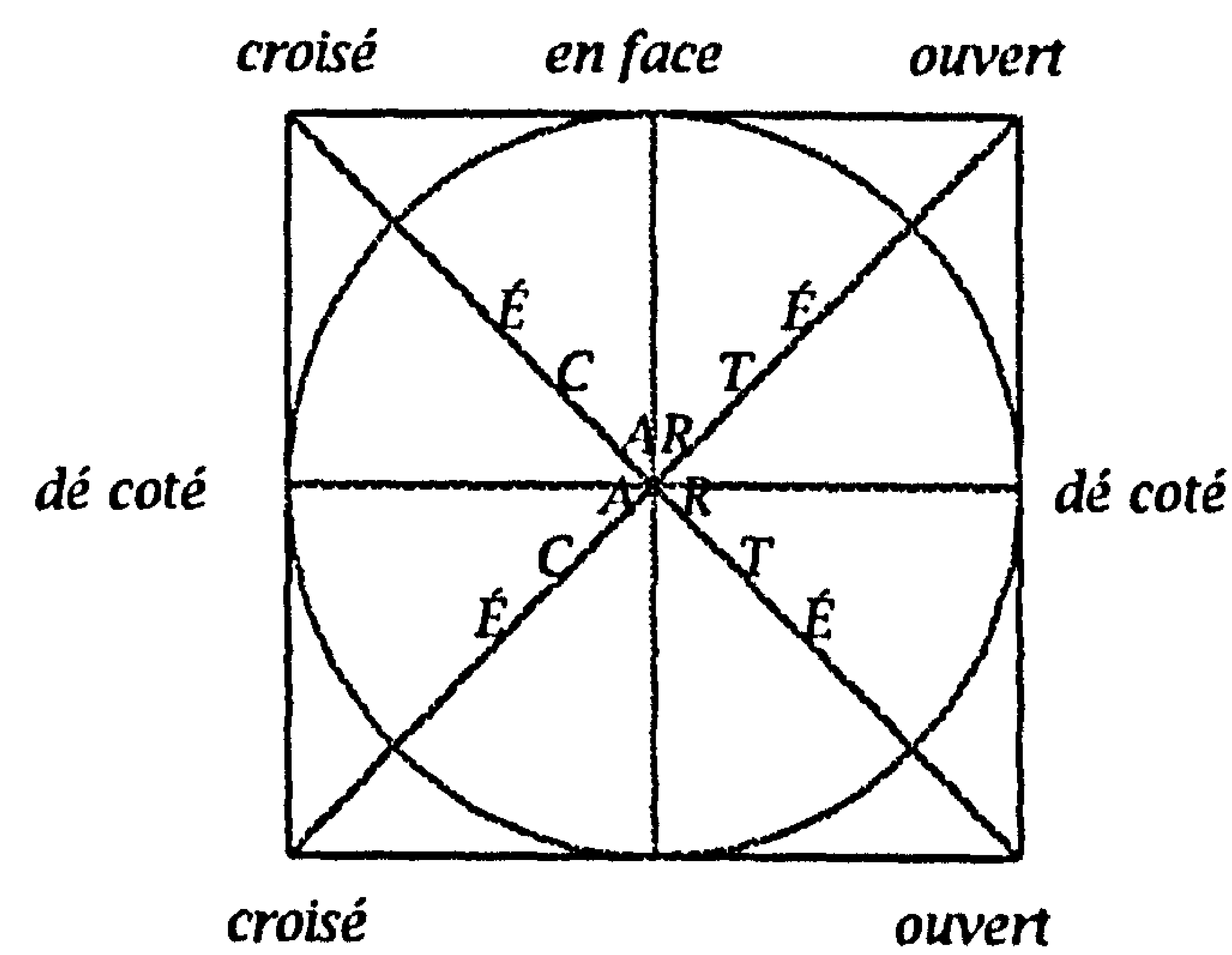


Figure IVA-16. "Personal square" for orientation of body facing (adapted from Royal Academy, 1991, p. 1)

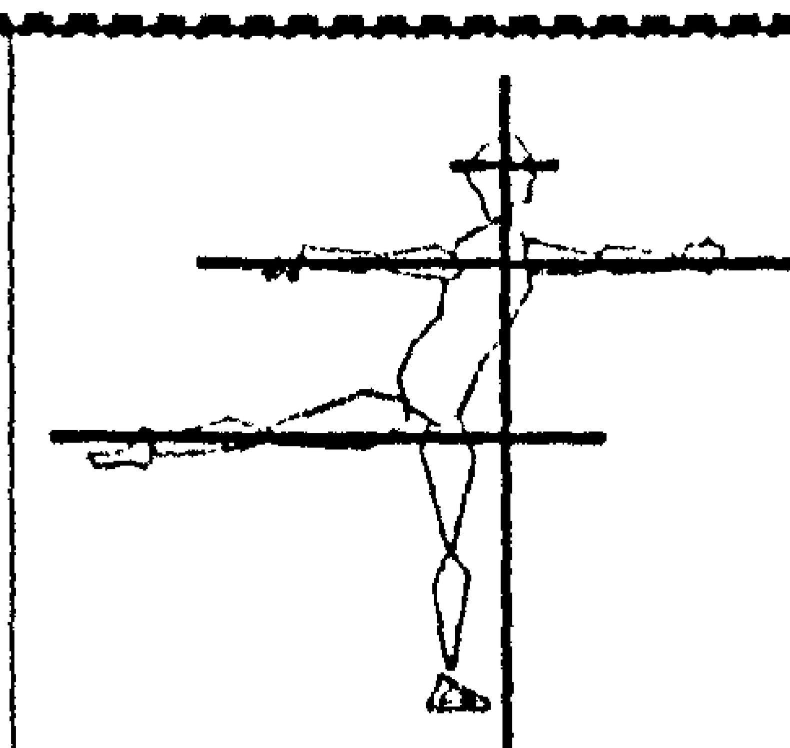
Diagonal facings (ie. 45° to the front of the stage space) are indicated with the French terms "*croisé*" (legs crossed), "*effacé*" or "*ouvert*" (legs open), "*épaulée*" (front shoulder crossing the body) and "*écarté*" (leg wide to the side). Dimensional facings are referred to with the French terms "*en face*" (facing the audience) or "*de coté*" (facing the side of the room). The orientation of the limbs relative to the body and the orientation of the body relative to the room are usually combined within the terminology for the different facings (Grant, 1982, p. 91). In some cases the egocentric/exocentric forward dimensional facing is not stated but is assumed as a (prototypical) default value, for example, "*á la quatriéme*" ("fourth position" of the feet while facing front) and "*á la seconde*" ("second position" of the feet while facing front).

IVA.62 Ballet Limb Orientation.

The orientations of limb positions and movements in ballet are also described in terms of dimensional and diagonal prototypes. A body-relative dimensional conception is evident within the Ballet positions of the feet. The vertical dimension is emphasized in the first, third and fifth positions where the two feet are pressed together. The sagittal dimension is emphasized in the fourth position where one foot is placed in front of (or behind) the other. The lateral dimension is emphasized in the second position where one foot is placed to the side of the other. Laban (1926, pp. 6-12) examined these dimensionally conceived ballet feet-positions together with the corresponding ballet arm-positions, and identified how they deflect into inclinations during their actual performance (see IVA.81).

The sagittal dimension is specified in ballet in many ways with the French "*en avant*" or "*en descendant*" (stage-forward) or "*devant*" (body-forward), "*an arriere*" or "*en reculant*" (stage-backward) or "*derriere*" (body-backward). In contrast, all room-relative diagonal directions for locomotion are referred to collectively as "*en diagonale*".

Figure IVA-17. Example of dimensional reference lines in the ballet "theory of design" (adapted [crudely] from Kirstein and Stuart 1952, p. 106).



Limb orientations relative to the body's vertical dimension are referred to as the "angle of the leg in the air", "positions of the leg in the air" or in the French "*positions soulevées*" (raised positions). These specify how high the leg is to be lifted (Grant, 1982). The initial distinction is between "*á terre*" (on the ground) in which the toe retains contact with the floor (angle with the vertical dimension is not specified), and "*en l' air*" (in the air) in which the leg is raised further and is not in contact with the floor. When the leg is raised in the air to a 45° angle with the vertical it is specified with the French "*á la demi-hauteur*" (to the half-height) and a 90° angle with the vertical is specified with "*á la hauteur*" (to the height).

The *demi-hauteur* (45°) position is conceived to be either within the frontal or the medial plane and so corresponds with choreutic diameters. This is one of the few body-relative non-dimensional directions which are specified in ballet. However, because of anatomical constraints many deflected directions occur during ballet movements (see IVA.70).

IVA.63 Ballet conceptual grids.

The prototypicality of dimensions in the ballet conception is also evident in visual illustrations where dimensional lines are superimposed over drawings of the human body to illustrate part of the "space module" and the "theory of design" for basic ballet positions in the classic text by Kirstein and Stuart (1952, pp. 2, 20, 30, 81,104, 106) (Fig. IVA-17). These dimensional line reference grids are a similar type of abstracted conceptual representation as the cubic and octahedral networks used by Laban (see IVA.20).

IVA.64 Deflected Ballet.

Ballet movements can be analysed to determine their dimensional (or other) conception and their actual deflected body performance. An explicit knowledge of these inclinational vectors implicit in ballet movements can bring increased mental and physical understanding. Conceiving of movement as dimensional/diagonal deflections can be used to develop a deflected, organic, inclinational-based, para-ballet technique. Analyses of typical deflections from several common ballet movements showed that this is a practical, informative, and potentially revolutionary undertaking for future research (see Appendix XII).

IVA.70 Anatomical Constraints

Knowledge of anatomical structure can reveal which movements and positions are producible by the body. In studies of visual recognition of moving humans, Johansson (1973, p. 201) reasons that "The geometric structures of body motion patterns in man and higher animals are determined by the construction of their skeletons"; and in an early study of "dynamic anthropometry":

> Man exhibits some of his most distinctively human characteristics in his pattern of motion. The ease with which he spans distance and executes intricate maneuvers testifies to the harmony that exists between the construction of the body and its motor mission. (Elftman, 1955, p. 553)

Therefore it would be beneficial for an implicit knowledge of "biological constraints" to be included within systems for the visual recognition of body movements (Vaina and Bennour, 1985, p. 224).

Laban (1966) states that "The structure and function of the human body limits the number of movements which the human being can perform" (p. 16) and so movement "is produced by limbs of the body and is governed by their anatomical structure which permits only certain movements to be made" (p. 84). Laban's choreutic conception poses that "The body itself, in its anatomical or crystalline structure, is built up according to the laws of dynamic crystallization" (p. 105) and so "In order to study harmony of movement we must consider the relations between the architecture of the human body and the spatial structure of the kinesphere. (p. 106).

IVA.71 Choreutic Deflections Arising From Anatomical Constraints.

The prototype/deflection hypothesis posits that inclinational directions occur in actual body movements as a result of anatomical constraints:

> Of course these six [dimensional] directions are not performed directly in the vertical-, lateral- and sagittal-dimensions, since these are not practicable for our limbs because of their attachment to the body. In movement it is always a matter of diagonals and spirals. (Laban, 1926, p. 25)

> It is the construction of the body which demands a modification of the purely cubic aspect of the directional scheme of the kinesphere, and alters slightly the emplacement of the twelve signal-points [ie. diametral loci] when the body moves. (Laban, 1966, p. 101)

> Because of the differences in flexibility of the spine in different segments and the range of the joints of the limbs, the planes are rectangular [ie. icosahedral] and the pull of one of the dimensions in each plane is dominant over the other. (Bartenieff and Lewis, 1980, p. 32)

> The structure of the body makes the performance of pure diagonal movements impossible although a skillful mover can give the impression of such movements which appear as extremes of ultimate flight and fall. . . .
>
> . . . Because the body limits the fulfillment of perfect three-dimensional shapes that pure diagonals would offer, most three-dimensional shapes are created through *modified* diagonals [ie. icosahedral inclinations]. . . These *are* available to the body. (Bartenieff and Lewis, 1980, p. 33 [italics theirs])

> . . . one-dimensional movements are always about to slip into two- or three-dimensional movements because of the three-dimensional potential of the ball and socket joints . . . The global structure of those joints causes subtle rotary adaptations to every change of direction and [in response] the torso will slightly shape itself for support. (Bartenieff and Lewis, 1980, p. 89)

IVA.72 Range of Articulation at Single Joints.

The "range" of movement is a basic anatomical constraint which specifies the space accessible for movement via articulations at single-joints or from multi-joint skeletal linkages. These have also been referred to as the "joint range" versus the "cumulative range of the end member" in ergonomic research (Dempster, 1955, pp. 568-570; see IIB.42). Laban (1966, pp. 106-107) called these the "'zones' of the limbs" in which "the body and its limbs can be moved only in certain restricted areas of the kinesphere" and their "super zones" through which "Every point of the kinesphere can be reached with any one limb". The more joints which are contributing to the range of the distal end of the skeletal linkage, the greater its range will be.

Laban (1966, p. 106) explores the articulation ranges of single joints and compares these with the hypothesized icosahedral-shape of the kinesphere. The joint-range data is identified as coming from "Anatomists" who measured "a large number of people in 'normal' living conditions" and "measurements taken from lifeless human bodies", but the actual source of this data is not cited. In ergonomic studies, Pheasant (1986, p. 145) points out that "There are surprisingly little joint range data available", and in their kinesiology textbook Rasch and Burke (1978, p. 32) add that measures of ranges of motion "are remarkable for their lack of agreement", most likely because of considerable differences between Subjects.

However, some measurements of single joint ranges are available which can be used to reevaluate Laban's conclusions. The angular measure of joint ranges can be compared to the angles between dimensions and diameters in variously-shaped kinespheric nets (for detail about sizes of angles; see Appendix X). This comparison was conducted and a consistent relationship was not found between single-joint ranges and the angles between directions as posited by the deflection hypothesis (see Appendix XI). Some single-joint ranges correspond to cuboctahedral diameters, others correspond to the hypothesised organically deflected icosahedral diameters, while others correspond to dimensions.

This does not directly contradict the prototype/deflection hypothesis since determining the structure of the kinesphere from single-joint ranges has little ecologic validity. The vast majority of body movements in real environments do not consist of single-joint articulations. Rather, organic movement consists of coordination among collections of joints and skeletal links. These are described as "coordinated structures" in which kinematic chains of body-segments function as a group rather than individually (see IIIB.60). If the kinesphere has a particular structure it should be evident in observations of organic movements involving integrated, coordinated collections of joints and body-segments rather than individual joint articulations.

There is also no reason to believe that individual joints are articulated to their full range during organic movement. Indeed, one may expect that when possible the full range of joint movement would not be used because of the ecological advantage of maintaining some margin for error (for when you really need it). Other considerations are more likely to govern the structure of the kinesphere. For example, the directions and range of motion might be governed by the need to maintain equilibrium (see IIID.50), the creation of a meaningful communicative expression, the desired quality of the movement (eg. delicacy, forcefulness), or by the exterior spatial layout of a particular task (eg. locations of shelves around a workspace will effect the directions and size of movements).

An underlying factor within all of the examples given above which may govern the structure of the kinesphere is the desirability for the movement to achieve its goal in the most efficient way possible. This is "another important principle of body mechanics: the individual tends to function in the way that affords the greatest conservation of energy" (Rasch and Burke, 1978, p. 98). Laban (1966, p. 45) refers to this as "economy of effort" according to which "It is natural for all living organisms to use the simplest and easiest paths in space". The ecological need for economy may be the greatest consideration which governs the structure of the kinesphere.

IVA.73 Oblique Joint Structure.

A brief review of anatomical joint structure reveals that the body tends to move in oblique orientations which do not lie within an egocentric Cartesian plane. Even at the most basic level the bones themselves are twisted so that adjacent joints in a skeletal linkage are slightly rotated with respect to one another (Dempster, 1955, pp. 569-570). This slight twist causes the two joints to articulate in different planes at a small oblique angle to one another.

A rod gripped in the hand and held by one's side so that the rod is approximately sagittal, will actually be held at an oblique "grip angle". This follows a direction downwards from the forearm (102° angle between the bar the central axis of the forearm) and slightly outwards (14° angle between the bar and the radial and ulnar styloid processes of the wrist) (Dempster et al., 1959, p. 290; mean of 40 men). This produces a sagittal deflection of the diagonal down-right-forward (for the right hand).

Because the head of the humerus is not a perfect sphere the articulation possibilities of the arm in the shoulder joint are not equal in all directions. The greatest elevation of the arm can be achieved in a forward and sideways-outward direction (Gray, 1977, p. 253). This is a vertical deflection (steep) of the diagonal up-right-forward (for the right arm).

At the elbow joint, the articulatory surface of the humerus (trochlea) with the ulna is oriented at an oblique angle to the lengthwise axis of the humerus. Because of this, when the elbow is extended and the forearm is supinated (palm forward) the forearm and the upper-arm do not lie in a straight line, but the lengthwise axis of the forearm is oriented at an oblique angle outward relative to the lengthwise axis of the upper-arm (≈13°). During flexion the forearm moves on an oblique path upwards and inwards towards the body's medial plane (Gray, 1977, p. 257; Nordin and Frankel, 1989, p. 251).

Similarly, during knee articulation the tibia and femur do not remain in the same plane because of the orientation of their articulating surfaces. The femur is not oriented vertically but is tilted laterally outward at the top. During knee flexion the tibia does not remain in a paramedial plane. Instead, the path of the ankle moves obliquely outwards (relative to the femur) so that at full flexion the tibia and femur are oriented in the same plane (tilted outward at the top approximately 10° from the vertical). During knee extension the tibia retraces its path. The ankle travels obliquely inwards towards the midline so that at full extension the tibia is oriented near to the vertical dimension (Gray, 1977, p. 279).

The structure of the inner and outer condyles which comprise the articulatory surfaces of the femur with the tibia at the knee joint also take the tibia movement out of a paramedial plane. The inner condyle has a greater length than the outer condyle, and its surface is inclined obliquely outwards. Because of this, just before full extension of the knee the tibia will glide upward and outward over this oblique surface causing the lower leg to rotate outwards at the knee joint. The reverse action occurs during knee flexion with the lower leg rotating inwards (Gray, 1977, p. 279).

Vertebral facets push against each other during spinal articulations and so guide the "coupled motion" of lateral spinal flexion always occurring together with spinal rotation (Nordin and Frankel, 1989, p. 216; also Rasch and Burke, 1978, p. 226). This rotation causes lateral spinal flexion to always twist slightly out of the Cartesian frontal plane.

IVA.74 Oblique Muscular Lines-of-pull.

In addition to oblique directions produced by the structure of articulatory surfaces in skeletal joints, the attachments and orientations of muscles tend to create oblique paths rather than motion within a dimensionally oriented Cartesian plane. This is referred to as a muscle's "line of pull" (Rasch and Burke, 1978, pp. 34, 117; Wells and Luttgens, 1976, pp. 37-38, 77). Even a cursory review of skeletal muscles reveals that their lines of pull are oriented at oblique angles to the body's Cartesian planes. Dimensionally oriented movements are accomplished by the simultaneous contractions of separate muscles whose oblique lines of pull neutralise each other, thus producing a dimensionally oriented trajectory midway between the two obliques.

The majority of muscles acting on the spine and head* have a combined action of lateral flexion together with rotation (Rasch and Burke, 1978, pp. 231-237). When these muscles act on only one side of the spine-head their combined actions create oblique movement paths resulting from lateral flexion and rotation which pulls the movement out of the frontal plane. This rotation always accompanies lateral flexion of the spine even though it may not be overtly visible (Ibid, p. 226). When the abdominal muscles (viz. transversus, rectus, obliques) act independently they will also laterally flex and simultaneously rotate the torso (Gray, 1977, p. 365), thus producing the bending+rotation which creates an oblique downwards and crossways path.

The pectoralis major simultaneously adducts, flexes, and inward-rotates the humerus (Gray 1977, p. 381). This follows the oblique direction down-forward-inward. When the latissimus dorsi acts upon the humerus it simultaneously adducts, extends, and inward-rotates it. Gray (1977, p. 341) points out that this oblique direction of humerus motion (down-back-inward) commonly occurs during a downward blow of the arm in fighting or in sabre practice.

The oblique orientations of the pectineus and the adductors brevis, longus and magnus causes these muscles to both adduct and outward-rotate the femur (Gray, 1977, p. 426). The outward rotation tends to pull the femur pathway out of the frontal plane during adduction. The gluteus maximus and the biceps femoris (one of the "hamstrings") each extend and also outward-rotate the femur pulling it out of the paramedial plane during hip extension. The gluteus medius and minimus each abduct and also inward-rotate the femur pulling it out of the frontal plane during abduction (Gray, 1977, pp. 431-433).

This brief review of muscular actions shows that bodily actions in obliquely oriented planes are kinesiologically simpler than bodily actions in Cartesian

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* Muscles acting on the spine and head include the multifidus; semispinalis thoracis and cervicis; iliocostalis lumborum, thoracis, and cervicis; longissimus thoracis, cervicis, and capitis; splenius cervicis and capitis; and the sternocleidomastoid.

dimensionally oriented planes. The independent action of most muscles produces body motion in oblique planes, whereas motion in Cartesian planes requires a higher degree of coordination in which two or more different muscles must cooperate and function as a higher-order system.

IVA.80 Choreutic Organic Deflections

In regards to collections of joints and skeletal links, Laban (1966) describes that when striving toward an inaccessible location, that "a number of interrelated movements" are used. That is, a collection of articulations at many joints all contribute their component movements towards allowing a body-part to reach a kinespheric locus. As part of the "law of harmony in movement" it is asserted that "between the angles of the component moves there is a precise relationship". In other words, within the multi-joint articulation the relative contribution of each individual articulation should be entirely predictable. This "law" might be more specifically referred to as the law of "determinable contributory movements" (pp. 106-107). A variety of multi-joint cumulative ranges have been considered in choreutics which produce various deflections and so create the structure of the kinespheric net.

IVA.81 Deflected Ballet Foot Positions.

Laban (1926) considers the five positions of ballet to be the "simplest spatial-orientation-method in the art of dance"* (p. 6). These dimensionally conceived positions are observed to deflect into inclinations during actual embodiment.

Laban reasons that the five positions actually consist of eight foot positions (since the third, fourth, and fifth positions can occur with either the right-foot forward or the right-foot backward), which are themselves reducible to six foot positions. However this reasoning appears faulty,# apparently in an effort to support a numerical

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* "*Raumorientierungsmittel*", translated as "spatial-orientation-method".

\# Laban (1926) explains that "when one stands on both legs" that the third and fifth position right-foot forward is the same as the third and fifth position left-foot backward and therefore "two directions drop out on each side" yielding six positions (p. 13). Laban's reasoning is incomplete here since he does not mention that fourth position right-foot forward is also identical to 4th position left-foot backward and so (using his logic) three directions "drop out on each side" leaving the original five positions.

A total of eight different foot positions can be derived from the five positions, these include forward/ backward variations of the third, fourth, and fifth positions. Or, alternatively, these could be considered to be five positions on each side, for example on the right-side the right-foot is always placed forward.

process leading to the twenty-four inclinational directions:

> The six positions on low level can be projected upwards as contrary-positions, so that one gets a total of twelve spatial-situations, which can be traveled to or fro making twenty-four [inclinational] directions in all. (Laban, 1926, p. 13)

Another line of reasoning which identifies the inclinations as deflections from the five ballet foot positions may be more consistent. Laban (1926) identifies the main directional component within each of the five foot-positions. The almost pure verticality of the first and fifth positions leads "steeply downwards", whereas the third position is very steep but also contains a diagonal component. The fourth and second positions are "leading more horizontally"; the fourth position leads towards the sagittal dimension and the second position leads toward the lateral dimension (p. 6). Laban then lists the twenty-four inclinational directions and states that they "correspond to the four forms of the second, third, and fourth position" (whereas the "first and fifth positions are purely in one dimension" and so are not included) (pp. 13-14, 19). Thus, the eight flat, eight steep, and eight suspended inclinational directions are conceived to be deflections from the second, third, and fourth positions in ballet:

Flat (lateral)	inclinations deflected from ballet	second	position
Steep (vertical)	" " " "	third	"
Suspended (sagittal)	" " " "	fourth	"

The process by which the second, third, and fourth positions are deflected into flat, steep, and suspended inclinations appears to be based on the body in dynamic motion rather than in a static position. Laban (1926) does not consider the five positions to be static positions of legs and/or arms. Rather, he presents a much more dynamic conception in which the five positions are "spatial-directions, which are strived* towards by the legs, and to which the upper-body makes the natural+ countermovement" (p. 6). That is, "The arm-posture or [arm-] movement should guarantee the equilibrium with the foot-movement by [a] corresponding countermovement" (p. 7). Thus, a "contrary-position" for the arms# is identified which

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* "*strebungen*", from "*streben*"; translated as "to strive".

\+ "*selbstverständliche*" literally "self-understandable"; translated here as "natural".

\# Laban's arm positions are approximate counter-directions to the foot positions. These are not the arm positions used in modern ballet, and different styles of ballet use different arm positions in conjunction with the five foot positions (Grant, 1982, pp. 130-133).

corresponds with each of the positions of the feet (p. 10). The arm positions are arranged so as to provide equilibrium with the foot positions according to the "law of countermovement" (pp. 17-18; see IIID.50).

In the fourth position the right-foot can be forward and slightly to the side of the left-foot (Laban uses the "open fourth position" as described by Grant, 1982, p. 82). Following the direction from the right-foot, up towards the body, and into a counterdirection of the left-arm, produces the diagonal up-left-backward. Moving from the left-hand toward the right-foot produces the opposite diagonal down-right-forward. The same process between the left-foot (backwards and to the side) and the counter-direction in the right-hand produces the diagonal up-right-forward/down-left-backward. The other two diagonals are produced by executing the position on the other side (left-foot forward, right-foot backward). In the fourth position the distance between the feet is largest along the sagittal dimension, therefore the diagonals will be deflected sagittally (suspended inclinations).

Diagonals occur in the third position in the same way as in the fourth position. However in third position the feet are very close together and so the counter-directions of the arms will tend to be deflected vertically (steep inclinations)

In the case of second position the counterdirections of the arms might appear to extend purely into the lateral dimension rather than along a deflected diagonal. The deflection of the second position into diagonals can be imagined when movements are considered rather than static poses. Laban (1926) describes that when a direction is performed with movement (rather than a static pose) then "we must yield[Y] around the body and thus give this direction a deflected situation" (p. 19). For example, in the second position the right-arm might start at its position toward the right side (lateral dimension) and move toward the left-foot position. In this case it must deviate either in front of, or behind the body on its way toward the left-foot. If the right-arm deviates in front of the body then during the movement a lateral deflection (flat inclination) of the diagonal down-left-forward will be produced. If the right-arm deviates behind the body then a lateral deflection of the diagonal down-left-backward will be produced. A similar process will produce vertical (steep) and sagittal (suspended) deflections in the third and fourth positions.

Y "*ausweichen*"; translated as "to yield"; also similar to make-way, dodge, evade, or deviate.

This outline reveals that the second, third, and fourth positions in ballet can be observed to deflect into flat, steep, and suspended inclinations respectively. This supports the hypothesis that the structure of the kinesphere consists of deflected directions rather than pure dimensions or diagonals.

IVA.82 Deflected Dimensions into Diameters .

Another typical description in choreutics is when each of the three pure dimensions are observed to deflect into the two nearby icosahedral diameters. Similar descriptions of this deflection process are given in several places (Laban, 1926, pp. 22-23; Ullmann, 1955, pp. 29-31; 1966, pp. 139-141; 1971, pp. 18-21):

> . . . The structure of our body, however, causes our movements to emphasize areas which are somewhat deflected from these fundamental [dimensional] points. It appears that two variations of each of them occur. (Ullmann, 1971, p. 18)

In the vertical dimension "grow upward until you have reached complete erectness extending your arms high". In this position because of the width of the shoulder girdle and the pelvic girdle, the two hands (and the two feet) will be to the right and left of each other. The vertical dimension has expanded into a rectangular-shaped frontal plane in which "There is a long extension between your hands and your feet, and a short one between hand and hand, and foot and foot" (Ullmann, 1971, p. 18; similar description in Ullmann, 1955, p. 29; 1966, pp. 139-140).

In the lateral dimension if the right arm attempts to reach toward the pure left dimensional direction it must go either in front or behind the torso. Or if the right leg attempts to step to the left it must go either in front of, or behind the left leg. The resultant movement does not accomplish the pure lateral dimension but expands into the horizontal plane (Ullmann, 1955, pp. 29-30; 1966, p. 141; 1971, p. 19).

In the sagittal dimension an arm and a leg can both reach toward the pure forward or pure backward dimension. However, since the shoulder girdle is anatomically superior to the pelvic girdle the resultant arm location will be higher than the leg location. Thus, the sagittal movement of the arm and leg expands into the medial plane resulting in the up-forward and up-backward directions for the arm and the down-forward and down-backward directions for the leg (Ullmann, 1955, p. 30; 1966, p. 140; 1971, pp. 19-20).

Another example in the sagittal dimension is during the attempt to "lift one arm forward and reach into that direction as far as we can". The "natural consequence" is that the torso flexes forward together with the arm, and the leg provides a counter-balance by reaching backwards. The conclusion is that "in order to make full use" of the sagittal dimension the body "enlists the help of an additional dimension" (the vertical) and so expands into the medial plane (Ullmann, 1966, p. 140).

The overall conclusion is that "the dimensions are not felt by the body as lines but as planes" (Ullmann, 1966, p. 141). Even casual observation reveals that these type of "dimensional planes" often occur, but the same anatomical constraints used to describe the dimensional planes can also be used to suggest different deflections. For example, if both arms reach forward in the sagittal dimension because of the width of the shoulder girdle the hands will reach into two directions slightly to the right and left of each other. In this example (as opposed to the example above) the sagittal dimension expands laterally and so creates a horizontal plane.

Ullmann (1966, p. 140) also points out that when one arm reaches into the sagittal forward dimension that the torso will tend to twist, thus enlisting the use of the horizontal plane. She discounts this, claiming that it "is not as decisive" as the enlisting of the medial plane while reaching forward. However, this horizontal twisting combined with reaching forward is surely part of the organic adaptations which allow the body to "make full use of the dimension" (ibid). For example, in the case of a "first arabesque" in ballet this horizontal twisting usually occurs spontaneously and has to be suppressed in the attempt to achieve a pure sagittal line of an arabesque. Thus, the sagittal dimension can be observed to also expand into the horizontal plane.

When reaching far into the right lateral dimension with the right arm, in order to gain full use of the dimension the torso will laterally flex and the opposite leg will counterbalance to the opposite side. In this example movement into the lateral dimension also includes vertical movements and so the lateral dimension can be conceived to expand into a frontal plane (rather than the horizontal plane as identified by Ullmann).

To experience the vertical dimension Ullmann (1971, p. 18) suggests a movement in which you "Crouch down very low on the floor" and "grow upward until you have reached complete erectness". To accomplish this motion the torso will usually curl slightly during the downwards motion and then extend during the upwards motion. This torso flexion/extension adds a small amount of sagittal movement and thus deflects the vertical dimension into the medial plane (rather than into the frontal plane as discussed by Ullmann).

In summary, the prominent choreutic conception is that anatomic constraints cause movement toward each dimension to deflect into one of the planes:

Vertical dimension expands into the					frontal plane
Lateral	"	"	"	"	horizontal plane
Sagittal	"	"	"	"	medial plane.

However, the examples presented here show that these same anatomic constraints can also cause each of the dimensions to deflect into a different plane:

Vertical dimension expands into the					medial plane
Lateral	"	"	"	"	frontal plane
Sagittal	"	"	"	"	horizontal plane.

Whereas the choreutic "dimensional planes" are identified as being within an icosahedral-shaped kinespheric structure (see IVA.25), these alternative deflections may create planes which can be constructed in a dodecahedral-shaped kinesphere. The use of the dodecahedron has been explored in choreutics (Bodmer, 1974; 1979, p. 17; 1983, p.14; Laban, 1984, pp. 19, 35, 38-39, 62, 67) although it has not received much attention. Integrating the variations of orientation within differently shaped polyhedral nets (eg. the icosahedron and its dual the dodecahedron) is a matter for future research.

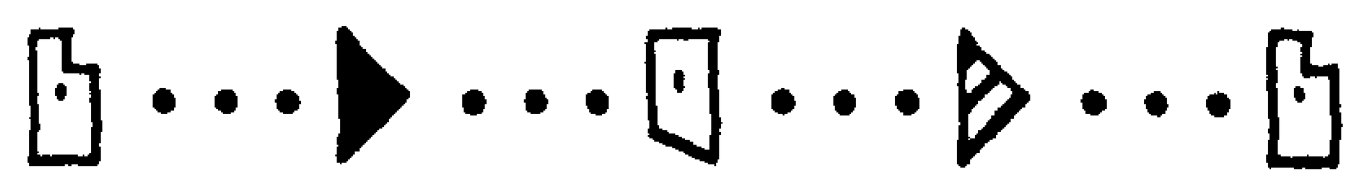
<u>IVA.83 Deflected Arm Circles</u>.

Arm circles conceived in Cartesian planes can be commonly observed to deflect into inclinations. During a beginning Labanotation class, the teacher Jean Jarrell (1992) made a statement typifying the process of dimensional prototypes deflecting into inclinations. Students were reading arm circles from sequences of direction symbols. Jarrell commented that people can read an arm circle notated in dimensional directions (for example):

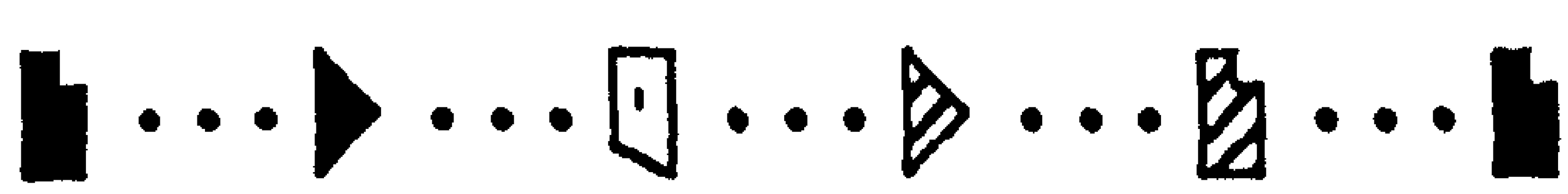
much more readily, faster, and easier than an arm circle can be read which includes notations of diameters (eg. for the right-arm):

even though this latter notation is more likely to actually occur in movement. A performance of the arm circle will reveal how the average shoulder-joint does not have the range to allow the arm to move fully into the dimensional backward orientation. Even when twisting the spine the pure backwards dimension is difficult to attain. Thus, when performing this arm-circle the right arm tends to deflect towards the diametral right-backward direction.

Further deviations may also occur.* Limits in shoulder joint flexibility require that in order to attain the most successful orientation of the arm into the backwards dimension the shoulder must rotate during the transition into, and out of, the dimensional direction. This shoulder rotation has an effect of bulging the arm's path slightly sideways. Thus, the following deviation of the arm circle may occur:



Further deviations may occur if the forward dimension bulges into the front edge of the medial plane. This resultant deflection consists of a cycle of five edges through an icosahedral-shaped kinesphere, and so can be referred to as a "peripheral 5-ring":



This example is illustrative of how a path conceived as a dimensional cycling around the medial plane (octahedral) can be deflected into a tilted cycle of inclinational directions and deformed into a 5-part rather than a 4-part cycle.

Other deflections of planar cycles have also been outlined. Ullmann (1971, pp. 22-26; also 1955, pp. 31-34) reviews the "transformation of one-dimensional directions into three-dimensional inclinations". According to these examples the dimensionally oriented movement of cycling around any one of the Cartesian planes is deflected so that the planar cycle tilts into an inclinational orientation. For example, the vertical and lateral dimensional lines of motion within a frontal planar cycle:

might be deflected into steep and flat inclinations:

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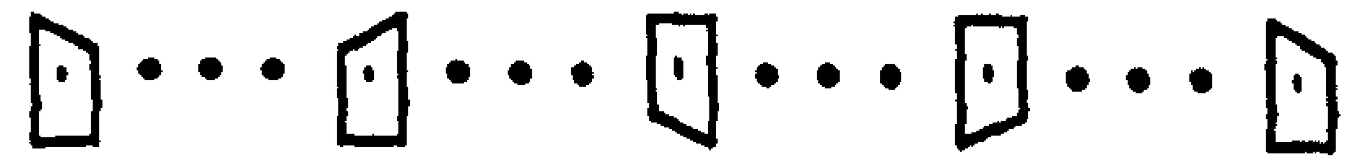
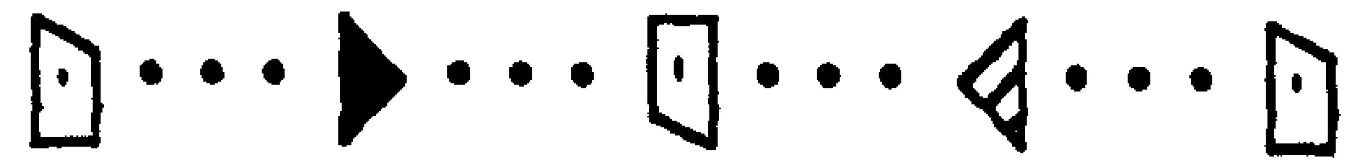
* In discussions of movement it should always be noted that the particular performance must be observed since different Subjects have difference joint ranges and a single Subject may execute the movement differently from time to time. This can be thought of as the continual oscillation of the kinesthetic-motor net as a single topological form is embodied slightly differently on each occasion (see IVB.34).

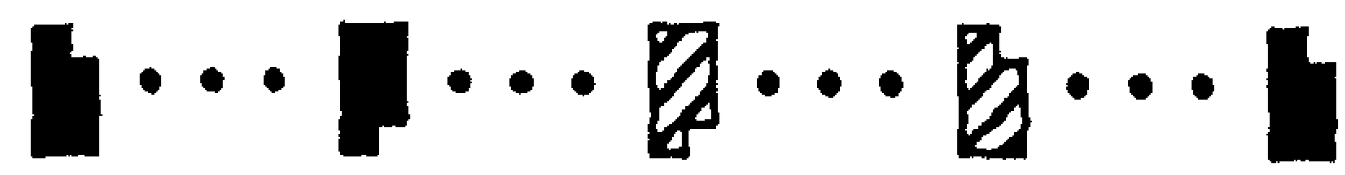
The lateral and sagittal motions within a horizontal planar cycle:



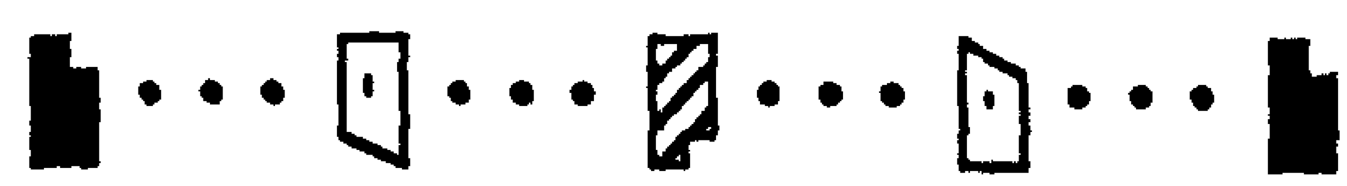
might be deflected into flat and suspended inclinations:



The sagittal and vertical movements in a medial planar cycle:



might be deflected into suspended and steep inclinations:

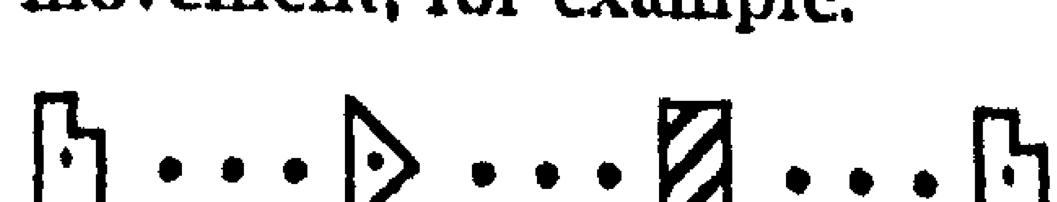


Ullmann (1971, pp. 22-23) describes that these deflections might occur "to break the monotony" or with the goal of "liberating the movement" from the restriction of a pure Cartesian plane. This suggests a more expressive source of the deflections. Movement purely within a Cartesian plane may have a flat, rigid, or contained expression, whereas when movement is deflected this monotony is broken and the expression is liberated. Anatomical constraints can also be identified which operate in conjunction with the expressive aspect. If the movements are performed with the arm and torso the rotary articulations in the shoulder tend to bulge the pathway out of pure Cartesian planes. The expression of restriction or containment which may be associated with a purely planar movement might arise from the kinesiological restriction or containment which must be imposed to keep body movement close to a pure plane.

IVA.84 Overshooting Dimensional Locations.

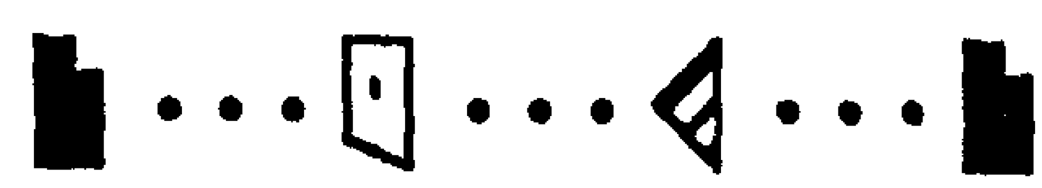
During previous research (Longstaff, 1989), a behavior was observed but was not reported in which dimensional directions were "overshot". This resulted in a deflection of the lines of motion into inclinations.

Several dancers were each assigned an "octahedral 3-ring" (Preston-Dunlop, 1984, p. 27; also listed by Ullmann, 1971, pp. 13-14) with which they were instructed to freely improvise with bodily movement, for example:

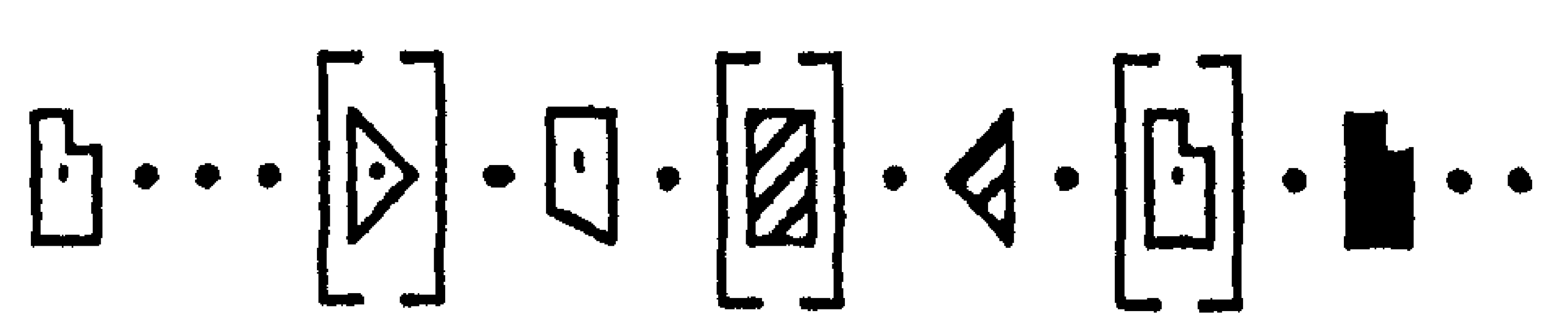


Even though they were repeatedly instructed to do so, during their improvisations it was observed that the dancers would not remain within the dimensional orientations of their limbs at each position (signified by each direction symbol) and the lines of motion between positions did not remain within the appropriate Cartesian plane. The dancers succeeded in remaining within the dimensional positions and planar motions only by continuously and consciously restricting their movement so that they would arrive, almost to a full stop, at each of the dimensional directions. However, this was an obviously severe limitation of what was spontaneously attempting to occur.*

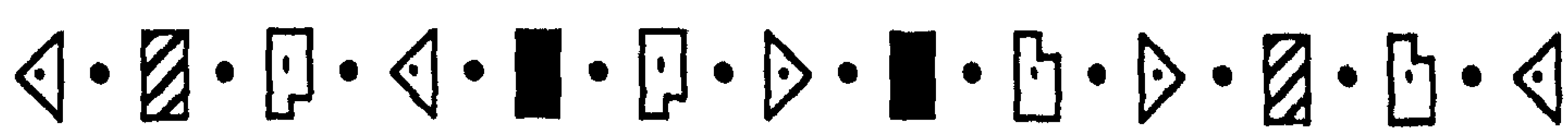
Upon closer observation it was determined that the dancers were tending to perform "icosahedral transverse 3-rings" (Preston-Dunlop, 1984, p. 37). The octahedral 3-ring given above tended to deflect into the following icosahedral 3-ring (for the right-arm):



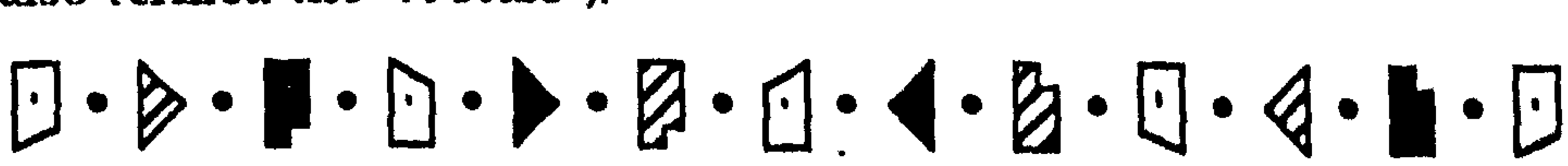
It appeared that this deflection occurred as a result of physical momentum carrying the body movement beyond the dimensional orientations. This overshooting can be specified by notating the dimensional end-points in brackets:



Upon further investigation it was found that other (icosahedral) inclinational sequences can be derived by overshooting (octahedral) dimensional sequences. For example, an "octahedral 12-ring" (Laban, 1966, p. 116; Preston-Dunlop, 1984, p. 29):



can be performed with overshooting, thus deflecting into the "icosahedral transverse 12-ring" (also termed the "A-scale"):

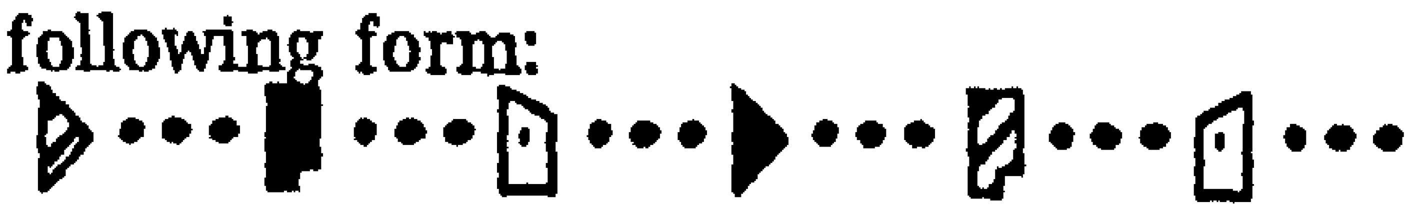


Although Laban never published a discussion of this over-shooting deflection it is implicit within the choreutic sequences presented for bodily practice. Spatial forms can be identified within octahedral, cubic, and icosahedral networks which transform into one another through types of over-shooting. This can be conceived of as the continual oscillation of the kinesthetic-motor net as a single topological form is embodied slightly differently on each occasion (see IVB.34).

* It may be pertinent to note that the dancers used (Longstaff, 1989) had a tendency towards highly dynamic freely flowing movement and so limiting the movement to the pure Cartesian planes seemed all the more restrictive.

IVA.85 Dimensional Scale Deflects into Inclinational A-Scale.

Laban (1966, p. 39) based several of his movement scales on the parrying movements of fencing which he referred to as the "defense sequence" and conceptualises it as pure dimensional directions. These can be observed to deflect into inclinations (for more details see IVB.33b):

> The defense-scale takes on a slightly altered expression when the fundamental [dimensional] directions are replaced by primary deflected ones. For example:
>
> 
>
> often shows the following form:
>
> 
>
> which is a deflected variation of the natural defense-scale.
> (Laban, 1966, p. 42)

This "deflected variation" is the first half of a choreutic icosahedral transverse 12-ring (the "A-scale"). This similarity between the defense scale and the first half of the transverse 12-ring is pointed out in other places (Laban, 1966, p. 80) and it is stated that "these six directions [of the dimensional scale] are not performed directly in the vertical-, lateral-, and sagittal-dimensions, since these are not practicable for our limbs because of their attachment to the body", rather, movement towards each of the dimensions "leads to" a corresponding inclinational direction of the transverse 12-ring (Laban, 1926, p. 25). This deflection is also included in choreutic education where students are taught to "deflect the dimensional scale into the A-scale" (Preston-Dunlop, 1989) and was part of Laban's dance training in England during 1948-1949 (Preston-Dunlop, 1996).

IVA.86 Infinite Deflections.

Laban (1966, p. 17) describes that "there is no end to this process" of deflecting the six dimensional and eight diagonal directions since "the number of possible inclinations is infinite". The prototype/deflection hypothesis can be conceived in relation to these infinite possible deflections. Pure dimensional and pure diagonal orientations each specify a single particular orientation (relative to a reference system, typically the vertical line of gravity and the facing of the torso). In between these pure dimensions and pure diagonals are an infinite number of other possible orientations referred to as deflections or inclinations. The plastic structure of anatomy reveals that it is unlikely that body movements will align with pure dimensions or diagonals. Even the slightest deflection will result in an inclinational orientation. The infinite variety of inclinations are then categorised into groups which are referred to according to the closest diagonal and the closest dimension (flat, steep, suspended). This choreutic system provides a cognitive structure and terminology to mentally conceive and distinguish between these many types of inclinational directions which occur during actual movement.

IVA.90 Ergonomic Shape of the Workspace

The choreutic conception of deflected directions and the resultant kinespheric structure is very similar to measurements of body movements with the intention of designing efficient work spaces in ergonomic research. The most typical work space (see IIB.42) is the "normal working area" in the horizontal plane which is defined by the pathway of the hand as it sweeps across a table. Traditionally it was thought that the shape of the normal working area in the horizontal plane was semicircular, with the shoulder joint at the centre of the curve (Barnes, 1963, pp. 259-261; International, 1978, p.156). This assessment of a circular edge of the hand's cumulative movement range appears to be the result of a simple prototypical sphere-like conception of the kinesphere (see IVA.21).

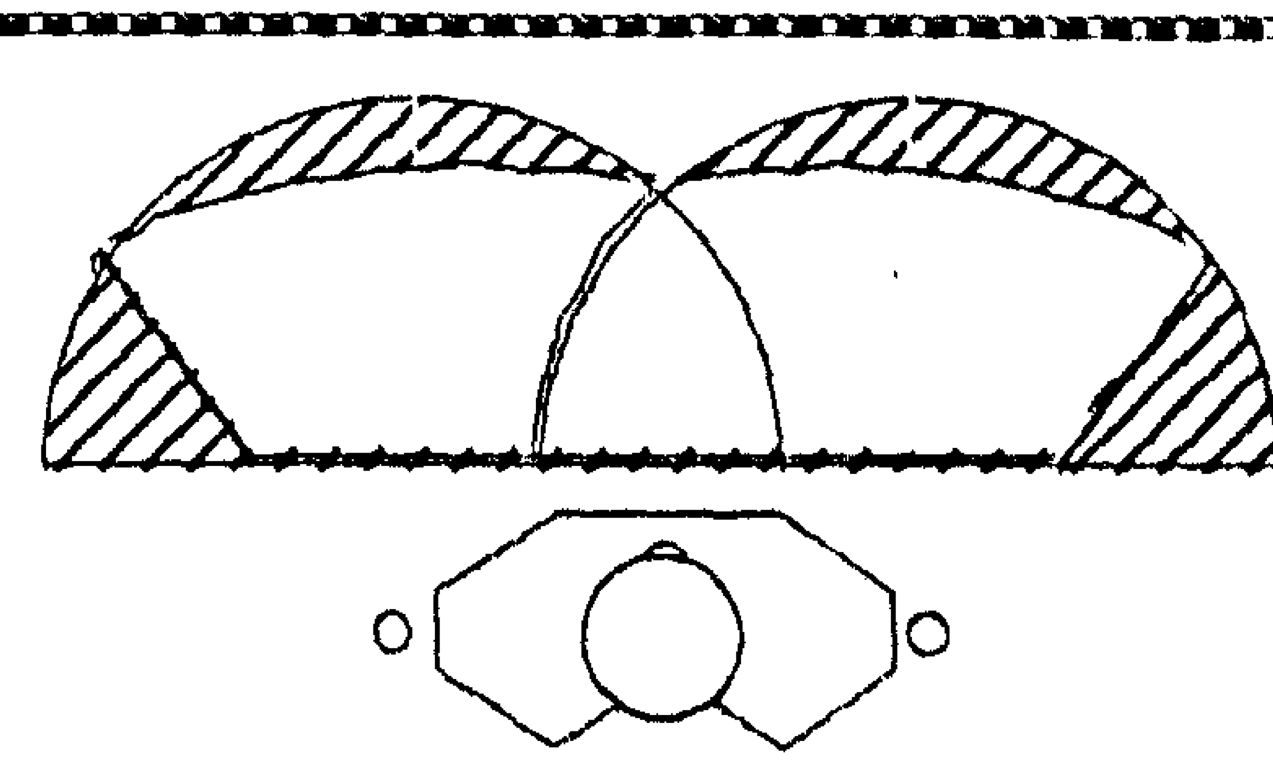


Figure IVA-18. The shape of the normal working area in the horizontal plane as semicircles or as prolate epicycloids (adapted from Squires, 1956, p. 2).

In contrast, Squires (1956) stated that "To portray the normal horizontal work area as a region consisting of two overlapping semicircular fields is misleading" and that "this portrayal has appeared persistently in the leading texts without exciting adverse critical comment" (p. 1). The articulations which occur when the hand traces a horizontal planar arc over a table-like surface were closely observed: Beginning by sitting with the forearm horizontal and the upper arm relatively vertical by the side of the torso, it was found that the elbow does not remain fixed, like a pivot-point for the arc of the hand. Rather, while the shoulder rotates outward (creating the arc of the hand) the shoulder also slightly circumducts (combined extension and abduction) creating a small arc of the elbow through space. These actions of shoulder rotation and shoulder circumduction occur simultaneously throughout the movement. Therefore, Squires (1956) found that the pathway of the hand which is "in harmony with naturalness, ease, and efficiency of human operation" is actually wider and flatter than a semicircle, in a curved shape identified to as a "prolate epicycloid" (Fig. IVA-18). Because of the limits of shoulder-joint rotation an angular peak occurred at the right-forward and left-forward directions. Similar results were found in Goel's (1968) reassessment. The shapes of these curved hand paths correspond closely to the choreutic conception of a laterally deflected (rectangular-shaped) horizontal plane (see IVA.82).

Dempster and Colleagues (1959) measured the range of the hand's pathway through a series of cycles in several parallel frontal planes which were combined into a single solid three-dimensional shape which they termed the "kinetosphere" (p. 291) (similar to a choreutic "kinesphere", but that the hand maintains a single orientation throughout; see IIB.38). This solid shape was then sliced through its centre (kinetosphere centre, not body centre) in order to illustrate the shapes of the frontal, horizontal, and paramedial planes (pp. 303-310).

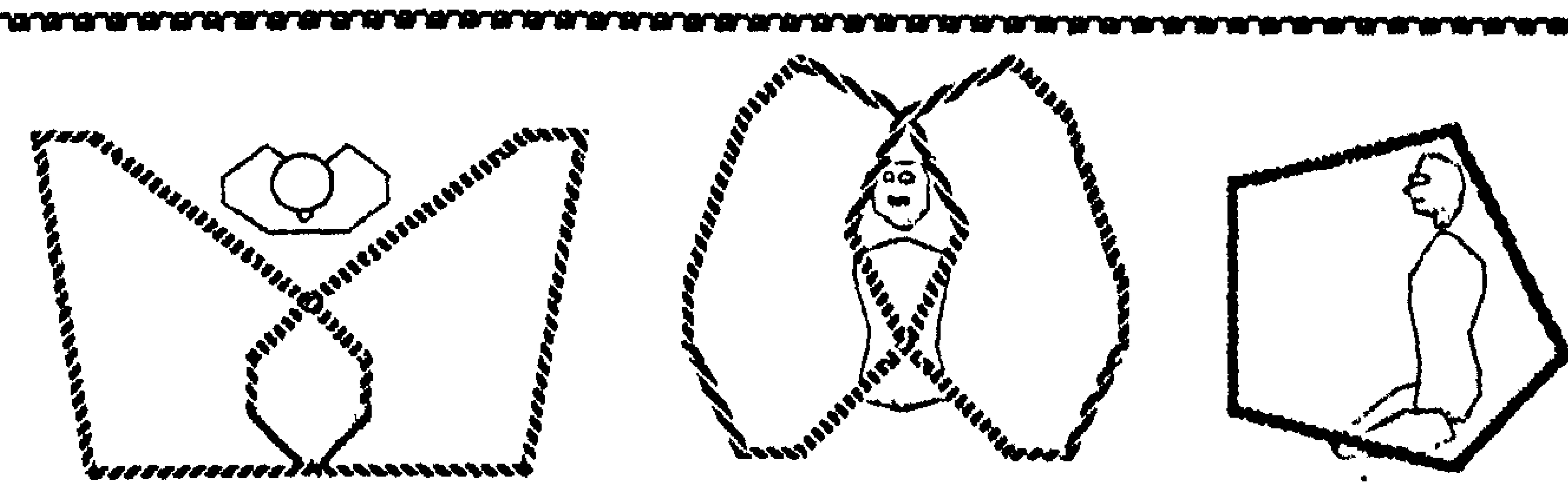


Figure IVA-19. Horizontal, frontal, and paramedial cross-sections through a kinetosphere (adapted from Dempster et al., 1959, p. 304).

Many similarities are evident between Dempster and Colleagues' (1959) kinetospheric planes and the shape of the choreutic deflected kinespheric planes (see Fig. IVA-19). While the edges of the planes are generally curved, corners can be identified by the presence of obvious curvature peaks. When the kinetospheres of both arms are combined then four peaks are evident within a horizontal cross section which roughly corresponds with the four corners of the choreutic (laterally deflected) rectangular-shaped horizontal plane (with "wings" stretching to the right-backward and left-backward directions). The frontal planar cross sections are in the shape of "narrow vertical ellipses" (p. 298) with their peaks above and below the shoulder joint (and slightly wider), thus creating a vertically oriented rectangular plane similar in shape to the choreutic (vertically deflected) frontal plane. The paramedial planar sections contained peaks which correspond to the up-forward and down-forward corners of the choreutic (sagittally deflected) medial plane.

Other attributes of Dempster and Colleagues' (1959) kinetospheres are also similar to the hypothesized shape of the choreutic kinesphere. For example, the "maximum contour" (p. 306) which passes through the up-forward and down-forward peaks of the paramedial plane and also through the right-backward (or left-backward) peak (ie. the "wing") of the horizontal plane has a remarkable similarity to choreutic pentagon-shaped "5-rings" which are in this same orientation (Preston-Dunlop, 1984, pp. 81; see IVA.83).

Many differences are also evident between Dempster and Colleagues' (1959) kinetospheres and the hypothesized deflected shape of the choreutic kinesphere. The kinetospheres rarely extended very far behind the mid-frontal plane of the body nor did they extend far below the waist. This occurred for the kinetospheres because of the constraints imposed on the body movement for the sake of obtaining precise measurements. The torso was held immobile which limited the range of motion downwards and backwards. An apparatus was also held in the hand which required the orientation of the hand to be fixed throughout the movement (eg. the palm always facing forward). With this constraint on hand orientation the limits of wrist articulation severely restrict the extent to which the hand can reach behind the body.

IVA.100 Conclusions: Prototype / Deflection Hypothesis

A prototype/deflection hypothesis was identified in choreutics which posits that kinespheric dimensional and diagonal orientations serve as idealised conceptual prototypes of pure stability and pure mobility, while actual bodily movements occur as deflections ("inclinations") between nearby dimensional and diagonal directions.

Similar spatial prototypes are evident in the English language where dimensions are given the greatest conceptual specificity, diagonals (45°) are given less, and off-diagonal inclines are given the least specificity. Prototype effects are also demonstrated in spatial cognition research where (for example) dimensional orientations are perceived and responded to more readily than diagonal orientations ("oblique effect") and lines or angles are perceived/remembered to be more dimensional, or to be closer to 90°, than they actually are.

Anatomical constraints are identified as a principal source of deflections.

Measurements of ranges of motion at single-joints did not support the deflection hypothesis but these are not ecologically valid measures of whole-body kinespheric structure. Kinesiological analyses of joint structures and muscular lines-of-pull both supported the hypothesis that body movements tend to move out of pure dimensionally-oriented Cartesian planes and into obliquely tilting paths. Therefore, oblique directions must be considered to be kinesiologically simpler than dimensional and Cartesian planar paths.

Deflections are described in choreutics as arising from many sources including; rotary joint articulations which take the motion out of a pure Cartesian plane; effects arising from the physical forces generated during a movement (eg. momentum): and also from the desire by the mover to produce a particular expression or communication. The physical forces and expressive qualities of moving within Cartesian planes are flat, rigid, and contained, compared with the physics and expression of movement along inclined planes. Laban (1951, p. 11) made a similar observation that the inclinations are "most obvious in the expressions of emotional excitement" when the dynamism of inclinational slopes would be overtly exhibited.

The hypothesised deflected inclinations create an icosahedral-shaped kinespheric structure with rectangular-shaped Cartesian planes. This is remarkably similar to ergonomic measurements of the shape of the workspace or "kinetosphere".

The choreutic conception can be considered to be a counter-part to the ballet conception. Ballet is based on a conception of dimensions which are implicitly deflected towards nearby diagonals during actual body movement. In contrast to this, choreutics is based on a conception of diagonals which are explicitly deflected towards nearby dimensions during actual body movement. Laban (1926, p. 64) summarises that ballet is "oriented in dimensional stability" while the "new dance" is "oriented in diagonal lability" and so Laban used the choreutic diagonal scale as the principal exercise in his dance technique classes (Bodmer and Huxley, 1982, p. 18). A few examples of ballet movements deflecting into inclinations are given here. The further development of a choreutic diagonally-based para-ballet movement technique is possible with an understanding of organic deflections into inclinational directions. This is a direction for future research.

IVA.110 Experiment: Probing for Kinespheric Reference Points

An experiment was designed as a test of the prototype/deflection hypothesis which posits that dimensional and diagonal directions serve as conceptual prototypes while actual body movements occur as deflected directions ("inclinations"). This suggests that deflected directions may be represented in memory according to their relationship to the more easily imaged reference points of the dimensional and diagonal directions. Psychological research has found evidence for the use of cognitive reference points in tasks involving colours, line orientations, numbers (Rosch, 1975a), and geographical locations within a city or a university campus (Sadalla et al., 1980). The purpose of this experiment was to address the question of whether cognitive reference points are also used in the mental representation of the kinesphere.

IVA.111 Reference Points.

Wertheimer (1923, p. 79) suggested that certain stimuli which display a high degree of the Gestalt "*pragnanz*" (see IVB.27) serve as ideal types, and that other less ideal stimuli are perceived and remembered according to their relationship to the ideal types. Rosch (1975a) referred to this notion of ideal stimuli as "cognitive reference points" which are stimuli within a category that other stimuli within the same category are seen "'in relation to'" (p. 532), and speculated that prototypical members of categories might serve as reference points for other less prototypical members of the category. Rosch designed two experimental tasks in order to test whether stimuli in a category are conceived "in relation to" a prototypical reference stimulus.

The first task involved "linguistic hedges" which are used in language to express metaphorical distance between concepts. Hedges were arranged into sentence frames each containing two blank spaces (for example):

"___ is essentially ___";	"___is basically ___";
"___ is roughly ___";	"___ is almost ___";
"___ is sort of ___";	"Loosely speaking ___ is ___".

Subjects were presented with pairs of stimuli in the same category (ie. colours, numbers, line orientations) and their task was to place the two stimuli into the two blanks in the order that the sentence seemed to be most true or make the most sense. The hypothesis was that prototypes (reference stimuli) should be more often placed in the second blank and deviations (non-reference stimuli) should be more often placed in the first blank. For example, the sentence "996 is essentially 1000" seems to make more sense than "1000 is essentially 996", thus indicating that the number 1000 serves as a cognitive reference point for the number 996.

In the second experiment Rosch (1975a) used a semi-circular grid in which one stimulus was fixed at the origin of the grid and the Subject's task was to physically place the other stimulus at a location within the grid which best represents the perceived similarity or difference (ie. "psychological distance") between the two stimuli. The hypothesis was that non-prototypes are conceived to be closer to a prototype than vice versa. Therefore, when a prototype is fixed at the origin of the grid the non-prototype should be placed closer to it than vice versa.

The results for both experiments supported the hypothesis that prototypical colours (determined in previous research by Berlin and Kay, 1969 and Rosch-Heider, 1972); vertical and horizontal oriented lines (and planar-diagonals in the verbal hedges task); and numbers of multiples of 10; served as reference points for other less prototypical members of their respective categories.

Sadalla and Colleagues (1980) used these same experimental tasks to probe whether reference points are also used in memory for locations in a city or in a University campus. They reiterate the assumptions implicit in the concept of a spatial reference point:

> . . . the position of a large set of (nonreference) locations in a particular region is defined in terms of the position of a smaller set of reference locations. . . .
>
> . . . the location of different places within a region is known with different degrees of certainty. Reference points are those places whose locations are relatively better known and that serve to define the location of adjacent [non-reference] points.
>
> . . . [Thus, in interests of cognitive economy] the relationship between reference points may be [explicitly] stored and the position of other points computed from the knowledge that they are proximate to specific spatial reference points. (Sadalla et al., 1980, pp. 516-517)

Reference points are the prototypical spatial locations. Other loci are derivatives of these prototypes. The derivatives are more apt to be conceived "'in spatial relation to'" a reference point than vice versa. This leads to the "asymmetry hypothesis" which posits that "Adjacent places should be judged closer to reference points than are reference points to adjacent places" (Sadalla et al., 1980, p. 517).

Following Rosch (1975a), Sadalla and Colleagues (1980) used both the linguistic hedges task and the grid-placement task. Locations within a University campus and within a large city were used as stimuli. Both experiments supported the hypothesis that certain locations were utilised as cognitive reference points for other (nonreference) locations.

These studies suggest an experimental method for testing the choreutic prototype/deflection hypothesis. According to this hypothesis the orientation of bodily movements is conceived according to pure dimensions, diagonals and Cartesian planes, but actually executed along deflected "inclinations". If this is so, then evidence should be able to be found that dimensional and diagonal directions serve as reference points for other directions.

IVA.112 Labanotation Direction Symbols as Kinespheric Stimuli.

In the experiment presented here Labanotation direction symbols (see IVA.13) were used as stimuli in the grid task developed by Rosch (1975a) in an attempt to assess if reference points are used within the cognitive representation of the kinesphere. The direction symbols were chosen for stimuli because each symbol presents relatively the same amount of information. This is not true in the case of words where diagonal directions are specified by a conjunction of three dimensional words. Therefore words may not be adequate stimuli since they introduce verbal cognitive structures rather than cognising about kinesthetic spatial representations. Indeed, because of the pictorial design of the Labanotation direction symbols it may be that experienced readers translate directly from the symbol into kinesthetic spatial information without any intermediary verbal stage.

Labanotation direction symbols are certainly initially learned and orally discussed according to their verbal labels. Thus it is probable that the verbal labels are always associated with direction symbols. The question remains as to whether an experienced reader recalls the verbal labels when reading a direction symbol if the task does not induce it. It was assumed for this study that Subjects with previous experience reading and writing Labanotation direction symbols would translate these directly into kinesthetic spatial information in the grid-task. However the linguistic hedges sentence-completion task was not used because this task appears to encourage the translation of direction symbols into words rather than images of body action.

IVA.113 Method.

IVA.113a Subjects.

Subjects were twelve adults who had previous experience reading and writing body movement with Labanotation direction symbols. Subjects' experiences ranged from the successful completion of a college-level course in Labanotation and a working knowledge of direction-symbols, to advanced teachers in the field. Subjects took part voluntarily at the Experimenter's request.

IVA.113b Stimuli.

Labanotation direction symbols.

Pairs of Labanotation direction symbols were selected for use as stimuli. There are symbols for the 27 main directions (1 central, 6 dimensional, 8 diagonal, and 12 diametral directional points; see IVA.13), this yields a total of 351 possible stimulus-pairs. It was estimated that a 15 minute test period would be within Subjects' attention span, and that ample time for a distance judgment might be 7.5 seconds. This yielded an estimation for a total of 120 distance judgments within the test. Of these, 4 were set aside for "warm-up" judgments, leaving 116 judgments during the actual test. Each stimulus-pair must be judged in each direction (ie. x-y or the reverse direction y-x) so it was estimated that approximately 58 stimulus-pairs could be selected for use in the experiment.

It is probable that non-reference points will be nearby their corresponding reference point. For example, in the kinesphere it can be hypothesised that the left-upward and the right-upward directions are known in relation to the more prototypical dimensional upward direction. Therefore, pairs of direction symbols should be selected which are nearby.

The choreutic system of directions (see IVA.20) distinguishes between dimensional, diagonal, and diametral directions which can each be notated with a single direction symbol. Notation of inclinational directions typically requires two direction symbols so these were not tested.

Pairs of direction symbols were selected which represented different possible pairings of nearby dimensional, diametral, and diagonal directional points. It was predicted that reference point effects would be found in these pairings of nearby directional points so they were considered to be test-pairs. In addition to test-pairs, other pairs of direction symbols were chosen as distractions in which no reference point effects were expected. These consisted of nearby directions of the same type (eg. two dimensional directions, two diametral directions) and also radii and full axes through the kinesphere. A final group of 59 pairs of direction symbols were chosen for use as stimuli (see Appendix XIII.10). These were divided into test-pairs and distractor-pairs and further divided into the specific type of pair:

Test-pairs:	
Dimensional / Diametral	16 stimuli-pairs
Dimensional / Diagonal	10 stimuli-pairs
Diametral / Diagonal	8 stimuli-pairs
Nearby distractor-pairs:	
Dimensional / Dimensional	7 stimuli-pairs
Diametral / Diametral	4 stimuli-pairs
Distant distractor-pairs:	
Radii	6 stimuli-pairs
Full axes	8 stimuli-pairs

Semi-circular grids.

A 25.25 cm diameter semi-circular grid (47 semi-circular lines) was printed on sheets of A4 paper (29.5 x 21 cm). The sheets were oriented long-side down so that the origin of the grid was at the bottom centre of the page. One direction symbol was printed at the origin of the grid, another direction symbol was printed at the upper-right corner of the sheet (see Appendix XIII.50).

Test books.

Test books were loosely bound and contained 122 pages of grids with direction symbols and 3 pages of task instructions and examples. When the tests were taken the test book was oriented long-side down so that pages turned upwards.

IVA.114 Procedure.

Subjects read the first three pages of the test book which contained one page of instructions, a page consisting of a sample grid and direction symbols, and a page of clarifying information. Subjects asked questions until they understood the task.

The written instructions directed Subjects to "Read the beginning direction from the symbol at the centre of the grid", "Read the ending direction from the symbol outside of the grid", and then to "Write the ending direction symbol at a location within the grid which best represents the distance of movement from the beginning direction to the ending direction". They were then given three examples of different kinespheric distances. Subjects were further instructed to "Proceed through the test booklet one page at a time", to "Make one distance estimation for each page", to "proceed as quickly as possible, while still retaining accuracy", and that "Once you have turned a page, it is finished and you are not allowed to turn back" (see Appendix XIII.40).

Each stimulus-pair was presented twice to each Subject, once with stimulus 1 at the origin of the grid, and once with stimulus 2 at the origin (for test-pairs half of the hypothesised reference-points were labeled stimuli 1, and half were labeled stimuli 2; for distractor-pairs the stimuli were arbitrarily labeled stimulus 1 or 2). Stimulus-pairs were randomly ordered with the constraint that no similar combination of dimensional, diametral, diagonal or central directions occurred within 2 judgments of each other. The stimulus list was presented in one order to half the Subjects, and in the reverse order to the other half of the Subjects (see Appendix XIII.20-.30).

Four other stimuli-pairs (exemplifying of a variety of kinespheric distances) were presented at the beginning of all Subjects' tests as a warm-up. These were presented in two different random orders, each given to half of the Subjects.

IVA.115 Results and Discussion.

Each distance judgment was measured to the nearest millimeter from the centre of the direction symbol printed at the origin of the grid to the centre of the direction symbol drawn by the Subject (see Appendix XIII.60). Each stimulus-pair was considered separately to identify whether an asymmetry in distance judgments had occurred. Therefore a paired grouped t-test (two tailed) was conducted for each of the 59 stimulus-pairs. Because of so many t-tests it is statistically likely that some would be significant just out of chance. A correction is needed to control for this type of error and so a low probability of effects being attributable to chance ($p < 0.001$) was chosen as the level of significance.

mean distance (mm)	32.4 24.8	30.5 25.2	26.3 22.1
t =	t=1.96	t=1.38	t=1.75
p <	p < .05	p < .20	p < .10

mean distance (mm)	41.9 27.8	31.3 24.3	39.0 32.8
t =	t=2.92	t=2.15	t=1.72
p <	p < .02	p < .05	p < .10

Table IV-10. Six test-pairs (out of thirty-four) which approached significance (first symbol in each bracket was fixed at the centre of the grid).

None of the stimulus-pairs reached significance at this level (Appendix XIII.70). Only six (out of thirty-four) of the test-pairs even approached significance (Table IV-10). In three of these when the dimensional direction was at the origin of the grid the judged distance to the diametral direction was larger than vice versa. This is the opposite effect as predicted by the asymmetry hypothesis for dimensional prototypes. For the other three test-pairs which approached significance when the diagonal-locus was at the origin of the grid the judged distance to a dimensional point or a diametral point was smaller than vice versa. This is consistent with the effect as would be predicted by the asymmetry hypothesis for diagonal prototypes, but the size of this effect was too small to reach significance. Therefore the results of this experiment do not support the hypothesis that kinespheric locations are mentally represented according to a set of prototypical reference points.

It may be that cognitive reference-points are used for kinespheric information but that this experiment failed to demonstrate an effect. Several potential problems with the experiment were identified. While Subjects were taking the test it was often observed that they used body movements towards the directions indicated by the direction symbols. Sometimes two body-parts (eg. both arms) reached into both directions simultaneously, at other times a single body-part was moved back and forth between the two directions two or three times. One advanced Subject also reported that she visualised the interval between directions rather than the motion from one direction to another. These attributes indicate the possibility that Subjects were estimating the length of the line between the two directions regardless of which direction was to be considered as the starting point.

Similarly, Subjects with advanced knowledge of Labanotation direction symbols were sometimes overheard making computational judgments about the distance between directions, for example, "45°", "90°", "full way" (180° between directions) or "half-way" (90° between directions). This computation would be identical regardless of which direction was considered as the starting point.

It was stressed in the instructions that distance judgments should be made from one direction to another direction. However these observations indicate that Subjects may have been estimating the length of the line or the size of an angle, between two directions regardless of which direction was designated as the starting point. If this is true then placing one direction symbol at the origin of the grid would be inconsequential since Subjects would tend to treat both direction symbols equally.

Other tasks may induce a sequential conception (from one location towards another location). The verbal sentence-completion task using linguistic hedges developed by Rosch (1975a) was ruled out because it may elicit verbal rather than kinesthetic processing of the direction symbols. However this task could indicate if there is an effect of dimensional reference-points for verbal representations of spatial directions. A variation of the sentence-completion task might be to simply present Subjects with two direction symbols and ask that they arrange them into the most logical sequence. Another possibility would be measuring the reaction-time for judgments of the distance or direction between two kinespheric locations. This type of task was used by Sadalla and Colleagues (1980) to identify reference points within the spatial representation of locations in a university campus or in a city. Labanotation direction symbols could be presented one at a time to ensure that the judgment was made from one direction towards the other direction. The representation of a non-reference point implicitly includes the reference point since the non-reference point is hypothesised to be mentally represented "in relation to" the reference point. Therefore a non-reference point would prime the Subject for the reference point, and accordingly, reaction times should be shorter when the non-reference point is presented first.

Recall of kinespheric locations could also be tested by presenting Subjects with body-poses which they are later required to reproduce with their own body. Similar tasks have found a bias toward the planar-diagonal when recalling the location of a dot within a circle (Huttenlocher et al., 1991) or the incidental memory bias toward the horizontal when recalling an arm position (Clark and Burgess, 1984). The hypothesis would posit that the locations of limbs in body-poses would be recalled more similar to prototypical locations than they actually were.

IVA.116 Conclusions: Kinespheric Reference Points.

Subjects were presented with two kinespheric directions (notated with Labanotation symbols). One symbol was drawn in a semi-circular grid at a location which represented its distance from another kinespheric direction. Each stimulus-pair was judged once in each direction (once with stimulus 1 fixed at the origin of the grid, once with stimulus 2 fixed). Distance judgements were not significantly different regardless of which stimulus was fixed at the origin of the grid This did not support the hypothesis of reference points in the mental representation of the kinesphere. However, it appears that Subjects tended to estimate the static length of a line or the size of an angle rather than a distance from one location towards another location. Alternative experiments are suggested.

IVB. Categories of Kinespheric Form

This section reevaluates varieties of spatial form producible by the body. This includes a review of taxonomies of kinespheric forms presented in choreutics and dance, characteristics of perceiving forms as identified in spatial cognition research, and the structure of anatomy which constrains the physical production of kinespheric forms. A need for distinctions between classes of body movements is identified within the schema theory for motor learning and it is argued here that choreutic theory can contribute to solving this problem. Topological categories of kinespheric forms are observed to deflect slightly from one execution to the next and so can be conceived as the "co-ordinational net of the motor field . . . oscillating like a cobweb in the wind" (Bernstein, 1984, p. 109). This is virtually identical to the choreutic conception of a topologic form as deflecting between variously-shaped polyhedral cognitive maps of the kinesphere. An experiment is presented which verifies that kinesthetic spatial information is subjectively organised into categories during learning and memory processes. Results indicated that kinespheric categories were best predicted by their form (movements with the same shape were clustered together in free recall), while prototypicality was best predicted by the orientation (dimensionally oriented paths were recalled first in a cluster). Continuing research determining psychologically valid kinesthetic categories is suggested.

IVB.10 Introduction

IVB.11 The Need for Kinespheric Categories in Psychology

In psychological theory there is a need to develop criteria for distinguishing between different categories of body movement information. This is especially true in regards to the schema theory for motor learning. Probing the structure of kinespheric (ie. kinesthetic-spatial) categories can contribute to this lack of knowledge.

A schema theory for motor learning was developed by Schmidt (1975; 1976; 1982) and is described as "currently [the] dominant psychological theory of motor learning" (Jordan and Rosenbaum, 1989, p. 753). Schema theory posits that movements are not stored in memory as individual items, but as members of categories based on the movements' core attributes. A range of movements within the same "general type" of movement are perceived or produced by allowing variations in the initial sensory conditions, the selected parameters for execution (eg. how forceful, how quick), the sensory feedback resulting from the execution, and the environmental effects of the movement. Schema theory explains that novel movements are perceived or produced by comparing them to, or deriving them from the "basic pattern". However, the foundation of the schema, the "general type" of movement, that forms the basis for distinguishing between different categories of schema families, remains undefined.

A major prediction of the schema theory is known as the "variability of practice hypothesis" which predicts that experiences of a wide variety of movements within the same "general class" will "transfer" to (ie. be equivalent to having practiced) a new movement within that same general class, but which itself has never before been experienced (Schmidt, 1975, p. 257). Intuitively it seems likely that a wide variety of experiences will allow a more ready perception and response to novel experiences but experimental tests of the variability of practice hypothesis have not demonstrated consistent results (For reviews see; Lee et al., 1985; Shapiro and Schmidt, 1982, pp. 118-129; and Appendix XIV).

The major problem in evaluating the variability of practice hypothesis has been identified as the lack of criteria for determining when movements belong to the same schema family or not (Newell, 1991, p. 221; Sheridan, 1984, p. 79; Van Rossum, 1980). It is typically left up to the personal judgment of the Experimenter as to whether movements are considered to be variations of the same schema or not. Schmidt (1975) referred to a schema family as containing movements with the same "basic pattern" and which therefore belong to the same "general type" (p. 235) or to the "same class" (p. 257). However, the criteria for determining this membership is neglected. The closest definition given is that movements of the same general type are those which attempt to satisfy the same goal (p. 235). Later, Shapiro and Schmidt (1982, p. 136) speculated that a general class may be defined by the pattern of relative timing between the elements of the sequence (ie. "phasing), however this severely limits the range of each class and would appear to negate the benefits of a schema representation. Categories of movement as outlined in dance and choreutic studies may contribute to solving this problem of distinguishing between general classes of bodily movement.

IVB.12 Paths, Poses, and Virtual Forms.

This research is focusing on distinguishing among kinesthetic spatial, that is, "kinespheric" categories (see IIB.38). A preliminary distinction among categories of kinespheric form can be made between paths, poses, and "virtual forms". In an analysis of spatial forms in dance Preston-Dunlop (1980, pp. 87-93, 109-135; 1981, pp. 54-60; 1984, p. x) distinguishes four different manners by which spatial forms can be created by the body. Preston-Dunlop calls these the "realisation" (1984, p. x), of the four "manners of materialisation" (1981, p. 54) by which the forms are "'embodied' by the dancer" (1980, p. 109; also 1979, p. 142). "Spatial progression" refers to embodying a form within the pathway of a body-part or the body's centre of gravity as it moves through space. "Body design" refers to embodying a form within the sculptural positions and mass of the body itself. "Spatial tension" refers to embodying a form by causing it to be perceived as connections between body-parts in separate locations. "Spatial projection" refers to embodying a form by causing it to be perceived as flying outwards beyond the body into the general expanse of space.

In Preston-Dunlop's (1981) approach spatial forms are always considered in relation to the process through which they are made visible to an observer. For example a body-design is regarded as being present only if "the dynamics of the performance draws the audience's eye to that design" (p. 55). Thus, a kinespheric form is not considered to be an objective, actual entity, but is regarded as "virtual" in that it is "dependent on dynamics, for its perceptibility" (p. 57) and is considered to be occurring only when "made visible by the performance given to it by the dancer and/or by the relationships and dynamics structured by the choreographer" (p. 30).

In a slightly different approach, this study will focus on defining objective criteria for categorising kinespheric form. Spatial progressions and body designs have often been studied in motor control and spatial cognition research since they lend themselves to objective analysis. For example, Smyth and Colleagues (1988) called these "patterns" and "positions" respectively. They are referred to here as "paths" and "poses".

However, the observation of kinespheric form "embodied" by spatial tension and spatial projection is based almost entirely on subjective perception. In studies of perception in art, Arnheim (1974, pp. 16-18) referred to these as "psychological forces" to distinguish them from "physical forces". They can be referred to collectively as "virtual" forms, following Preston-Dunlop (1981, pp. 30, 48-49, 55, 57) and the philosopher Susanne Langer (1953, pp. 72, 186-187). Particular arrangements of spatial stimuli can tend to include perceptions of spatial "tensions" (perceived lines of tension connecting between body parts across empty space) or "projections (perceived lines projecting out from beyond the body). These are perceived just as if they were "virtually" real but they do not have any objective physical reality* Virtual forms have not been a focus of this research but a brief review is included in Appendix XV.

IVB.13 Linear, Planar, and Plastic Forms.

Another preliminary distinction is between linear, planar and plastic forms. The terms one-dimensional, two-dimensional, and three-dimensional are often used to refer to both a form and an orientation. For example, in their analysis of body movements "three-dimensional" forms are typically considered to be different than "linear" forms (Moore and Yamamoto, 1988, p. 196). However, sometimes a linear form is also three-dimensional in the case of a diagonal oriented line. The dual definition of "three-dimensional" as a form or as an orientation often leads to students' confusions (personal observation) and so it is desirable to distinguish between these terms.

"One-dimensional", "two-dimensional" and "three-dimensional" will be used here to refer to the orientation relative to the dimensions of a Cartesian coordinate system. Orientations are considered in an earlier section (see IVA). The terms "linear", "planar" and "plastic" will be used here to refer to the shape of the form. A linear form spans across a distance, a planar form describes an area, and a plastic form encompasses a volume of space. The term "plastic" is used in this volumetric sense by Bernstein (1984, p. 84) and in many choreutic texts# (Dell, 1970, p. 55; Laban, 1926, p. 17; 1966, pp. 18, 20-21; Ullmann, 1966, p. 208) and is defined as "relating to moulding or modeling: the plastic arts" (Collins, 1986). This is similar to the "constant blending of the muscle group functions in many joints" (Dell, 1970, p. 55) or how "the bodily coordination required is more complicated, often involving [combinations of] flexion/extension, abduction/adduction, and rotation" (Moore and Yamamoto, 1988, p. 194) which are characteristic descriptions of plastic kinespheric forms.

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* This is not intended to deny the possibility that certain people can perceive the spatial arrangement of other real forces emanating from or surrounding the body (eg. electromagnetism, body auras).

\# Rarely "plastic" is used to refer to the orientation rather than the form (Laban, 1966, p. 77) which further necessitates the distinction between form and orientation.

IVB.20 Kinespheric Poses

A kinespheric "pose" refers to the positions of the body's physical mass. This is also referred to as a "body design" (Preston-Dunlop, 1984, p. x;) or a "limb constellation" (Bartenieff and Lewis, 1980, p. 180). A variety of kinespheric pose categories have been distinguished in choreutics and dance studies. These can be refined by conceptions of body poses in spatial cognition research.

IVB.21 Pin-, Wall-, Ball-, and Screw-shaped Poses.

Laban (1980, p. 63) distinguished four types of "body carriage and its shape" according to the "structural and functional factors of the body": 1) "Pin-like" shapes arise from the "spine and its pin-like extension"; 2) "wall-like" shapes arise from a flat surface created by the "right-left symmetry of the body"; 3) "Ball-like" shapes arise from the "curling and circling" of the limbs together with the trunk; 4) "Screw-like" shapes arise from the "shoulder-girdle and the pelvis twisted against one another".

Other authors adopted these four categories of kinespheric poses. Preston-Dunlop (1980, pp. 90-92) begins with two more fundamental categories of poses, "large" body shapes which are "done by the whole body" and "small" shapes which are "done by smaller parts" of the body. Pin-like shapes are conceived to be variants of the large shape and consist of an "elongated" "'line from head to foot'" which "penetrates the space". Wall-like shapes are also variations of the large shape. They are "spread out" and "flat" in which "the limbs extend away from one another in two dimensions, with the centre of the body as the hub" and have a character of "dividing the space". Ball-like shapes are derived from the small shape. They consist of "curling up" in which the "whole body, and in particular the spine, rounds itself" while the limb extremities "try to meet and merge" and have a character of "surrounding the space in concave positions or displacing it in convex positions". Screw-like shapes are derived from a mixture of the small and large shapes in which "the extremities of the body pull against one another . . . in different directions around an axis" so that the different body-parts are "twisting away from one another".

Bartenieff and Lewis (1980, p. 110) refer to these four poses as "body attitudes". The pin shape is "straight and narrow" and penetrates space. The wall shape is "straight and spread" and divides space. The ball shape is "rounded" and surrounds or fills space. And the screw shape consists of the "upper body twisted against [the] lower" and is "winding" in the space.

IVB.22 Straight, Curved, and Angled Poses.

Preston-Dunlop (1981, p. 44) presents an analysis in which all poses are classified as either straight or curved. The modern dancer Doris Humphrey (1959, pp. 49-58) referred to body poses as "static line" and categorised these as either "oppositional", that is "opposed, in a right angle" and expressing maximum power, or "successional", that is "flowing, as in a curve" and expressing gentleness "in curves or straight lines". Thus, while Preston-Dunlop distinguishes between curved and straight categories of poses, Humphrey categorises curved and straight into the same category and distinguishes a separate category for angles.

IVB.23 Arabesque and Attitude Poses.

In the ballet tradition two general categories of body poses are distinguished. Grant (1982) defines the arabesque as "one of the basic poses in ballet" in which the body stands on one leg with the other leg extended and "the arms held in various harmonious positions creating the longest possible line from the fingertips to the toes". Many variations are possible within this category of poses since "forms of arabesque are varied to infinity" (p. 2). The attitude pose was derived from the statue of "Mercury by Giovanni da Bologna" (p. 9). In this category the gesturing leg and arms are bent so that they appear to be gently curved. Thus the arabesque and attitude categories of poses in ballet are essentially categories of straight versus curved poses.

IVB.24 Poses Arranged in Geometric Networks.

In the choreutic tradition, and also in art and architecture, kinespheric poses are often conceived according to their relationship to an imaginary polyhedral or polygonal network. This is essentially a mapping of poses relative to the nodes of a conceptual kinespheric network. A variety of networks have been used such as squares, rectangles, pentagons, and pentagrams in various orientations. An unique contribution of choreutics its its use of various polyhedra for conceptual kinespheric networks. These have been introduced in earlier sections (IIIC.30) and analysed in greater detail (IVA.20).

IVB.25 Counterdirections and Chords.

In the choreutic tradition a pose which consists of an arrangement of at least three limbs can be referred to as a "chord" (in the musical sense) (Preston-Dunlop, 1984, p. x), a "chordic interrelationship of the three limbs", as "triadic chordic constellations", or as a "chordic tension" (Bartenieff and Lewis, 1980, pp. 107-108, 116, 193).* The limbs within the chord may be oriented to that they equally balance each other and provide an overall equilibrium to the body (see IIID.50). This 3-part equilibrium chord is a plastic version of the equilibrium created by the 2-part "countertension" or counterdirection in which limbs are oriented into two opposite directions (Bartenieff and Lewis, 1980, pp. 103-108, 114).

IVB.26 Kinespheric Pose Primitives: The Body Segment.

Conceptions of kinespheric poses are based on the physical structure of the body. The skeleton gives the body its structure. Other tissues add to this structure but the skeleton determines the overall shapes that the body can create. Therefore, all poses will have the structure of the skeleton at their basis.

Bones have a variety of shapes which include bulges on their surfaces, spirals within bony structure, flat and curving bones of the scapula and skull, curved ribs, and the S-shaped curve of the vertebral column. Nevertheless, most bones which give the body its form have an overall straight shape. these straight segments of the skeleton can be referred to as "body segments". Categories of kinespheric poses must necessarily be based on an arrangement of straight body-segments.

Marr and Nishihara (1978; Marr, 1980) identify the straight body segment as the primitive component in the visual representation of body poses. They point out that an object (eg. an animal's body) has a "natural decomposition into components" which each exhibit a "principal axis of elongation or symmetry". The longest dimension of a form will tend to be assigned as the principal axis along which the figure will be remembered (also noted by Attneave, 1968; Rock, 1973, p. 38). Each elongated axis becomes a line within a "stick figure" representation of the body. The easy recognition of an animal's body from stick figure drawings indicates that the straight segments of the stick figure are the essence of the mental representation of the body structure (Marr, 1980, p. 211). The stick figure can be conceived at different levels of detail so that there is a "hierarchy of stick-figure specifications". At the highest level a single line represents the entire body along its most elongated axis. At

* A chord is sometimes referred to as "chordic countertension" which has only two opposing directions (Bartenieff and Lewis, 1980, p. 116; Preston-Dunlop, 1984, p. x) but this would seem to dilute the meaning of a 3-part "chord" versus to "counter" which typically refers to two elements in direct opposition. If used in a musical analogy a "chord" will refer to three or more simultaneous elements.

the next level each limb and the spine is represented with a single line along their lengthwise axes. Through progressive levels of detail, smaller and smaller body-segments are specified with an individual line in the stick-figure.

This same cognitive structure is evident in Labanotation symbols for body-parts. A single symbol can be used to represent an entire limb or the entire torso. Variations of the full-limb symbols are then used to refer to lower-order parts of the limbs (Hutchinson, 1970, pp. 248, 317).

IVB.27 Gestalt Principles of Higher-Order Perceptual Groupings.

Poses are not typically perceived as individual body segments. They tend to be spontaneously organised into higher-order groupings which are then perceived as curved, spiraled, figure-8, tetrahedral etc. poses. The question for an objective analysis is: What factors contribute towards certain higher-order groupings being perceived?

Certain principles have been identified which describe how various types of stimuli tend to be perceptually organised into higher-order groupings. Gestalt psychologists referred to the fundamental factor as the law of "*pragnanz*" (Koffka, 1935, p. 110). This is literally translated from German as "concise" or "terse" (Collins, 1969) which are defined as "neatly brief" and "expressing much in few words" respectively (Collins, 1986). Koffka (1935, pp. 108-145) and Wertheimer (1923, pp. 79-83) describe *pragnanz* as organized groupings of stimuli which are the most "good", "regular", "simple", "stable", "logically demanded", with "inner coherence", "inner necessity", "wholeness", and that within each element exist the principle of the whole group of elements. They hypothesize that perceptual processes will always organize the stimuli to be as "good" (ie. according to *pragnanz*) as the conditions will allow. More specific manifestations of *pragnanz* were identified (Koffka, 1935, pp. 148-171; Wertheimer, 1923, pp. 75-87):

According to "proximity" when stimuli are near to each other in time or space they tend to be grouped together relative to more distant stimuli.

According to "similarity" (called "equality" by Koffka, 1935, p. 165) when stimuli have a similar shape, colour, orientation etc. as each other they tend to be grouped together relative to other more dissimilar stimuli.

According to "continuation" (called "direction" by Wertheimer, 1923, p. 80) a continual series of stimuli (eg. a row or a column of separate objects) will tend to be grouped together as a single unit. A continuation of a straight line maintains its direction and a curved line maintains its curvature.

According to "closure" if a collection of stimuli completes, or nearly completes, a circuit which encloses space, this entire area will tend to be grouped together as a single unit.

According to "common fate", stimuli which are moving at the same time, in the same direction, or traveling the same distance, tend to be grouped together as a single unit.

According to "*unum and duo*" (Koffka, 1935, p. 153) a stimuli configuration will be perceived as one figure, or perceptually divided into two or more sub-figures, depending on which of these groupings arranges the stimuli into figures which exhibit the greatest amount of simplicity and symmetry.

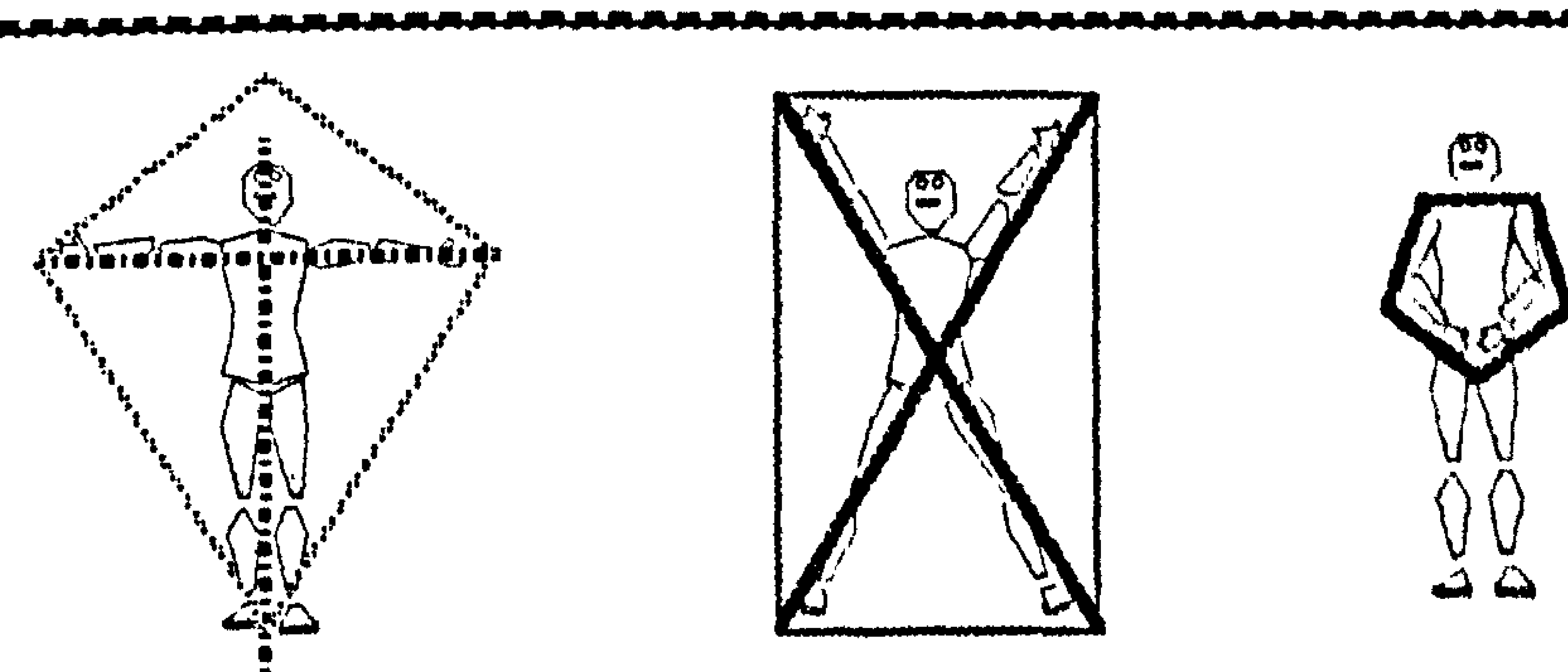


Figure IVB-1. Higher-order pose configurations; types of frontal planar "walls"; cross-shaped, "X"-shaped, pentagon shaped.

In many cases these principles of organisation all work together in agreement to derive a particular grouping of the stimuli. In other situations the principles may be in conflict and so, for example, an organisation according to proximity might dominate a different organisation which would have occurred according to similarity.

The causes of *pragnanz* can be discussed according to the Nature versus Nurture debate:

> Gestalt laws of perceptual organisation make reasonable intuitive sense, but they are obviously descriptive statements possessing little or no explanatory power. The Gestaltists appear to have believed that their laws reflected basic organisational processes within the brain [ie. Nature], but it is much more plausible to assume that the laws arise as a result of experience [ie. Nurture]. It tends to be the case that visual elements which are close together, similar, and so on, belong to the same object, and presumably this is something which we learn. (Eysenck and Keane, 1990, p. 58)

The overall Gestalt principal of *pragnanz* describes how perceptual and cognitive processes attempt to group stimuli into the simplest, most concise, most symmetrical manner possible. This provides a great deal of cognitive economy and so is a beneficial strategy for an organism, even at the risk of remembering stimuli as more concise than they actually were. This is a type of perceptual bias related to the perception of prototypes (see IVA.32).

In the perception of kinespheric forms if many body segments are aligned in a straight line these may be organised into a single higher-order unit according to the Gestalt principles of continuation, similarity, and unum-duo. An arrangement of straight body segments can be made even more concise by organising them into even higher-order units such as an "X"-shape, a cross, or a pentagon (which also includes the Gestalt principle of closure) (Fig. IVB-1). Likewise, if several body-segments are arranged in a series of similar sized angles these may be organised into a single higher-order curved pose according to Gestalt principles of continuation, similarity, and unum-duo. When the ends of body-segments are almost touching each other the curve may be perceived to connect across the empty space to form an entire circle according to the principles of closure and proximity (Fig. IVB-2).

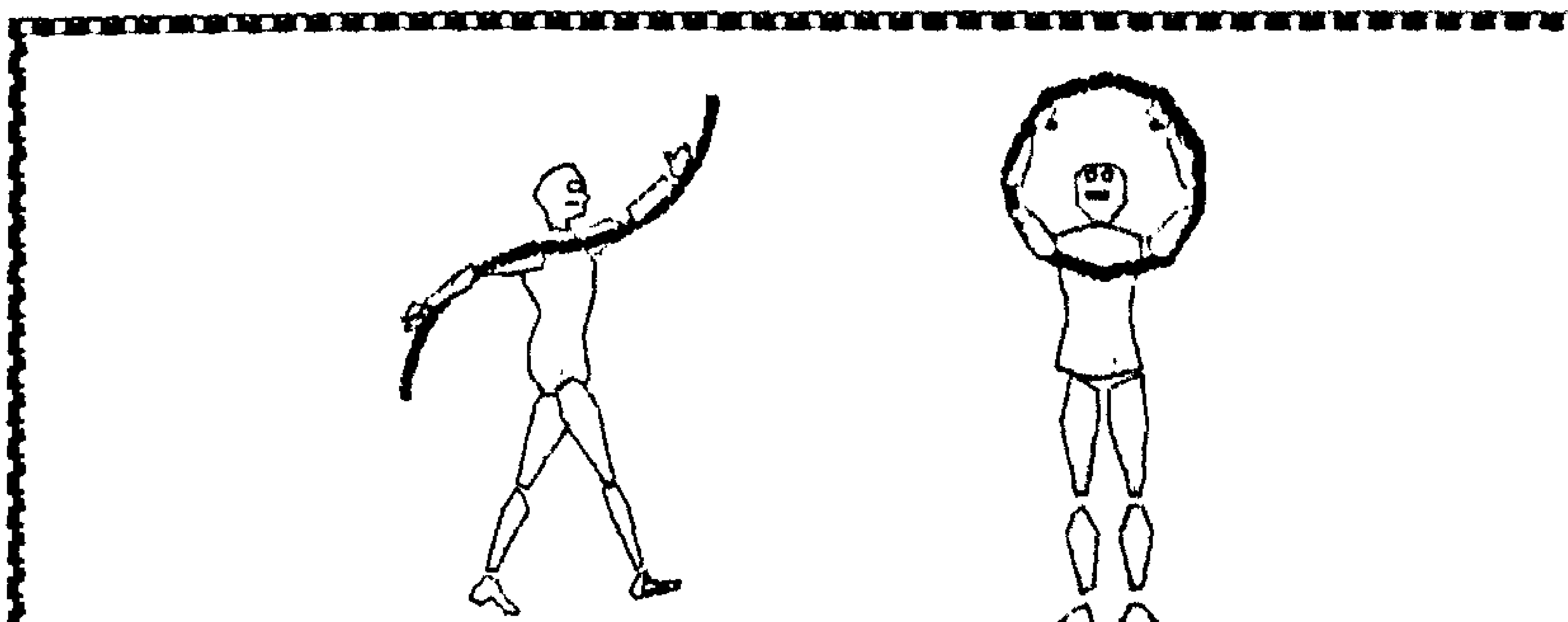


Figure IVB-2. Higher-order curved pose, and higher-order connection across empty space into a circle.

The angles between body segments leading to the perception of curved versus angled poses may be derived from a series of body segments which all have similar sized angles, or from a performer's dynamics (eg. relaxed versus tensed muscles). Perception of the pose as a pin, wall, ball, screw, or any other descriptive over-all shape occurs through this automatic process of perceptual grouping. These higher-order groupings provide the most concise description and economical mental representation of a kinespheric pose.

IVB.30 Kinespheric Paths

A kinespheric path refers to the form created by the lines of motion as the body moves through space.

IVB.31 Generalised Inwards / Outwards Movement.

A basic distinction is often made between paths which generally condense inwards towards the body versus paths which expand outwards away from the body. Laban (1980, pp. 83-86) referred to these "two main action forms" as "gathering" and "scattering". Gathering movement "can be seen in bringing something toward the centre of the body", is a movement of "possession" by which "an object is gripped", and is preserved in ballet as "attitudes" which surround the space. Scattering movement "can be observed in pushing something away from the centre of the body", is a movement of "repulsion" by which an object is propelled "outwards into space", and is preserved in ballet as "arabesques" which "radiate from the centre of the body" outwards. In another work Laban (1966, pp. 49-50) limits gathering and scattering to being the "most apparent activities for the arms" as opposed to "taking steps" for the legs. Furthermore, "Gathering or taking is usually associated with a turning of the palms towards the body" and gives "a feeling of contraction" whereas "scattering, or rejecting, [usually occurs with] an outward turning of the palms" and "gives a feeling of opening out and of expansion".

Laban (1966, p. 53) attempts to outline the relationship between gathering/scattering and the kinespheric pathway. He first asserts that the pathway (ie. "gesture-line in space", or "trace-form") has "an independent life" from the "particular way of using a limb" (ie. gathering or scattering). That is, any pathway can be performed with either gathering or scattering movement. He then adds that "This independence, however, is not a reality". This statement is not explained and the reader is referred to another chapter which contains a discussion of the kinesthetic perception of paths from within, versus seeing paths from an outside viewpoint, but contains no mention of gathering/scattering (pp. 83-91). It may be that Laban conceives of gathering/scattering as resulting from a "muscular trace-form" which is perceived from the interior while the "gesture-line in space" is perceived from the exterior (p. 53) and that these two are dependent since certain paths require certain interior skeletal-muscular articulations which will encourage either gathering or scattering.

Laban (1966) also identifies the tying and untying of "knots" which are similar to gathering/scattering. "In moving inwards towards the centre of our body we follow trace-forms which resemble knots" and "in moving outwards . . . we usually employ such untying or untwisting movements" (p. 92):

> All movement is an eternal change between binding and loosening, between the creation of knots with the concentrating and uniting power of binding, and the creation of twisted lines in the process of untying and untwisting.
> (Laban, 1966, p. 94)

Dell (1970) defines gathering/scattering as part of "shaping" movement in which the body changes its shape so as to "accommodate to the plastic character of objects" and to "mold space . . . in clay as the sculptor does". This requires a "constant blending of the muscle group functions in many joints" and emphasizes "either coming toward the body or going away from the body, rather than any particular directions in space" (pp. 55-56). This is distinguished from a general inwards/outwards movement known as "shape flow", sometimes also called "growing and shrinking" in reference to the "inflation and deflation of the trunk in breathing", or as "folding or closing" toward the centre and "unfolding" or "opening" away from the centre in reference to the limbs (pp. 45-48). In their anthropological "choreometric coding book" Lomax and Colleagues (1968, p. 269) also include shape flow as a "vague unfolding or folding" or as an "indefinite" shape of a path.

Bartenieff and Lewis (1980, pp. 85-86) use "shape flow" to refer to a path which is "toward or away from the body center", which "hollows and bulges, shrinks and grows" and which are the "Primary body movement shapes". They report that during the movement development of children and movement retraining of injured adults that shape flow occurs during a "'pre-space' period" when general inwards/outwards paths occur at an earlier stage before clearly defined spatial paths. This growing/shrinking of "body shaping" with no specific relation to space is distinguished from the gathering/scattering of "spatial shaping" which exhibits a specific form.

Hutchinson-Guest (1983, pp. 175-177) describes "gathering" as "inwardness, of bringing the energy and the line of movement or 'a volume of space' to the self" and "scattering" as "concerned with sending the energy or the line of movement away from the self, of pushing 'a volume of space' outward and away from one's center". These are considered to occur when the arm sequentially curls or uncurls in curved paths accompanied by shoulder rotation, whereas if the ends of the limbs follow straight paths the inward/outward motion is referred to as "taking" and "giving". This distinction of straight versus curved inward/outward movement is identical to Dell's (1970) "spoke-like" and "arc-like" movement and is the beginning of a more specified description of the shape of the path.

Hutchinson-Guest (1983, pp. 75-76) discusses the more general concepts of "flexion" and "extension" (not in the strict anatomical sense) which consist of "drawing in toward the center, becoming smaller, folding up, [and] contracting" and "expanding, moving out from the center, becoming larger, [and] growing". It appears that Hutchinson-Guest's' notions of "gathering" and "taking" are examples of "flexion" while "scattering" and "giving" are examples of "extension".

Hutchinson-Guest's (1983) definitions come to a complication when it is asserted that bending the torso backward could be flexion if it is a "relaxed curve" or extension if it is "elongating" (p. 80). The problem is that movement can "become smaller" either across the front or across the back of the torso. Thus, the "centre" reference point must always be specified for determining whether the movement is inwards or outwards.

Preston-Dunlop (1980, p. 52) refers to "gripping and releasing" as part of the "instrumental use of the body" which can occur towards or away from the centre of the body, or also towards and away from any point in the kinesphere (eg. the centre of the palm, above the head, behind the back, towards the feet, etc.)

Sometimes the generalised inward/outward movement is not classified together with pathways. Preston-Dunlop (1980) categorised gathering/ scattering together with other "actions" such as jumping, turning, falling, traveling, etc. and distinguished these from "abstract shapes" (eg. forms of paths or poses). Winearls (1958, pp. 43-46) gives a similar treatment to "scooping and strewing" which are categorised together with contractions, tilts, falls, swings etc. rather than as part of "form", or "direction and design".

Generalised inward/outward motion of kinespheric paths is analogous to a system of elemental phonemes devised by Jakobson and Halle (1956; also described by Gibson, 1969, p. 84) and a system of elemental colours devised by Berlin and Kay (1969) which are both based on the developmental sequence occurring during a child's learning process or during the development of a culture. Berlin and Kay (1969, pp. 105-110) describe the first distinction as one of "energy" or "amplitude". In phonology this translates as "loudness". The first utterance of a child closely resembles the sound "pa" which contains the virtually silent "p" requiring the least amount of energy and the loudest "a" requiring the greatest amount of energy. In colour this first distinction translates as "brightness". The first colour terms to be developed in primitive cultures consist of a word for the maximum brightness of "white" and the minimum brightness of "black". The analogous distinction for the kinesphere could be "size" in which the fundamental motions are getting small, and getting large.

IVB.32 Path Hierarchy: Straight, Curved, Twisted, Rounded etc.

The ballet master Feuillet (1700, pp. 9-10; 1706, pp. 9-10) classified the "almost innumerable . . . Figures the leg makes in moving" into one of five categories; straight, curved, twisted, rounded, or beaten (Fig. IVB-3):

1) In a straight step ("*droit*") the foot moves along a straight line and has two variations, straight forward or straight backward.

2) In an open step ("*ouvert*") the foot moves along an opening pathway either outwards (curving from the front to back), inwards (curving from the back to front), or to the side (a straight path towards the side, thus an "*ouvert droit*" step).

3) In a round step ("*rond*") the foot moves in a circular path (shaped like a loop in Feuillet's drawings) either inwards or outwards.

4) In a waving step ("*tortille*") the foot follows a wavy, serpentine-like path which alternates between inward and outward curves either forwards, backwards, or to the side.

5) In a beaten step ("*battu*") the moving foot is beaten against the other one thus following an angular path either forward, backward, or to the side.

Feuillet's analysis mixes together paths, poses, and dynamics. The "opening" step refers to the final pose to the side rather than the path, thus two of the opening steps are curved while the other ("*ouvert droit*") is straight. The beaten step refers to a dynamic quality while Feuillet's drawings imply that it is an angular path.

Laban (1926) adopted Feuillet's five forms into his spatial system (p. 54) and then reduced these five forms to four: "straight", "simply curved", "doubly curved (twisted)", and "round, rolling spiral" (p. 62). Presumably the angular path (*battu*) is eliminated since it consists of two straight paths.

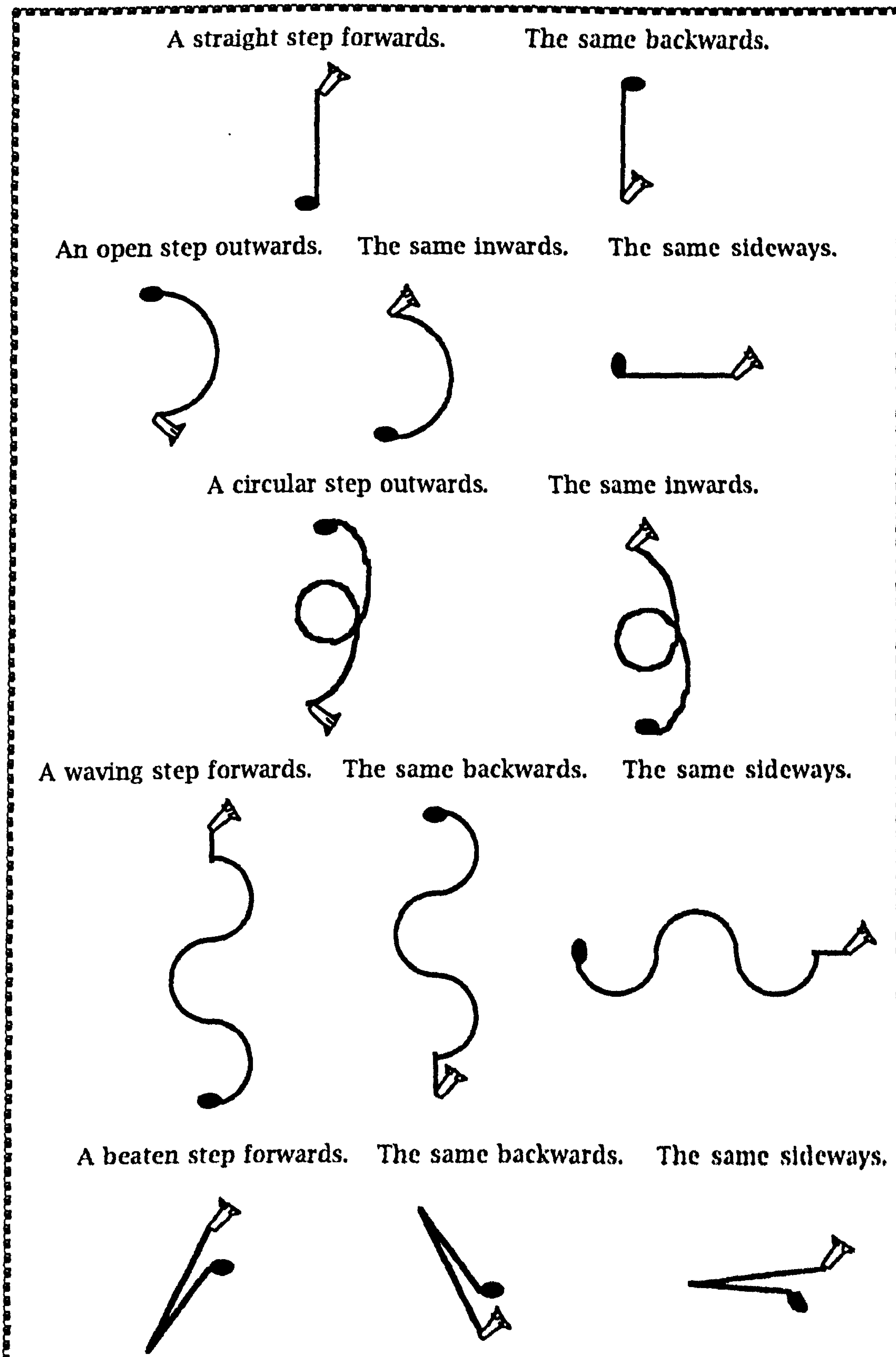


Figure IVB-3. Feuillet's pathways: straight (*droit*), open (*ouvert*), round (*rond*), waving (*tortille*), and beaten (*battu*) (adapted from Feuillet, 1700, pp. 9-10; 1706, pp. 9-10) (the path begins at the dot and ends at the drawing of the foot).

In a later work Laban (1966, pp. 83-84) begins with these "four fundamental trace-forms" and then further reduces these to just three, the "simple line" (the straight and curved paths categorised together), the "double wave" and the "round". These three are then further reduced to just one since all paths are "parts or metamorphoses of one basic trace-form, the spiral", but this statement is never explained. Laban's inconsistency is further evident in another work where he first lists the "spatial forms of movement" which are "basic" as "round", "angular", and "twisted" and later lists the "elementary aspects" of paths as "straight", "angular", and "curved" (Laban, 1980, pp. 33, 38).

North (1956, p. 13) subscribes to the view that "all the possible shapes are simply angular, round, or twisted" and other forms are created from a combination of these basic ones. These same categories are reiterated in a later work (North, 1972, p. 19).

In the Jooss-Leeder method of modern dance (which was influenced by choreutics since it was developed by two of Laban's students), Winearls (1958, pp. 102-105) classifies paths into four categories: straight, half-circle, winding "S", and full-circle. These four categories retain their roots in Feuillet's system* but are defined in terms of anatomical function and can be produced by any limb (not just Feuillet's foot paths). A coordination of simultaneous articulations in two or more joints can cause the distal end of a limb to follow a straight path (*droit*) which is direct and linear. A bending articulation of a single joint will cause the distal end of the limb to follow a half-circle path (*ouvert*) which is curved and planar. A rotary articulation followed by a bending articulation will cause the distal end of the limb to follow a winding "S"-shaped path (*tortille*) which is plastic (ie. does not remain within any single plane). A circumduction of the global joints (hips or shoulders) or of the spine causes the end of the linkage to follow a full circle path (*rond*) which is circular and planar.

Winearls' anatomical description is one of the most objective analyses of path forms, however certain problems are evident. A full circle path of the hand does not necessarily require shoulder-joint circumduction (as described by Winearls) but may also be produced by a sequence of shoulder rotation and elbow bending. This sequence of rotate, bend is described as creating plastic S-shaped paths by Winearls but in this case these articulations may create a circular path. The possibility of

* Winearls' path-forms are so fundamentally different than Feuillet's that it is questionable as to why the French terms are maintained. Winearls' limits the *ouvert* path to bending articulations (eg. elbow or knee) whereas Feuillet's *ouvert* foot path consists of a hip circumduction. The multi-joint articulation of Winearls' *droit* has no similarity whatsoever to Feuillet's *droit* which articulates only at the hip.

producing a planar winding S-path (rather than plastic) is also not acknowledged.

Preston-Dunlop (1980, pp. 87-88; 1981, p. 44) and Hutchinson-Guest (1983, p. 167) consider the fundamental categories of paths as either straight or rounded. Preston-Dunlop (1980, pp. 87-88) describes a hierarchical taxonomy in which other categories of path-forms are derived from these two (Fig. IVB-4). "Angular" paths are composed of a series of two straight paths. "Simple curves" (ie. half-circle) are composed of a portion of a rounded path. "Circles" are a complete rounded path cycle. "Spirals" are rounded paths which gradually increase or decrease their diameter. "Repeated curves" are composed of a series of rounded paths. "Twisted" paths are rounded paths which change direction in the middle. "Simple twists" (S-shaped), "repeating twists" (8-shaped) and "twists with spiral" (S-shaped with a spiral at one end) are all variations of twisted paths.

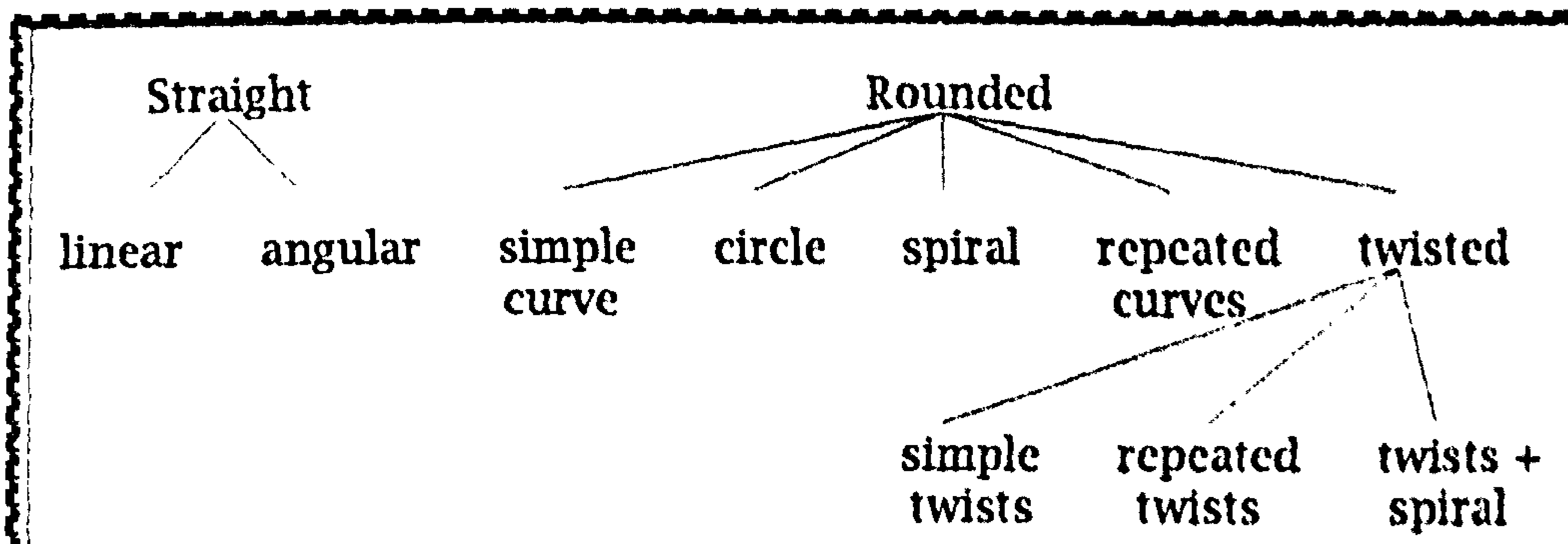


Figure IVB-4. Hierarchical path-form taxonomy (adopted from Preston-Dunlop, 1980, pp. 87-88).

Preston-Dunlop's analysis demonstrates how a large number of path categories can be organised into a hierarchical taxonomy. However, the underlying joint articulations which create the different paths are left unspecified. For example the unidirectional articulation which can only create a half-circle (eg. the curved path of the hand resulting from elbow articulation) is not distinguished from the changing directions of articulations required to produce a full-circle. This type of anatomical constraint identifies these as two separate types of path (as specified by Wincarls, 1958) rather than being derived from the same category.

In Lomax and Colleagues' (1968, pp. 262-273) "choreometric" coding book for use in anthropological studies of folk dances, they first describe the "shape of the transition", or the "linking point or hinge joining two phases of a movement" (p. 267) which includes categories of; vague, simple reversal, cyclic, angular, rotation, curved, and loop. In vague transitions the path is unclear and impossible to characterise. In simple reversal transitions the moving body-part returns to its starting point by retracing its path. In cyclic transitions the body-part returns to the starting point through a continuous circular path. In angular transitions the body-part changes its direction by sharply turning a corner. In rotation transitions the body-part changes its direction by using a rotary action. In curved transitions the body-part gradually changes its direction along a curved path. In looped transitions the body-part "links three different dimensions together" (p. 268). These categories need more clarification. For example, it appears that the same shape of path could be produced in both cyclic and curved transitions. The distinction of whether the path remains in the same plane is also vague. A curved transition is described as "a change of direction or plane" but later it is stated that it "must be continued within one plane" or it is called a loop (p. 268). Surely a plastic curve is not sufficient to form a loop, and this also does not allow for planar loops, or would these be considered to be cycles?

Lomax and Colleagues (1968) also describe the "shape of the main activity" or the "ways in which movement develops and defines patterns in space" (p. 268). Five categories are distinguished; "indefinite", "directional, use of planes-arc", "use of planes-round", and "three-dimensional". Indefinite shapes refer to a vague folding or unfolding of body-parts without a clear emphasis on any direction. Directional shapes are linear paths with a clear direction. Use of planes-arc are fan-like paths created by the motion of an entire limb or limb-segment within a single plane. Use of planes-round are rounded paths created by the successive folding or unfolding of all the segments of a limb within a single plane. Three-dimensional shapes are paths which do not remain in a single plane.

Some of these categories are also unclear. Why must "use of planes-round" require successive use of limb-segments? Into which category would a planar-round path created by circumduction be classified? If the continual changing directions of a circumduction is part of "use of planes-arc" then it is not distinguished from unidirectional arc-like motions. Are plastic loops classified together with plastic S-shaped waves as types of "three-dimensional" paths? The overall difference between the "shape of the transition" versus the "shape of the main activity" is also unclear. How are these distinguished? For example, what is the difference in the form of a path created by a "curve" transition versus a "planar-arc" main activity?

Some of these categories are similar to Moore and Yamamoto's (1988, p. 194) three general categories of pathway; 1) "straight lines", 2) "curved and arc-like", and 3) "complex three-dimensional loops, twists and spirals". These are essentially linear, planar, and plastic categories (see IVB.13).

Dell (1970, pp. 43-58) distinguishes three kinds of "change in the form of movement"; "shape flow", "directional", and "shaping", which each describe a "kind of bodily adaptation that may create the form" (p. 63). Shape-flow consists of generalised growing/shrinking, opening/closing movements without any clear spatial direction. Directional movement is "the most basic form in which movement establishes a relationship to the surrounding space" (p. 49). "Spoke-like" directional consists of simultaneous articulations in several joints within a limb causing the distal end to follow a straight path. "Arc-like" directional consists (typically) of articulation in a single joint causing the distal end of the linkage to follow a curved planar path. "Shaping" movements consist of the body molding itself in a sculptural-like way which "allows the mover to accommodate to the plastic character of objects in space" and requires the "constant blending of the muscle group functions in many joints" (p. 55).

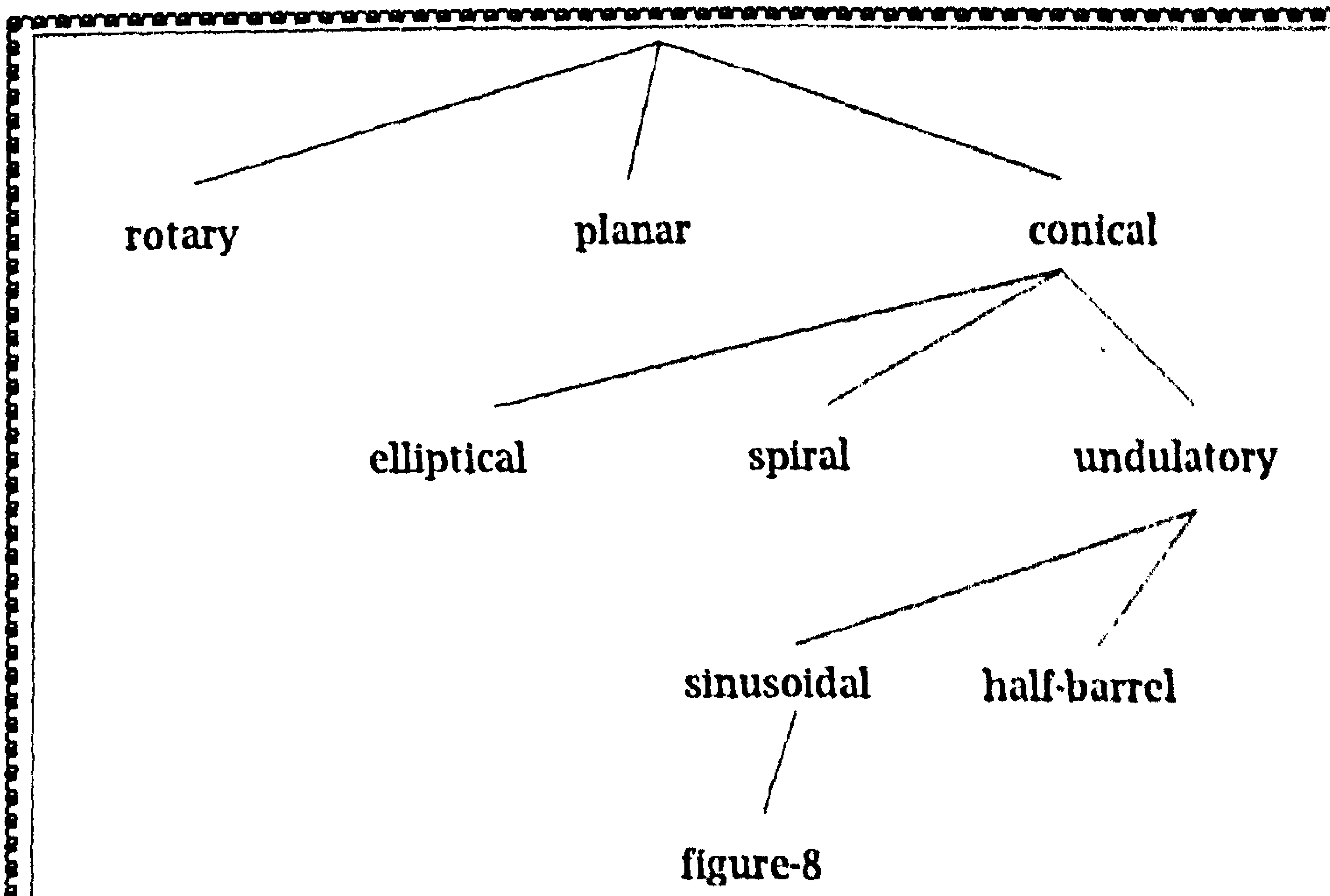


Figure IVB-5. Hierarchical path-form taxonomy (derived from Eshkol and Wachmann, 1958, pp. 6-11, 101-108).

Eshkol and Wachman (1958, pp. 6-11, 101-108) developed a hierarchical taxonomy of path-forms (Fig. IVB-5) based on the elemental anatomic constraint that the motion of the distal end of a body-part will always create a curved path with the articulating joint at the centre. Three types are initially distinguished; 1) "rotary movement" consisting of a body segment rotating around its own longitudinal axis; 2) "plane movement" consisting of a body segment moving within a plane; or 3) "curved surface movement" consisting of the body segment creating a cone-shaped path, later called "conical" movement (p. 101). Lower-order types of conical movement are categorised as; 3a) "elliptical" movement consisting of a elliptical-shaped path; 3b) "spiral" movement consisting of a series of conical or elliptical paths turning around the same axis while gradually becoming larger or smaller; and 3c) "undulatory" movement consisting of a series of conical or elliptical paths, each turning around a different axis. Two further categories are distinguished within the class of undulatory movements; 3c-1) "sinusoidal" undulatory movements consisting of a series of curves, each turning in the opposite direction (eg. "S"-shaped; a figure-8 is comprised of two sinusoidal movements); and 3c-2) "half-barrel" undulatory movements consisting of a series of curves turning in the same direction (eg. "m"-shaped).

Several similarities can be identified among these various conceptions of kinespheric path categories. A linear path of the distal end of a limb created by multi-joint articulations is well defined and explicitly identified as a straight path (Winearls, 1958), a spoke-like directional (Dell, 1970), a directional shape of the main activity (Lomax et al., 1968), and (implicitly) as composed of simultaneous component curved movements (Eshkol and Wachmann, 1958, p. 117). A planar curved path created by the unidirectional articulation of a single joint is also well defined and explicitly identified as a half-circle (Winearls, 1958), as arc-like directional (Dell, 1970), as use of planes-arc (Lomax et al., 1968), and as plane movement (Eshkol and Wachmann, 1958). A plastic path created by a sequence of articulations in many joints is explicitly identified as a winding S-path (Winearls, 1958), as shaping movement (Dell, 1970), as three-dimensional (Lomax et al., 1968; Moore and Yamamoto, 1988), and as loop transitions (Lomax et al., 1968).

Several discrepancies are also evident. Multi-joint linear paths are not often distinguished from single-joint planar paths (Feuillet, 1700; 1706; Moore and Yamamoto, 1988; Preston-Dunlop, 1980), indeed, Laban (1966, pp. 83-84) appears to group these together as a "simple line". Another problem is that the unidirectional articulation which carries a limb through a planar curved path (which can never be a full circle) is not explicitly distinguished from a series of directional articulations in one or several joints which carry a body segment through a conical-shaped curved path (which may be a partial or a full circle) (Dell, 1970; Lomax et al., 1968; Moore and Yamamoto, 1988; Preston-Dunlop, 1980). These two have been somewhat distinguished as half-circle versus full-circle (Winearls, 1958) or as plane movement versus conical movement (Eshkol and Wachmann, 1958).

In addition, joint articulation terminology needs to be kept distinct from the shape-of-the-path terminology. For example, when "rotation" transitions (Lomax et al., 1968) and "rotary movement" (Eshkol and Wachmann, 1958) are used to refer to path-shapes, this tends to neglect various other paths which can also be created by rotary articulations (eg. planar-curved, conical).

IVB.33 Choreutic Natural Sequences.

In the choreutic tradition certain sequences of paths have been categorised as "scales" (in the musical sense) or as "natural sequences":

> A series of natural sequences of movement exists which we follow in our various everyday activities. . . . [and] are determined by the anatomical structure of our body. These sequences, or scales, always link the different zones of the body and its limbs in a logical way. (Laban, 1966, p. 37)

Many choreutic scales are devised according to patterns of dynamic equilibrium which create three dimensionally symmetrical pathways (see IIID.50). Laban (1966) also considers that the pathway of movement often has a very particular form and that "the determining factor of this special arrangement is the purpose of the movement", which is attempted to be accomplished "with the greatest economy of effort" (pp. 43-44). Since "Everywhere economy of effort is in evidence" (p. 45) movements will be chosen which satisfy the goal in the simplest and easiest way. Laban's concept of economy of effort is identical to an important principal of body mechanics which states: "the individual tends to function in the way that affords the greatest conservation of energy" (Rasch and Burke, 1978, p. 98)

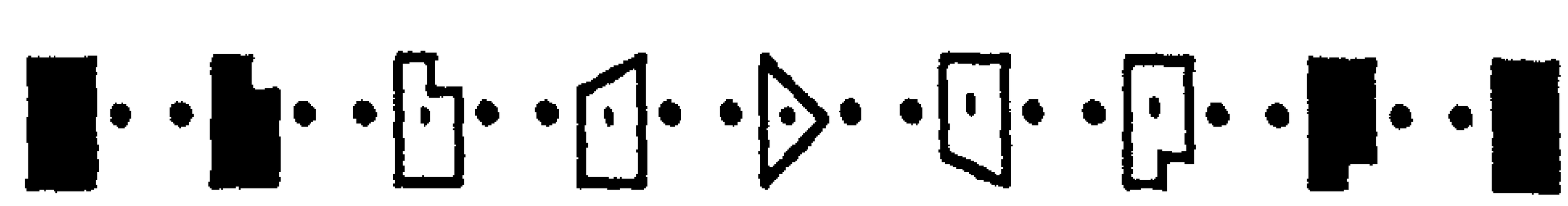
IVB.33a Zones and Super-zones of the Limbs.

Laban considers the range available for a limb's motion as a type of basic scale for that limb. He outlines the philosophy behind this approach:

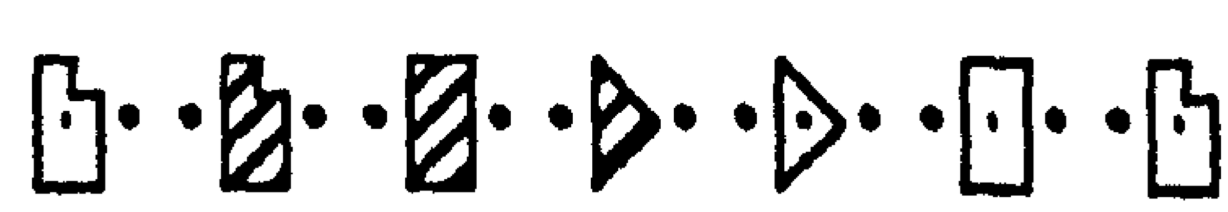
> Our body is constructed in a manner which enables us to reach certain points of the kinesphere with greater ease than others. An intensive study of the relationship between the architecture of the human body and its pathways in space facilitates the finding of harmonious patterns. . . .
>
> This science of harmonic circles has its origin in the discovery of the laws which rule the architecture of the body. It is obvious that harmonious movement follows the circles which are most appropriate to our bodily construction. (Laban, 1966, p. 25)

These "circles" seem to consist of the roughly circular paths referred to by Laban (1966) as "'circuits'", "chains", or "'rings'" (p. 21), which mark the maximum spatial range for each of the limbs. The terms "zone" or the "normal zone" of a limb are used for "that part of the kinesphere which can be reached by moving only the limb in question, without much additional movement" (p. 21) and the "'super-zone'" refers to the space which can be reached by the limb combined with torso movements (p. 23). These are similar to the concepts of the "normal work area" and "maximum work area" in studies of ergonomics (Damon et al., 1966, p. 317; Pheasant, 1986, pp. 141-142; See IIB.42) and might be referred to as the "cumulative range of the end member" (Dempster, 1955, p. 570; see IVA.72). A small amount of additional articulations from other joints is allowed within the conception of a limb's zone, and a large amount of additional articulations is allowed within a limb's super-zone. Limb's zones and super-zones contribute to determining the categories of paths which are available to the body.

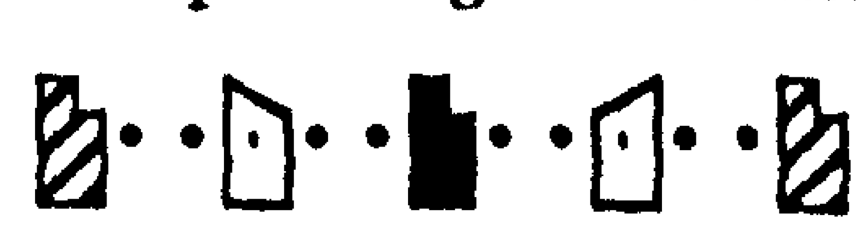
The normal zone of the leg is identified as an eight-part circuit (Laban, 1966, p. 22) (right-leg):



The normal zone of the arm is identified as a six-part circuit (Laban, 1966, p. 23) (right-arm):



A "zone easily followed" for the torso is identified as a four-part circuit which is "the prototype of a tetragonal or quadrangular circuit" (Laban, 1966, p. 23):



The super-zone for the arm is identified as a six-part circuit (Laban, 1966, p. 24) which is later referred to as a "girdle" (p. 69) or an "equator" (Preston-Dunlop, 1984, p. 41) (right-arm):

A seven-part circuit is also identified as a super-zone for the arm which "gives the basis for a harmonic order of the inclinations" (Laban, 1966, p. 25). This statement is not explained but appears to be related to an even more obscure discussion later:

> Plastic models of seven-linked movable chains [Fig. IVB-6] can be constructed which, when turned either by hand or in a mechanical manner, show by their progressive displacement spatial relationships in angles and distances. These correspond exactly to the sequences of the circle of fifths which constitute the backbone of the order of our musical tones. The borders of certain super-zones of the limbs of the body have the same formal rhythm showing identical harmonic relations. (Laban, 1966, pp. 120-121)

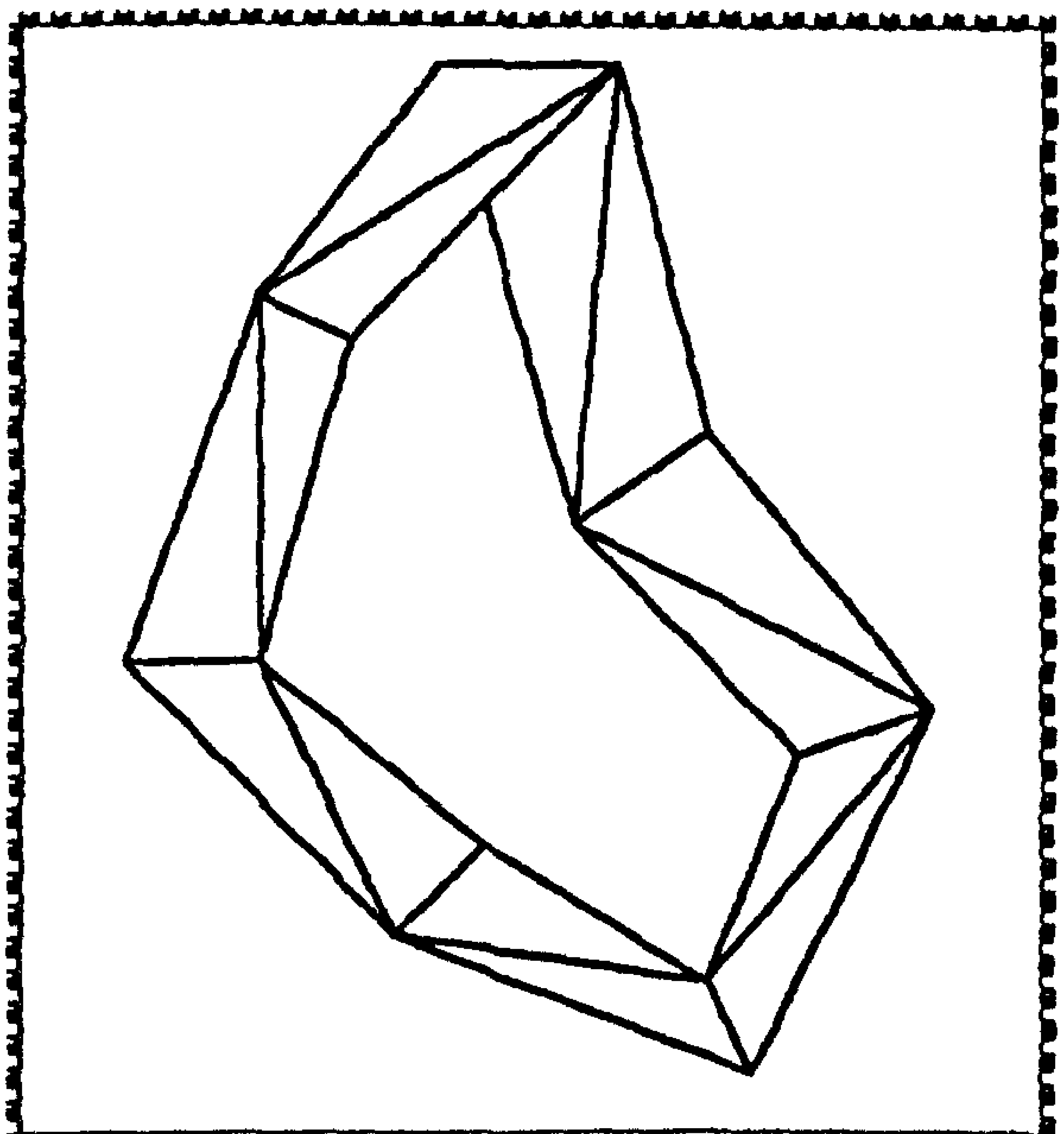
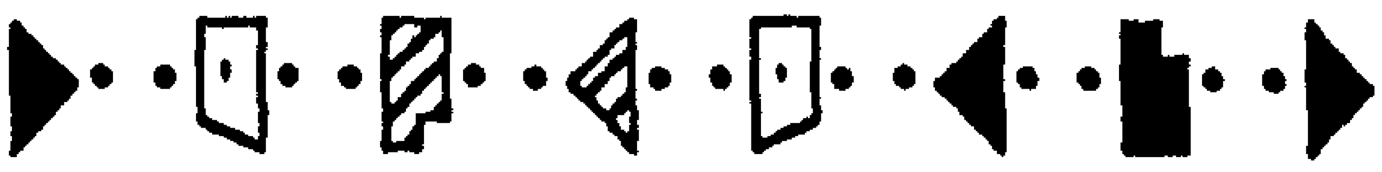
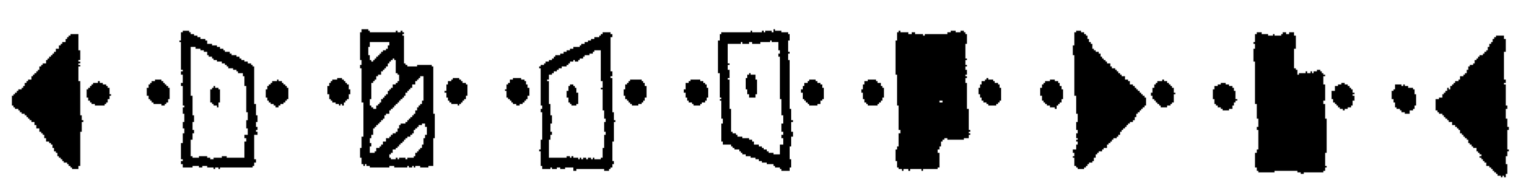


Figure IVB-6. Seven-link movable chain (adapted from Laban, 1966, p. 121).

This super-zone for the arm is later referred to as a "peripheral 7-ring" (Preston-Dunlop, 1984, p. 101) (right-arm):



The super-zone for the leg is identified as an eight-part circuit (Laban, 1966, p. 25) (right-leg):



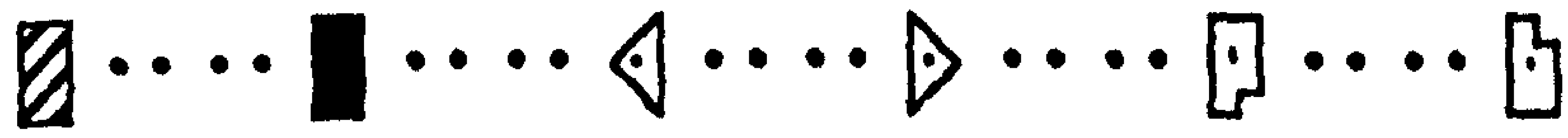
These differently shaped zones and super-zones appear to be at the basis of the development of choreutic natural sequences. Thus, they are the elemental forms of circuit-like paths.

IVB.33b Defense Sequence.

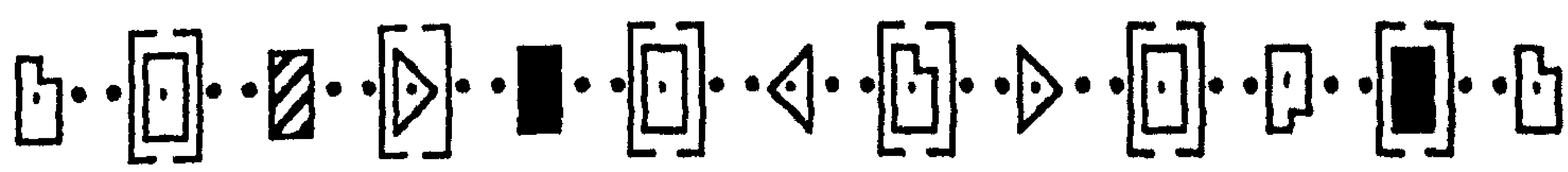
One of the principal "harmonic" paths identified by Laban is based on six movements used when defending oneself when fighting. These are especially identified in the "parrying" movements of sword fencing but Laban also conceives of "fighting" in a broader sense:

It is natural for all living organisms to use the simplest and easiest paths in space when fighting, not only when the fight is a matter of life and death, but also in other activities, since all working is a kind of fighting and struggling with objects and materials. (Laban, 1966, p. 45)

The defence sequence can be represented as a series of dimensional directions (for the right-arm) (Laban, 1966, pp. 37-38):



Laban (1966, p. 39-40) observes that the "defence sequence" actually "deviates" along curved paths either toward the centre or toward the periphery (deviations are in brackets):



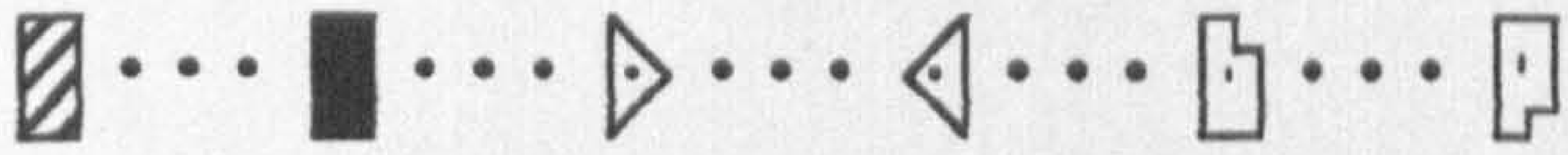
Laban (1966) states that these dimensional versions of the defense sequence are "simplified", and "In reality, the movement follows more complicated paths" (p. 39) (this is related to the deflection hypothesis; see IVA.85). In this case the "defense-scale takes on a slightly altered expression", "which is a deflected variation of the natural defence-scale" (p. 42) and appears as:

In addition, Laban (1966) describes a "dance-like variation" of the defense sequence which is "transformed into pure diagonals", has "a more flowing expression" and so is "less useful for practical defense" (p. 42):

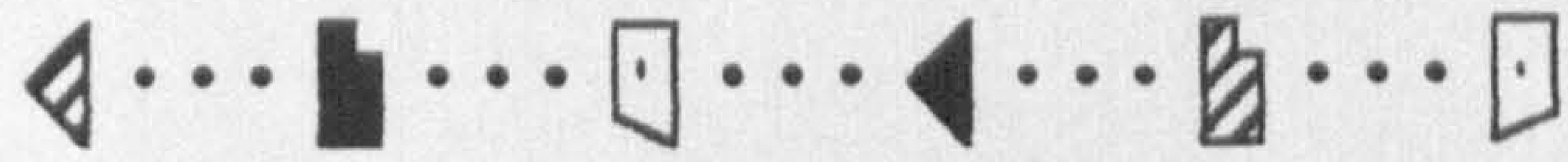
Laban (1966, p. 42) continues by suggesting that even "further variations of the defense scale" can be derived which are composed of mixtures of all the variations cited so far.

IVB.33c Attack Sequence.

Laban (1966, pp. 38-41) also refers to a pathway of attacking movements which is the "counterpart" of the defense sequence. These "proceed towards the central area of the adversary's body" and "the attacker shows a confluence of his movements approximately in front of himself no matter from which area they come". Later the "attack scale" is specified as a forward/backward and right/left reflection of the defense sequence (p. 80),* this yields the following:



This dimensional attack sequence is then conceived to deflect into the first six movements of a "transversal standard scale" which is considered to be the attacking "response- or echo-form" of the defensive transversal standard scale (Laban, 1966, p. 80):



IVB.33d Three-part Knot.

The defense sequence, the attack sequence, and the transversal standard scales are different from each other in that they are oriented in different directions and/or deflected into different inclinations. However these all appear to be variations of the same topological form which might be referred to as a "three-part knot".

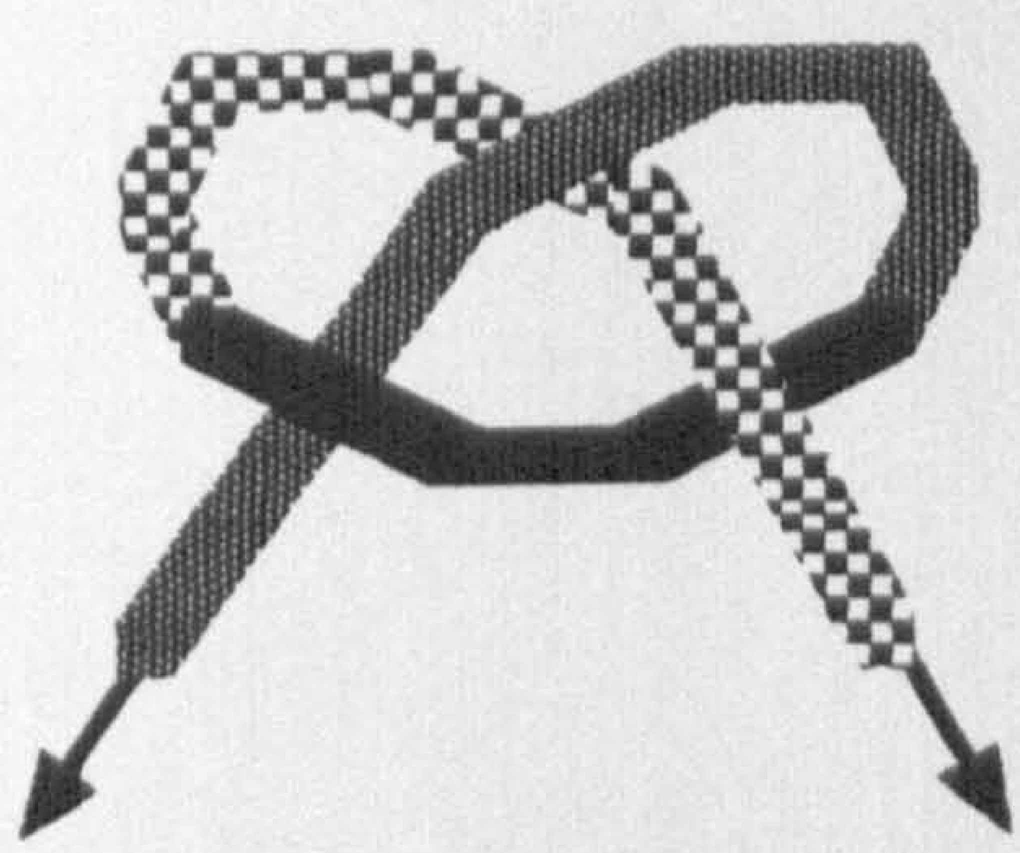


Figure IVB-7. Overhand knot.

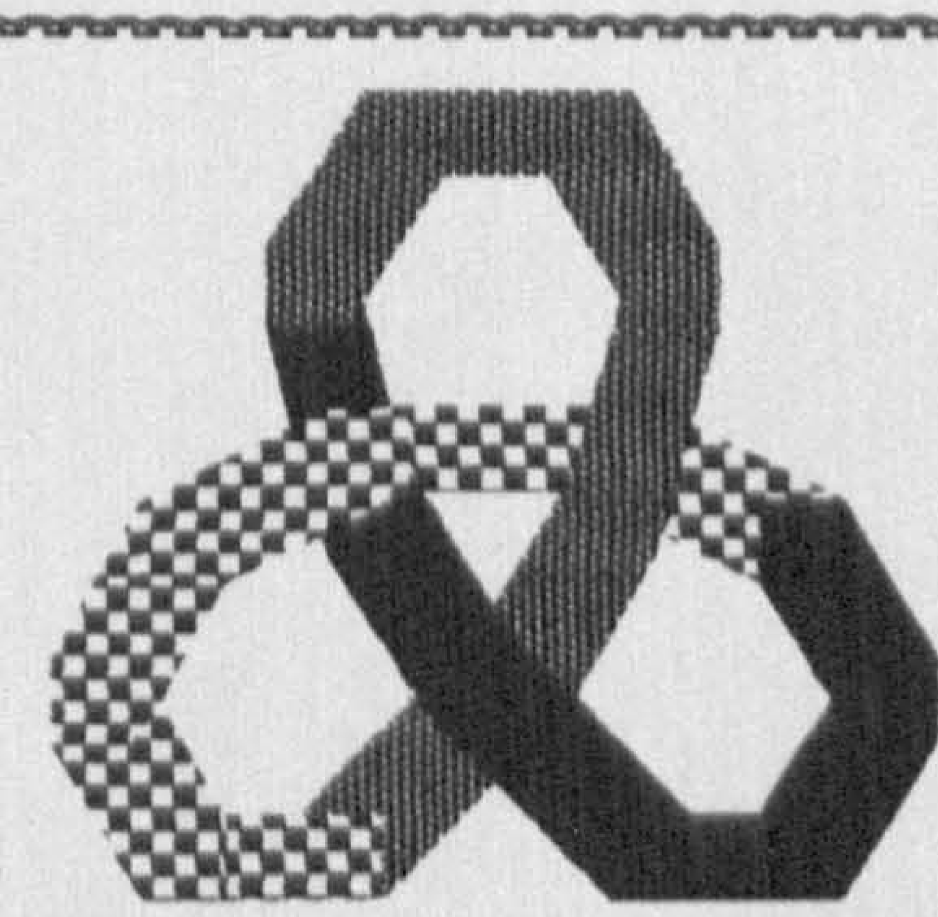


Figure IVB-8. Three-part knot (Adapted from Laban, 1966, p. 95; Laban Collection, S. B. N1, p. XXIX).

All knots are plastic forms since physical lines cannot remain in the same plane when they overlap. The "overhand knot" (Fig. IVB-7) "is the most common form of tie in existence, being used by almost everyone for many different purposes" (Graumont and Wenstrom, 1948, p. 49). If the ends of an overhand knot are joined then a three-part knot is formed (Fig. IVB-8). This knot was included in an unpublished book by Laban (Laban Collection, S. B. N1, p. XXIX).

Laban (1966, p. 96) used a three-part knot as a spatial model for the "standard scale of the dynamosphere" (ie. a sequence of dynamics, eg. force, timing) and

* If the paths of the "defense movements around our body can be fixed in space" and if "we turn half-way round, we find a scale which becomes an attack scale" (Laban, 1966, p. 80). This symmetrical transformation yields a reversal of the forward/back component and the right/left component relative to the body.

described its woven "knot-form" shape as "a kind of basket". Laban and Bodmer aligned this knot-form with the Cartesian planes of an icosahedral network (Laban Collection, 258.47) and refer to it as a "9-part knot" (Laban Collection, S. B. N1, p. XXIX) (Fig. IVB-9). Laban also illustrated the dimensional sequence with peripheral transitions along each of the Cartesian planes aligned with an octahedral network which can create the knot form (Laban Collection, 091.12) (Fig. IVB-10).

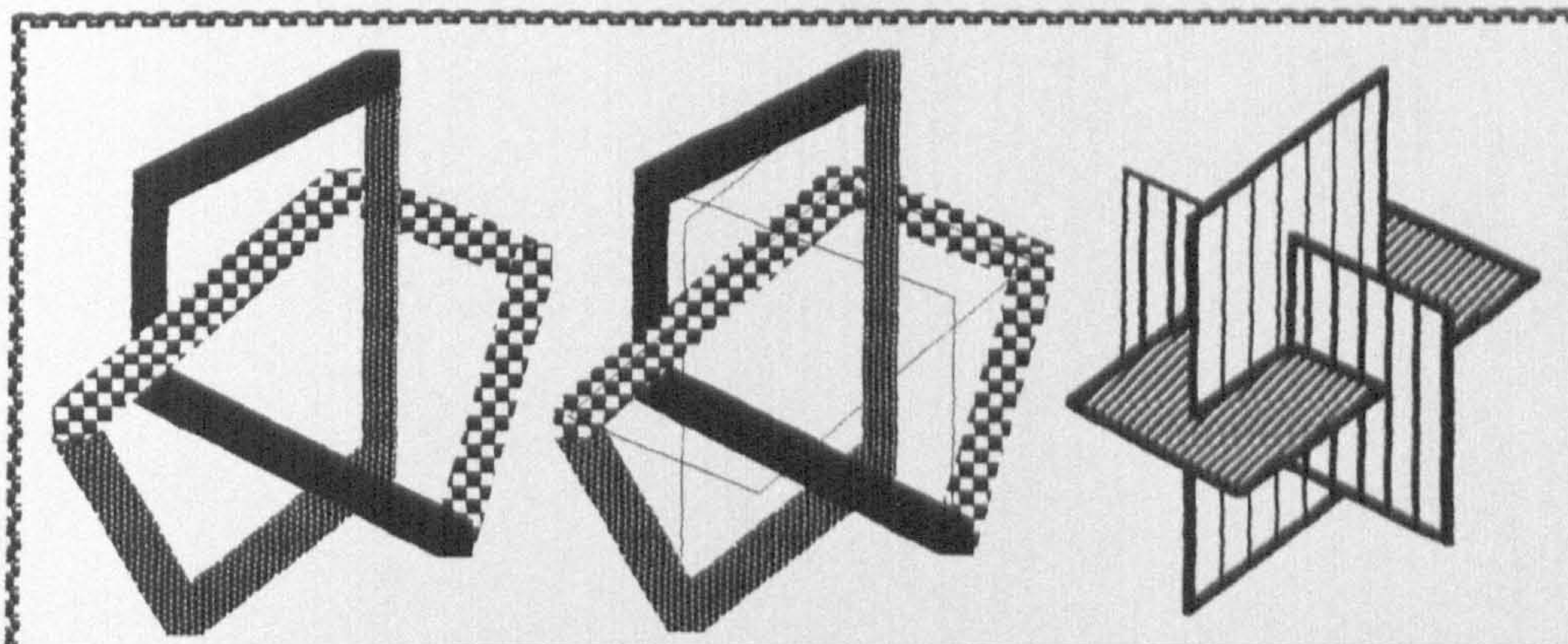


Figure IVB-9. Icosahedral planar sequence as 9-part plastic knot (adapted from Laban Collection, 258.47; S. B. N1, p. XXIX).

Whenever this knot is discussed it is closely associated with the peripheral 7-ring (see IVB.33a), and usually also with the lemniscate (see IVB.33e) and the 7-part movable chain (Fig. IVB-6). These all appear to be basic to Laban's choreutic conception and thus attest to the fundamentality of the knot in choreutics. The transversal standard scale (see IVB.33g) also consists of two three-part knots joined together.

The three-part knot is one of the simplest plastic shapes. It uses each of the three dimensions equally and can be divided into three identical parts. In its most symmetrical form each loop of the knot contains a curve relatively parallel to one of the Cartesian planes, followed by a transition to align with a different Cartesian plane. This pattern is repeated three times to complete the knot.

IVB.33e Lemniscate.

The form of a "lemniscate" or "Mobius strip" appears to also play a fundamental role as a path in choreutics but its use is obscure. Laban (1966) states that "They are of a dynamospheric [eg. force, timing] rather than of a kinespheric character" (p. 99) but the same terminology is used in both cases (the lemniscate is also referred to as a "trace-form") so whether this distinction between space and dynamics was always intended is not clear. Other lemniscates are described as "shadow-kernels of seven-ring sequences" (p. 99), referring to the seven-part super-zone for arm movement (see IVB.33a).

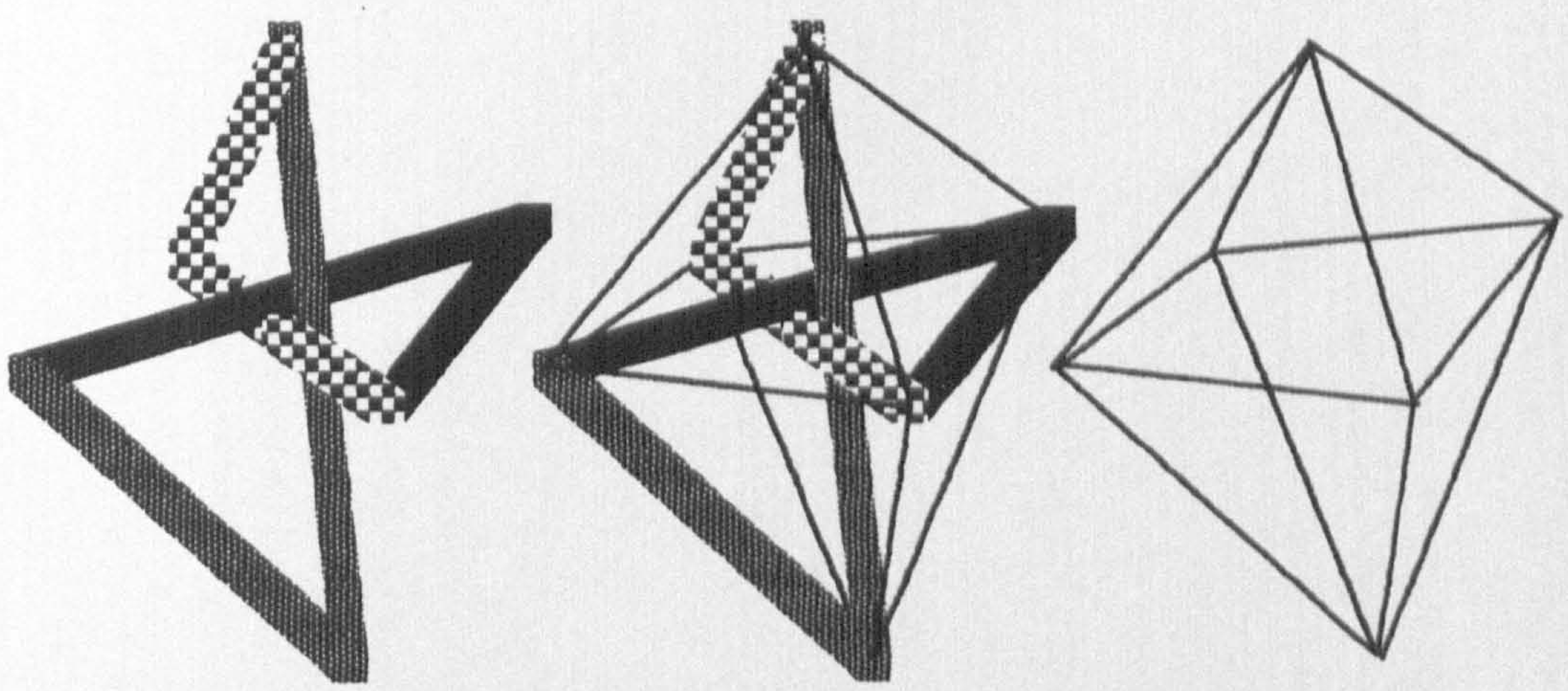


Figure IVB-10. Dimensional sequence as 6-part knot (adapted from Laban Collection, 091.12).

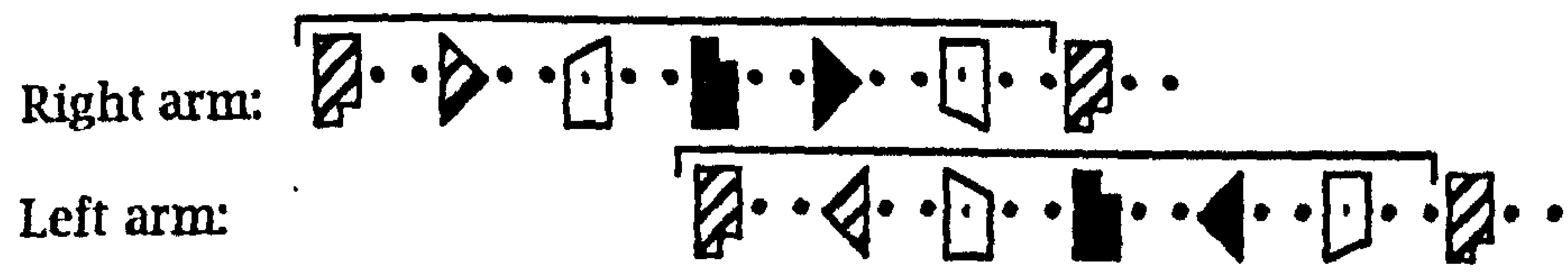
Interviews with Laban's students (McGivering, 1990) supports the interpretation that the lemniscate was used as a metaphor for the sequence of "inside-outside-inside-outside" etc. rather than as a strict geometric shape of a kinespheric path. Informal experimentation by this author has failed to identify any objective lemniscate-shaped forms which are typically produced by body movement. A typical figure-8 performed by an arm is common and exhibits the kinesthetic inside-outside sensation through the rotary articulations (see Appendix XVI) however, the forearm does not describe a lemniscate in space. Many of Bodmer's drawings and writings indicate the universal expressive metaphors associated with the lemniscate (Laban Collection, S. B. 38; S. B. 48 "The Lemniscate"), while other writings by Bodmer treat it as an objective kinespheric form (Laban Collection, "Three papers. . .") Future research might yield more information about the role of the lemniscate within choreutics.*

IVB.33f Crawl-like Movement.

Laban (1966, pp. 43-45) identifies a "winding loop" path which occurs during a "'crawl-like' movement of both arms" as when "propelling oneself through water". Each arm performs the path with one arm starting half way through (ie. in canon)

* For example, the Laban Collection (S. B. N1) contains a large hand-written untranslated German text "copied by S. Bodmer from a book by R. Laban" titled "*Harmonie lehre der Bewegung*" which appears to discuss the knot-form, lemniscates, 7-rings, and the 7-link movable chain. Unfortunately translation of this text was beyond the scope of this research.

(symbols read from left to right):



Laban (1966, pp. 43-44) considers the crawl-like movement and the defense sequence as representing fundamentally contrasting types of kinespheric paths. In the defense sequence "the dimensional directions prevail", a "firm foothold" is used which is "relatively static", "movements tend to be centralised" and consists of "a solo effort of one side of the body". In contrast, the crawl-like movement is "diagonally located", "fluid and much more mobile", "essentially peripheral" and consists of a "canon-like . . . duet" between the two arms. This crawl-like path does not appear to be explicitly referred to in any other choreutic literature.

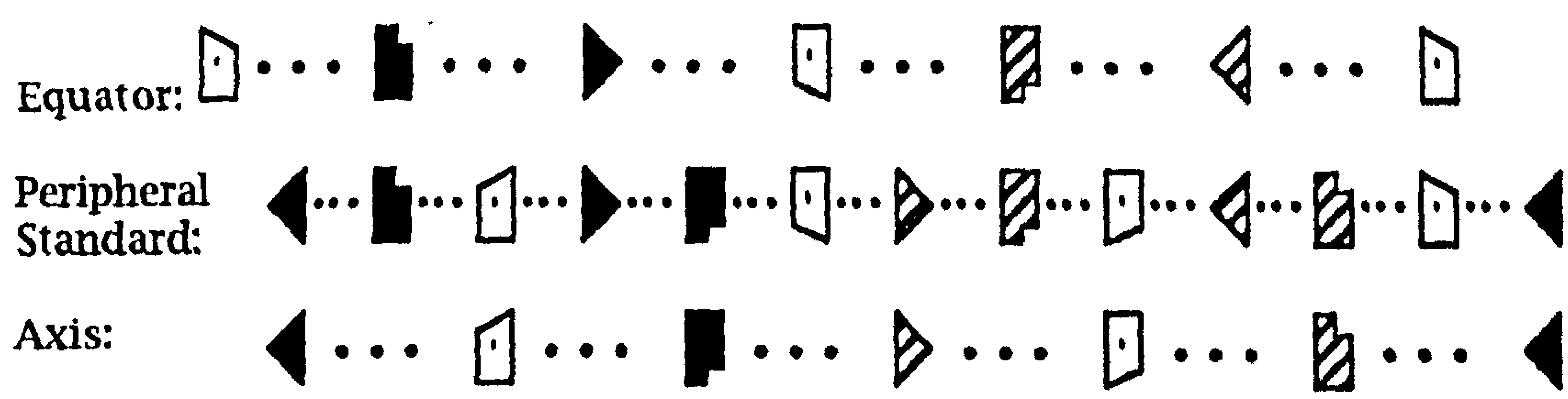
IVB.33g Axis, Equator, and Hybrid.

Laban (1966, pp. 68-72) draws a fundamental distinction between "axial" and "equatorial" movements (p. 70). This is a similar distinction as the one made between the defense and the crawl-like sequence.

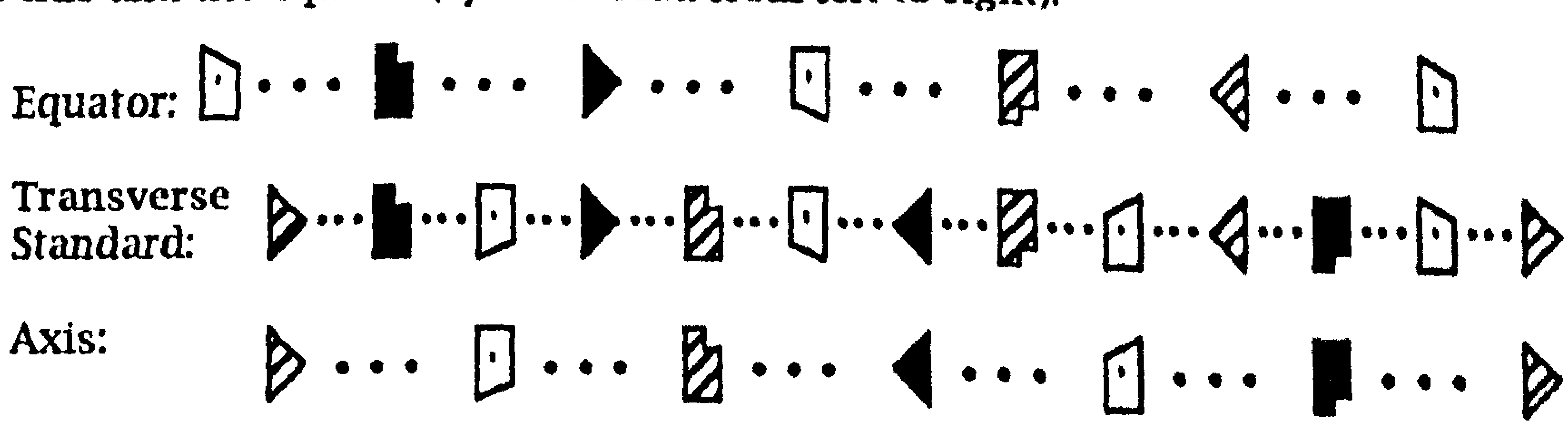
Axial paths include pure diagonal lines and a series of six transverse inclinations surrounding a diagonal which are roughly parallel deflections of it (for discussion of "deflections" see IVA.25). This zig-zag form is known as a "cluster" (Laban, 1966, p. 69), an "axis scale" (Ullmann, 1966, p. 179), or a "transverse 6-ring" (Preston-Dunlop, 1984, p. 39). Quadrangle-shaped paths are also identified, known as "mixed two rings" (Preston-Dunlop, 1984, p. 35), or "four-rings" (Laban, 1926, p. 36), which are described as having a relationship to the axial paths of a "connecting nature" since these are "bound together" (Laban, 1966, pp. 75-77).

Equatorial paths include six-part peripheral rings (one of the super-zones of the arm, see IVB.33a) known as a "girdle" (Laban, 1966, p. 69), an "equator scale" (Ullmann, 1966, p. 177), or a "peripheral 6-ring" (Preston-Dunlop, 1984, p. 41) and three-part peripheral rings around each end of the diagonal known as a "polar triangle" (Laban, 1966, p. 70) or a "peripheral 3-ring" (Ullmann, 1966, p. 181). These have the geometric forms of a great circle and a small circle respectively (Rich, 1963, p. 206). Other types of triangular-shaped equatorial paths are identified, some known as "transverse 3-rings" (Preston-Dunlop, 1984, p. 37), and others known as "cubic 3-rings" (Preston-Dunlop, 1984, p 31), which are described as having a relationship to the equatorial paths of a "separating nature" since they are roughly parallel (Laban, 1966, p. 76).

Laban (1966) contrasts the back-and-forth movements of axial paths which are "unconscious" "involuntary" and "automatic" with the orbital movements of equatorial paths which are "wakeful", "inspired" and "emphatic". A "hybrid offspring" is then identified as a "third mode of movement" which consists of "intermediary links" between the automatic and the emphatic. This third mode is used in "everyday working movements and general locomotion" and is considered to be "the prototype of all ordinary movement chains" in that it "can be shown to contain a series of shapes which are the basic elements of almost all trace-forms employed in movements". Thus, it is known as the "'standard' scale" or the "'primary' scale" (pp. 70-72). Choreutic standard scales are considered to be the model of kinespheric "harmony" and to represent "the criterion by which harmonic relations can be evaluated" (p. 82). One of the axis scales, its orbiting equator, and their intermediary hybrid standard scale is notated as follows (symbols read from left to right):

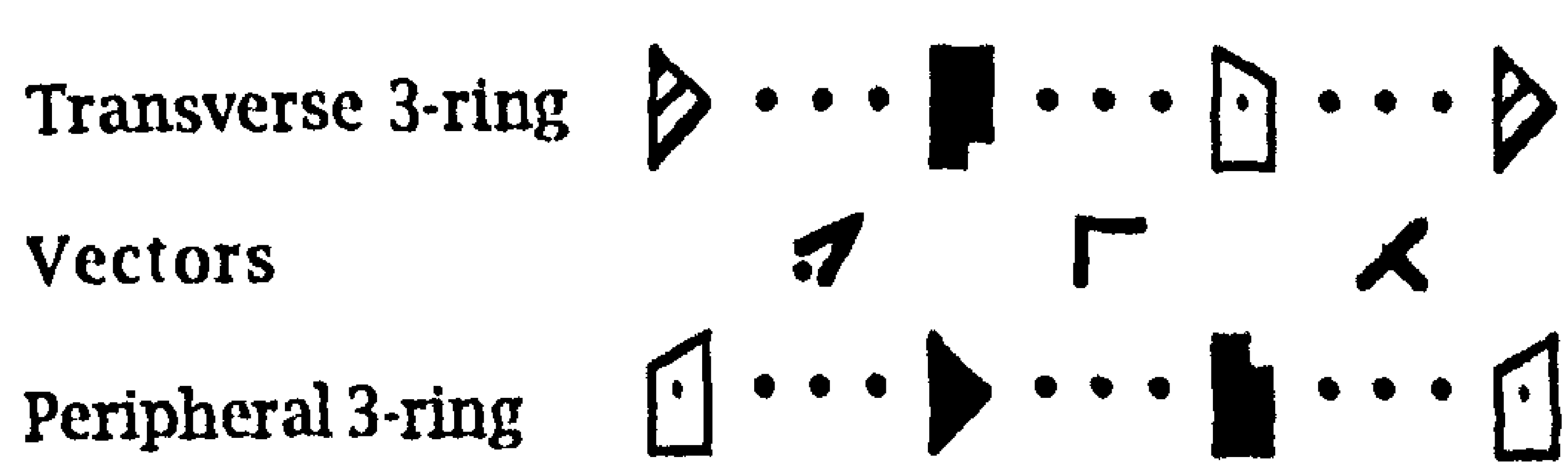


Another path is identified consisting of twelve transversals which is an "inner [ie. transverse] counterpoint of the surface [ie. peripheral] standard scale" and so is known as the "'transversal standard' scale" (Laban, 1966, p. 78), as the "A-scale" or "B-scale" (Ullmann, 1966, p. 157) or as a "transverse 12-ring" (Preston-Dunlop, 1984, p. 66). The transversal standard scale also has an intermediary hybrid relationship to the axis and the equator (symbols read from left to right):



The relationships between these choreutic forms can often be observed in the deviations which occur when they are bodily performed. For example, if a transverse path is bulged outward in its middle it will become a peripheral path. This deviation can result in a transverse 3-ring transforming into an equator and a (transverse) axis scale transforming into a (peripheral) standard scale (Salter, 1977, p. 137). Ullmann (1966, pp. 175-181) describes this type of deviation as the "circumvention of transversals".

Another transformation occurs between the equatorial transverse 3-rings and peripheral 3-rings. It can often be observed that when performing the great circle of a transverse 3-ring (eg. with the arm) that the small circle of a parallel peripheral 3-ring also spontaneously occurs with another part of the body (eg. the head) (personal observation). Indeed, these can be conceived as being the same identical path (ie. same slope of inclination), the one simply being performed larger than the other. Similarly, Ullmann (1966, p. 182) refers to the peripheral 3-rings as "reflections" of the transverse 3-rings. These both have the identical series of lines of motion and so can be notated with an identical series of "vector symbols" (see IVA.25c), for example (symbols read from left to right):



IVB.34 Kinespheric Paths as Topological.

In his famous studies of motor control, Bernstein (1984, pp.102-110) makes a distinction between the general configurations of topology and the specific sizes of metrics. Topological geometry considers the overall shape of a figure regardless of its specific size or metric distortions, this includes attributes of whether a figure is closed or open, if the lines intersect or not, which features are next to each other, or if one figure completely surrounds or encloses another figure. Bernstein further designates "topological properties of the first order" (p. 103) which includes the number of features (eg. angles, crossing lines) which are present in a figure.

Bernstein (1984) points out that each letter of the alphabet is in a separate first order topological class and that letters can be visually recognised regardless of metric variations (eg. relative length of line-segments, degree of curvature or straightness, embellishments and flourishes, and much of what could be called "style" in handwriting) (p. 104). Apparently visual recognition processes require only that the first order topological form which is unique to each letter be distinguished. Bernstein also proposes that "movements of live organisms, to no less a degree than their [visual] perceptions, are determined by topological categories" (p. 105). For example, it is not likely that a geometric form can be drawn to the exact same metric properties twice without the aid of a compass and ruler. Every new motor execution of a spatial form will have slightly different measurements, sometimes larger or smaller, more angular or more curved, more upright or more inclined (pp. 105-108). This metric variability always occurs involuntarily or it can be intentionally produced. The metric attributes of kinespheric form can be easily transformed as is shown in many varieties of motor symmetry transformations (eg. by changing size, changing the body use, rotating or moving the form, stretching or compressing its degree of curvature; see IIID). However, topological attributes can be easily reproduced at will, and recognised regardless of the metric variability. The essence of the form, which gives it its identity, is the particular collection of topological characteristics; "the general appearance - on a certain *je ne sais quoi* - that indubitably appears to be a topological category" (p. 105). Bernstein concludes that "the human motor system cannot attain any high degree of metric proficiency, but it can be said that our motor system is very sensitive to topological distinctions" (p. 105), and so "an obvious preference of the motor field [is] for topological categories as compared with metric ones" (p. 108).

The structure of the kinespheric network (see IIIC.30; IVA.80-.90) will vary according to the changing metric quantities (degree of curvature, angle of direction). Bernstein (1984) characterises the variable metric structure of the kinespheric net as the "co-ordinational net of the motor field [which] must be regarded, in distinction to a net in Euclidian geometry, firstly as non-rectilinear, and secondly as oscillating like a cobweb in the wind" (p. 109). These oscillations are the stretching and bending of the kinespheric net as the metric quantities of movement vary on each successive execution (depending on the conditions at the particular moment) while the overall essential topological pattern of the structure remains unchanged.

The choreutic system of kinespheric forms appears to be structured in this same way. For example, as discussed in regards to the "defence sequence" (IVB.33b) a single topological form can be bodily executed relative to the dimensional directions (octahedral net), diametral directions (icosahedral net), the diagonal directions (cubic net) or combinations and further variations of these. The choreutic concept of a "deflection" (see IVA.80) is related to Bernstein's concept of the "oscillation" of the motor field. Bodmer considers choreutic forms in this same way:

> I would like to stress at the beginning: That the same topological forms or links of spatial relationships can be traced through all the different crystalline structures. Regular and irregular [polyhedral] forms or structures can be formed in all equally. (Bodmer; in Laban Collection, S. B.48 "Space orientation and Harmony")

Bernstein (1984) supposes that the language of the kinesthetic perceptual-motor system is based on topological information. Kinesthetic-motor knowledge may be mentally represented as a "higher directional engram . . . which may be called the engram of a given topological class . . . [and] is extremely geometrical, representing a vary abstract motor image of space" (p. 109).

These types of topological classes can be deciphered within choreutic kinespheric forms. As reviewed above (IVA.85; IVB.33b) the topological shape of the defense sequence occurs as the "dimensional scale", the "diagonal scale" and the "'A' and 'B' scales". Also, for example, the topological shape of a "6-ring" occurs towards dimensional directions, diagonal directions, diametral directions, and may be either extended out to the periphery or contracted in through the interior (transverse) (Preston-Dunlop, 1984). The ability to distinguish the fine metric variations between the slightly different orientations of different movements only comes with increased practice and Laban (1966, p. 101) states that for "general observation" that the fine metric variations are "not vitally important".

In this way the choreutic kinespheric "scales" provide the performer with an organised cognitive structure (ie. topological forms mapped out on various conceptual kinespheric nets) which can be used to guide oneself through different kinespheric topological classes, each performed with a variety of metric variations. Each topological pattern (ie. a sequence such as a "6-ring") and each metric variation (eg. more dimensional or more inclinational), gives the mover kinesthetic spatial (and so neural-muscular-skeletal) experiences of systematically exploring the variety of possible kinespheric forms.

The fundamental role of topology has also been identified in other spatial cognition studies. The famous child psychologists Piaget and Inhelder (1967) used a variety of spatial tasks (eg. feeling an unseen shape and then recognising it visually; drawing the shape of a human body or of geometric figures; constructing shapes with match sticks; placing beads on a rod in a certain order; recognising or tying knots) which revealed that childrens' spatial knowledge begins at a stage where topological relationships are recognised, and gradually develops to a stage where Euclidean geometrical relations are comprehended. Sauvy and Sauvy (1974) report on similar experiments with children which produced similar results of topological characteristics being learned first.

Research into cognitive maps of larger scale environments (see IIIC.10) has also revealed that when learning a space through actual experience (eg. walking around a town centre or through the rooms in a building) that topological relations are learned first (eg. what-is-next-to-what along a particular route), and only after long-term learning are the true Euclidean directions and distances accurately learned (Moar, 1978). Indeed, map-like spatial representations are typically based on the "topological connectedness" of the order of loci and turns, however the exact distances traveled and angle of turns are not well known and so are approximated close to a prototypical value (eg. 45° or 90° angles) (Byrne, 1979, p. 153; see IVA.53).

IVB.35 Method for Deriving a Taxonomy of Kinespheric Paths.

A method is developed here for deriving a taxonomy of kinespheric pathways based on categories developed in choreutics and dance, anatomical constraints identified in kinesiology, and models of motor control. The initial taxonomy considers only pathways of limb-motions created by concentric (shortening) muscular contractions.

The taxonomy is based on the fundamental motion of the skeletal system which is angular movement. This is developed into more complex movements according to the three factors of; 1) single-joint versus multi-joint articulations; 2) single-phase versus multi-phase action; and 3) discrete versus gradual transitions between phases. These taxonomic attributes are briefly presented here, and an initial taxonomy is presented in Appendix XVI.

IVB.35a Skeletal system produces angular motion.

Skeletal articulations at a single-joint always produce angular motion, that is, a curved line of the distal end of the body segment with the articulating joint at the centre of the curve. Angular articulations (eg. bending the elbow) are typically distinguished from rotary articulations (eg. the humerus rotates around its own longitudinal axis) but these both produce angular motion of any point that is not exactly on the rotational axis. The angular motion resulting from a rotatory articulation can be very large as in the case of forearm/hand motion produced by shoulder rotation when the elbow is flexed. Therefore these both are considered to be essentially the same type of angular motion.

IVB.35b Single-joint versus multi-joint articulations.

The pathway of the distal end of a limb (eg. the hand) can be created by articulations in a single joint (eg. the shoulder), or in multiple joints (eg. vertebral joints, sternal clavicular joint, shoulder, elbow, wrist). Complexity increases as the number of articulating joints increases. These can generally be distinguished as single-joint versus multi-joint articulations.

IVB.35c Single-phase versus Multi-phase Action.

The notion of a phase of muscular action can be used to refer to a single action of a particular muscle group as it moves the body in a single direction. Muscles are attached to tendons which attach to bones. When a muscle contracts it pulls the points of bony attachment closer together along the shortest possible route which can be referred to as the muscles' "line of pull" or the "line of application of the force" (Rasch and Burke, 1978, pp. 34, 117; Wells and Luttgens, 1976, pp. 37-38, 77).

The amount of muscular shortening and skeletal motion are limited by several factors including: the muscle's shortest possible state; the longest possible state of the antagonist muscles and ligaments around the articulating joint; bony stops (eg. elbow or knee extension), and the bulk of muscle and fat tissue (eg. elbow or knee flexion). Once a limit of motion has been reached the only way for motion to continue is for a different muscle group to contract, thus changing the direction of the line of pull.

The mass-spring model of motor control posits that the elemental unit of body-movement consists of a single motion toward a new "equilibrium point" where there is equal tension between agonist and antagonist muscles (Bizzi and Mussa-Ivaldi, 1989; Jordan and Rosenbaum, 1989; see IIIB.20). In related studies of "trajectory formation" (ie. how the motor system produces complex pathways) measurements of the degree of path curvature and the velocity along the path both revealed that a path was divided into several "path segments" separated by "curvature peaks" (Abend et al., 1982; Morasso, 1983b; see IIIB.30). A model for the production of complex paths was developed in which the path segments are referred to as "strokes" which are "abstract representations" of kinespheric information (Morasso et al., 1983, p. 97) and so appear to be the "primitive movements in the motor repertoire" (Morasso, 1986, p. 44). Laban (1966, pp. 27-28) also identified these same attributes and referred to them as "'peaks' within the trace-form" and "phases of its pathway" (see IIIB.40).

The notion of a "phase" of action is used here as the muscular counterpart to a spatial "stroke" which indicates that one muscle group is shortening (also implying that the antagonists are lengthening). When a new muscle group begins to shorten this can be referred to as a new phase and will produce a new stroke. Since each muscle group has a different line of pull, each phase will produce a stroke moving in a different direction (even if only slightly).

This notion of "phases" of an action has also been used in kinesiology (Rasch and Burke, 1978, p. 50; Wells and Luttigens, 1976, p. 45), motor control studies (Tuller et al., 1982, pp. 259-260), and in choreutics (Bartenieff and Lewis, 1980, pp. 73-78; Laban, 1966, pp. 27-28) to refer to the different component sub-movements or individual contractions of muscle groups within a larger movement phrase. The term "phasing" is also used to refer to the relative timing among the components within a movement sequence (Shapiro and Schmidt, 1982, p. 136; Wing, 1980).

A single phase is a contraction of a muscle group which moves the skeleton along a single line of pull and exhibits a single spatial stroke. According to the mass-spring model of motor control, agonist/antagonist equilibrium positions serve as guiding points. Assuming the movement continues, at each guiding point a curvature peak will be exhibited during the transition from one phase to the next. The next phase necessarily consists of a different muscle-group (even if only slightly) which moves the skeleton along a new line of pull.

IVB.35d Phase transitions: discrete (angular) versus gradual (curved).

A traditional view in dance and choreutics draws an initial distinction between straight versus curved paths, and then posits that angles are composed of a series of straight paths while rounds, loops, figure-8s, etc. are composed of a series of curved paths (Preston-Dunlop, 1980, pp. 87-88; 1981, p. 44; Hutchinson-Guest, 1983, p. 167). This view is not adopted here for two principal reasons. Curved paths are the fundamental motion produced by skeletal articulations. Straight paths are comprised of two or more simultaneous component curved paths and so must be considered to be kinesiologically more complex. Also, straight paths are not necessary to produce angles since an angle may occur at an abrupt transition between two curved paths.

Instead, the conception of "trajectory formation" developed by Morasso and Colleagues (Morasso, 1986; Morasso et al., 1983) will be followed here. This model posits that the motor system executes a spatial trajectory by producing a series of "path segments" or "strokes". Angular transitions between strokes occur when they are performed in a discontinuous manner, whereas a partial time overlap between consecutive strokes causes one stroke to be blended into the next creating a smoothly curving transition. That is, one stroke begins before the previous stroke has ended and so the two strokes are momentarily superimposed. This model of "trajectory formation" is identified as being similar to "spline functions" which generate curved lines from a series of straight vectors in computer graphics (Morasso, 1986, pp. 38-42) such that "the desired shape is approximated by means of a polygon" and then "the sides of the polygon are generated and superimposed" (Morasso et al., 1983, p. 86). The amount which two consecutive polygon edges are overlapped (ie. "superimposed") determines the degree of curvature between successive strokes.

According to this model an "S"-shaped and a "Z"-shaped wave are classified into the same category, the only difference being the type of transition between strokes. This conception appears to have been implicitly followed by Laban (1966) when he classified a "2"-shaped path (which includes an angle) as being an "S"-shaped wave (pp. 83-84). Laban also asserted that "to perform angular sections, we must give each section a special accentuation" (p. 46), and thus a "cone-shaped trace-form" can be "executed smoothly in a continuously curving pattern" or the "same trace-form" can be "executed in a broken or angular way, with almost imperceptible pauses between each section" (p. 47). Similarly, Laban (1963, pp. 93-94) describes that "movements . . . can be performed either fluently or angularly. In fluent performance more stress will normally be laid on the paths, and in angular performance on the points".

The fluent, overlapping, transitions creating curves between strokes can be referred to as "gradual" phase transitions. The broken, abrupt transitions creating angles between strokes can be referred to as "discrete" phase transitions.

These four taxonomic attributes: 1) The fundamental curved movement; 2) Single-joint versus multi-joint articulations; 3) Single-phase versus multi phase actions, and; 4) Discrete or gradual phase transitions; can be used to develop a taxonomy of kinespheric paths. An initial exploratory taxonomy has been developed and is presented in Appendix XVI. Further refinements to this type of taxonomy based on characteristics of anatomy and motor control can lead to a kinesiologically valid categorisation scheme. This is a matter for future research.

IVB.40 Conclusions: Categories of Kinespheric Form

Hypothetical categories of kinesthetic spatial information are distinguished in dance and choreutics. These can possibly contribute to the need for defining a "class" of movement which has been identified as a fundamental problem in evaluating the schema theory for motor learning. Spatial perception research indicates that the primitive element of kinespheric poses is the straight body segment (eg. as in a "stick figure" representation of an animal's body). Individual segments are organised into higher-order groupings (eg. ball-like, pentagon-shaped, "X"-shaped) according to the Gestalt principles of perceptual grouping. Motor control research indicates that the primitive element of kinespheric paths is the curved stroke between locations. Individual curved strokes can be organised into higher-order groupings (eg. straight paths, angles, loops, figure-8) according the possibilities afforded by kinesiological constraints. A method for developing a kinesiologically valid taxonomy of kinespheric forms is presented. Further refinements to an initial taxonomy developed here is a matter for future research.

Since visual and kinesthetic spatial forms can be easily recognised or produced regardless of metric variations, Bernstein asserts that they are mentally represented as "topological categories" which are embodied with slightly different metric variations on each successive physical execution yet the essential topological form is unchanged. Thus, Bernstein (1984, p. 109) describes the "co-ordinational net of the motor field . . . as oscillating like a cobweb in the wind". This is virtually identical to the choreutic conception where kinespheric "natural sequences" are based on a contrast of "axial" versus "equatorial" shapes of motion, together with an intermediary "hybrid" and these topological forms are conceived to deflect across various polyhedral-shaped cognitive map-like images of the kinespheric network.

IVB.50 Experiment: Subjective Organisation in Kinesthetic Recall

A question for the psychological study of kinesthetic perception and memory is whether kinesthetic spatial (ie. "kinespheric") forms are actually cognitively organised into categories, and if so, what attributes determine category membership.

Does the notion of kinespheric categories have any psychological validity?

The well established "clustering" or "subjective organisation" effect in verbal cognition research describes how items are recalled in an order which is indicative of how they have been cognitively categorised. It was hypothesized here that this effect might also occur for kinespheric recall. If items are grouped together during recall it may be indicative of the type of kinespheric categories which are used.

IVB.51 Clustering and Subjective Organisation.

IVB.51a Theory.

Bousfield and Sedgewick (1944) noted that during the free recall of words "successive associations tend to occur in clusters" (p. 153). They observed that when Subjects listed members of a category (eg. "animals") the category members were spontaneously clustered together into groups of smaller sub-categories (eg. "domesticated animals", "animals commonly in zoos", or "related species in zoological taxonomy"). Many other experiments demonstrated this clustering effect which occurs whenever Subjects are free to recall a group of stimuli in any order (free recall). A variety of stimuli have been observed to be spontaneously organised into clusters, these include randomised lists of words from different categories (eg. animals, vegetables, human names, professions) (Bousfield, 1951; 1953), stimulus-response associated word-pairs (eg. table-chair; slow-fast) (Deese, 1959; Jenkins and Russell, 1952), sets of synonyms (Cofer, 1959), typical sequences of events in "script schemas" (Bower and Clark-Meyers, 1980; Rabinowitz and Mandler, 1983), and episodes within a story (Black and Bower, 1979). Clustering was also found to occur even when the group of items to be recalled did not obviously belong to any sub-categories but the words all appeared to be "unrelated" (Bousfield et al., 1964; Tulving, 1962).

In Miller's (1956) famous paper he discussed this clustering effect in terms of "chunks" and describes how learning and recall include an operation of "grouping or organising the input sequence into units or chunks" (p. 93). Since this organisation of the items is imposed by the Subject, Tulving (1962; 1966) referred to it as "subjective organisation". He discussed this organisation as consisting of "higher-order memory units" which are referred to as "subjective units" (S-units). Tulving's "S-unit" is generally synonymous with Miller's (1956) "chunk".

The clustering effect was explained as occurring when Subjects bring related items together on the basis of their "inter-item associative strength" (Deese, 1959; Jenkins and Russell, 1952). Deese (1959) statistically defined this as "the average relative frequency with which all items in a list tend to elicit all other items in the same list as free associates" (p. 305). Wallace (1970) proposed a "contiguity principle" to explain clustering and subjective organisation. Jacoby (1974) described how this "implicit contiguity" occurs as a result of actively associating items together by "looking back through memory so as to bring the items together in mental experience" (p. 483). Thus, when a subject "thinks" about two items together, then a contiguity of experience is created between these items, even if the items do not have an obvious association. When items are "experienced" together in this way they also tend to be recalled together.

IVB.51b Correlation of Subjective Organisation and Learning.

The amount of subjective organisation is usually correlated with the amount recalled (Anderson and Watts, 1969; Tulving, 1962). This correlation has been explained in several ways.

Deese (1959) asserted that if there is a high degree of "inter-item associative strength" that each item will serve as a cue to assist in recalling the other items. That is, "recall is good or poor depending, then, upon the tendency of free associations from items within the list to converge upon other items within the list" (p. 311).

Miller (1956) surveyed learning situations involving a range of stimulus-types and found that immediate memory has a general capacity of 7, plus-or-minus 2, chunks. Each chunk of information contains several "bits" of information. The capacity in immediate memory for 7 chunks appears to be relatively stable regardless of how many information-bits are contained within each information-chunk. Thus, memory capacity is increased by a strategy which involves recoding stimuli into fewer and fewer chunks, with more and more information-bits in each chunk.

Similarly, Tulving (1966) argued that the increase in amount recalled over successive free recall trials is a result of increasing the size of the S-units. This organisation benefits memory since a group of items is recalled all together as one, in a "higher-order memory unit", rather than each item having to be recalled separately.

This creates a memory hierarchy with higher-order units containing lower-order members. Subjects impose this hierarchical structure onto the items-to-be-learned as a strategy to assist learning and recall (Bower et al., 1969a; Tulving and Pearlstone, 1966). Mandler (1967) proposed additional levels of hierarchical organisation through an "extension of Miller's unitization hypothesis" (p. 332) in which the information-chunks themselves are recoded into even higher-order "superchunks". A hierarchical arrangement is proposed of high-order chunks or units containing many lower-order chunks which in turn contain many information-bits. This makes it theoretically possible to increase memory capacity indefinitely (Bower et al., 1969b; Ericsson et al., 1980). Mandler explains:

> A hierarchical system recodes the input into chunks with a limited set of [7 plus-or-minus 2] items per chunk and then goes on to the next level of organization, where the first-order chunks are recoded into "superchunks," with the same limit applying to this level, and so forth. The only limit [for the capacity of memory], then, appears to be the number of levels the system can handle. (Mandler, 1967, p. 332)

IVB.51c Typical Effects Accompanying Subjective Organisation .

Several learning and recall effects have been identified which are correlated with subjective organisation. These indicate the importance of categorical organisation within learning and memory: 1) The amount of subjective organisation is positively correlated with the amount of items recalled (Bousfield et al., 1964; Hyde and Jenkins, 1969; 1973; Puff et al., 1977; Tulving, 1962; Thompson et al., 1972). Sometimes this correlation does not occur if there is only a slight relationship between the members of the categories ("weak" categories) (Puff, 1970; Puff et al., 1977). 2) Pre-organised lists of items-to-be-learned are easier to learn than disorganised lists (Bower et al., 1969a; Bower and Clark-Meyers, 1980; Broadbent et al., 1978; Puff, 1970; Tulving and Patterson, 1968). 3) The amount recalled is higher for lists of items which can be readily clustered into obvious categories than for lists of items not containing any obvious categories (Deese, 1959; Tulving and Patterson, 1968). 4) When Subjects are forced to adopt a different organisation, or are prevented from utilising their own preferred subjective organisation, then the quantity recalled decreases (Bower, 1970c; Bower et al., 1969b; Mandler and Pearlstone, 1966; Tulving, 1966). 5) Recall and subjective organisation are higher when Subjects are specifically instructed to categorise the items (Mandler and Pearlstone, 1966), to judge the items in such a way that requires their categorisation (Hyde and Jenkins, 1969; 1973; Johnston and Jenkins, 1971; Mandler and Lewis, 1984), or if Subjects are cued with the category names (Tulving and Pearlstone, 1966). 6) Clusters are also revealed by the timing of responses. Items within the same cluster are recalled in rapid succession, there is then a short pause before another cluster of items is recalled in rapid succession (Mclean and Gregg, 1967; Reitman and Rueter, 1980).

IVB.51d Measurement of Subjective Organisation.

Initial measurements of the amount of clustering were based on Experimenters' foreknowledge about the categories which were available within the stimulus list. It was simply observed how may items belonging to the same (predetermined) category had been clustered together in Subjects' recall orders. However, subjective organisation was also found to occur when the group of items did not obviously belong to any categories, but appeared to be "unrelated" (Bousfield et al., 1964; Tulving, 1962). Therefore, researchers developed methods to quantify the amount of subjective organisation regardless of whether obvious categories were available in the stimulus list.

Tulving's (1962) statistical measurement of subjective organisation (SO measure) was based on the "sequential redundancy" (p. 345) which refers to the frequency with which items appear in the same adjacent order in consecutive recall trials. When the items to be remembered are presented to Subjects in a different random order for each of several learning trials (ie. an absence of sequential redundancy), the subjective organisation of the items is evidenced when the Subject recalls the items in a consistent order across several recall trials (ie. exhibiting sequential redundancy). The amount of subjective organisation across successive recall trials can be represented by the ratio of the obtained redundancy to the maximum possible redundancy.

The problem with the SO measure is that it does not include any correction for the amount of organisation which might be expected to occur by chance. A modified form of the SO measure was developed which also included a computation of "chance". This was termed "intertrial repetition" (ITR) (A. K. Bousfield and Bousfield, 1966; W. A. Bousfield et al., 1964). The "observed intertrial repetition" [O(ITR)] refers to the frequency with which two items are recalled in the same adjacent order on two consecutive recall trials. The "expected intertrial repetition" [E(ITR)] (ie. chance) is computed based on all the different possible random recall protocols. The total measurement of subjective organisation is then computed by subtracting E(ITR) from O(ITR). Anderson and Watts (1969) expanded this ITR measure to include ITRs recalled in the same adjacent order (unidirectional) and also ITRs recalled in the reverse adjacent order (bidirectional).

Another method was devised which uses an algorithm to determine the set of clusters for each Subject and represents these in a hierarchy referred to as an "ordered tree". This ordered tree graphically displays the cognitive structuring of the information (Mckeithen et al., 1981; Reitman and Rueter, 1980). This technique has also been modified to simply provide Subjects with a group of items and require that they be arranged into a linear series (rather than requiring the items to be recalled from memory). This creates less demand on the recall of the items and more reliance on the perceived relationships between the items (Naveh-Benjamin et al., 1986).

Sternberg and Tulving (1977) assessed many measures of subjective organisation and found that a form of bidirectional ITR was statistically superior to other measures. They referred to this bidirectional ITR as "pair frequency" (PF). This is the measure selected for use in the experiment presented here. The equation for computing PF is as follows (Sternberg and Tulving, 1977, p. 543):

$$PF = O(ITR) - E(ITR)$$

O(ITR): Observed intertrial repetition: The number of pairs-of-items recalled in two consecutive recall trials in either the same, or reverse, order.

E(ITR): Expected intertrial repetition: The number of O(ITR)s which can be expected to occur by chance.

The formula for E(ITR) is as follows:

$$E(ITR) = [2c\,(c-1)] \div hk$$

h = number of items recalled in one recall trial (ie. trial t).
k = number of items recalled in the next consecutive recall trial (ie. trial t+1).
c = number of common items recalled in the two consecutive recall trials (ie. items common to both trials t and t+1).

IVB.52 Prototypical Members of Subjective Categories.

Repeated groupings of items in Subjects' recall orders is indicative of the different categories which Subjects are implicitly using in their cognitive processes. That is, items within the same category are recalled together before moving on to items within a different category.

The order in which items are recalled can also be indicative of the relationship between items within the same category. Research on prototypical members of categories has demonstrated that items which are prototypical members of a category will be recalled before items which are less prototypical of that category (Battig and Montague, 1969; Bousfield and Sedgewick, 1944; Palmer et al., 1981; Rosch et al., 1976). These results have been used to infer that categories are economically represented in memory as prototypes and variations of the prototype (some of this has been considered in sections IVA.30, IVA.111).

Repeated clusters of items in free recall can be indicative of *different* subjective categories. The order of recall within clusters can be indicative of prototypical and less prototypical members within the *same* subjective category.

IVB.53 Paradigm for Kinesthetic Spatial Cognition Research.

The occurrence of subjective organisation suggests an overall framework through which to probe the cognitive structure of kinesthetic memory. The experimental task can consist of the learning and free recall of kinesthetic-items (analogous to verbal items). Recall orders can be examined for subjective organisation which would indicate the presence (if any) of kinesthetic categories which are implicitly used during the cognitive process. If clusters are identified then the recall orders within each cluster can be examined for evidence of prototypical members within the particular category. In this initial research the vast number of variable attributes possible within kinesthetic-items was made more manageable by delimiting the stimuli to only kinesthetic spatial (ie. "kinespheric") items.

This type of research can be used to evaluate whether kinespheric categories outlined within choreutics (or any other system of movement taxonomy) have any resemblance to the kinespheric categories which are actually used during cognition. In specific, the experiment presented here addresses the question:of whether kinespheric categories outlined in choreutics have any psychological validity.

This type of research can also contribute to the schema theory for motor learning (see IVB.11) in which a fundamental problem has been identified as the lack of criteria for distinguishing between different classes or categories of body movement. Kinespheric categories used in the mental representation of bodily movement can begin to be deciphered by identifying the subjective organisation in their free recall.

It is important for this research paradigm that body movements are maintained as discrete items (ie. not connected together into a series of movements). Movements are often learned in a sequence with one movement leading without a pause into the next. This may tend to create an event-like, sequential memory organisation even though the individual kinespheric-items may belong to several different general classes of movement.

This sequential organisation was evident in a preliminary experiment where Subjects were asked to freely recall any movements that they already know. Despite a requirement to segregate movements into discrete items (by saying "here's one", "here's another" etc.) Subjects persisted in producing sequences of movement-items, beginning each movement where the last ended. Subjects often required extra clarification and prompting to segregate movements into discrete items rather than presenting ongoing sequences and Subjects differed widely in how much movement would be included within "one item". Clearly distinguishing between separate movement-items is not a typical task. The spontaneous tendency is to recall movements as sequences.

At a finer level each movement-item itself has a sequential structure, a beginning, middle, and end. A problem for kinesthetic spatial cognition research is to distinguish what comprises "one movement". According to the mass-spring and trajectory formation models the elemental movement-unit would consist of a single "stroke" or single phase whereby a skeletal linkage moves from one position to another position defined by a new agonist/antagonist equilibrium point (see IIIB.20). However this is not necessarily how "one movement" is conceived in cognition. For example, cognitive structures have been identified in which a single "unit of motion" in dance is conceived as a sequence beginning at a stable position, progressing through a more unstable position, and ending at another stable position (Lasher, 1981, p. 394).

Clearly the sequential organisation of kinesthetic knowledge is a major aspect of kinesthetic spatial cognition, but this is not the focus of this research paradigm. It is also clear that movements exhibit a discrete cognitive representation. This is evidenced by the ability to deconstruct movement sequences into individual items, rearrange the individual items, and reconstruct the items into new sequences. This type of manipulation is common in dance practice and choreographic methods (Blom and Chaplin, 1982).

IVB.54 Method.

IVB.54a Subjects.

Subjects were 12 students and faculty at the Laban Centre, London (3 men, 9 women) who took part in the experiment voluntarily at the Experimenter's request.

IVB.54b Materials.

Experimental sessions took place in a large room. Subjects were standing during learning and viewed the kinespheric-items on a video monitor at approximately chest height. There was enough space around the Subject so that kinespheric-items could be physically rehearsed. The volume on the monitor was turned to "off". During recall Subjects were video-taped by a camera next to the wall of the room. The viewing angle of the camera was marked on the floor and Subjects were free to move within this area.

IVB.54c Stimuli: Kinespheric-items.

A preliminary experiment in which Subjects freely recalled any movements which they already knew revealed that kinesthetic-items may vary along several different attributes simultaneously. For example, a group of movements may vary according to the body-parts used, the direction of motion of the centre of gravity, the type of "action" (eg. turning, jumping, traveling, balancing, gesturing), the dynamic (eg. forceful, delicate, rapid, lingering), the rhythmic pattern, the form of the pose, or the form of the pathway. It is possible that movements may be subjectively categorised according to any of these kinesthetic attributes.

The purpose of this experiment was to asses whether categories of kinespheric form such as those presented in choreutics have any psychological validity. Therefore kinespheric-items were selected which differed along spatial attributes of form and orientation. All other kinesthetic attributes were equivalent (as much as possible) for all items.

The geometrical nature of the forms designated in choreutics may also make them ideal for experimental stimuli since they are abstract and unfamiliar. If well known movements were used (eg. from a particular dance technique, martial arts, sport, or physical labor occupation) then these may be organised according to meaningful associations with their respective well-known movement styles. In contrast to this, the choreutic forms are abstract geometric patterns which are not typically associated with familiar movements and so these kinespheric-items might draw on fundamental cognitive criteria for categorisation rather than already formed semantic associations. Furthermore, the geometric structure of the choreutic forms has been systematically developed (Preston-Dunlop, 1984) and so provides a large set of potential kinespheric stimuli which can be modified and varied along well defined attributes. Therefore, choreutic forms may be an ideal source of stimuli for probing the fundamental structure of kinespheric categories.

A preliminary test indicated that 16 items were enough to present Subjects with a challenge, yet was not so difficult as to be overwhelming. A group of 16 kinespheric-items were selected which varied according to their form (linear reversal, zig-zag, cycle, wave, figure-8) and their orientation (dimensional, Cartesian plane, or diagonal inclination). Briefly, the forms and orientations of the sixteen kinespheric-items were as follows (for Labanotation see Fig. IVB-11; Appendix XVII.20):

#1. linear reversal;	(pure) [ ] diagonal.
#2. zig-zag;	deflections of [ ] diagonal.
#3. 4-part cycle;	deflected frontal plane and [ ] diagonal.
#4. linear reversal;	(pure) [ ] diagonal.
#5. zig-zag;	deflections of [ ] diagonal.
#6. 4-part cycle;	deflected medial plane and [ ] diagonal.
#7. linear reversal;	(pure) [ ] dimension.
#8. linear reversal;	(pure) [ ] diameter.
#9. 4-part cycle;	(pure) medial plane.
#10. plastic wave;	3 deflected diagonals orbiting the [ ] axis.
#11. Large figure-8;	deflected frontal planes orbiting the [ ] axis.
#12. large 3-part cycle;	3 deflected diagonals orbiting the [ ] axis.
#13. small 3-part cycle;	3 deflected diagonals orbiting the [ ] axis.
#14. large 3-part cycle;	3 deflected diagonals orbiting the [ ] axis.
#15. small 3-part cycle;	3 deflected diagonals orbiting the [ ] axis.
#16. small figure-8;	deflected horizontal planes orbiting [ ] axis.

These kinespheric-items were selected to allow for different possible categorisations according to orientation or according to form. For example, would a linear reversal, a zig-zag (from an "axis scale"), and a 4-part cycle elongated along that same axis, be grouped according to their similar orientation? (items #1, #2, #3). Or would the linear reversals (items #1, #4, #7, #8) and the zig-zags (items #2, #5) be grouped together according to their similar form?

All items were virtually identical on other attributes. The starting position was standing, arms down to the side and legs slightly apart. The body-part usage consisted of the right-arm following the pathway with the rest of the body spontaneously accommodating and responding to the motion of the right-arm. The timing of each item was distributed evenly over 6 seconds (see below). The dynamic quality was unaccented neutral dynamics. The costume and setting of the demonstrator was black pants and black shirt against a light-blue background.

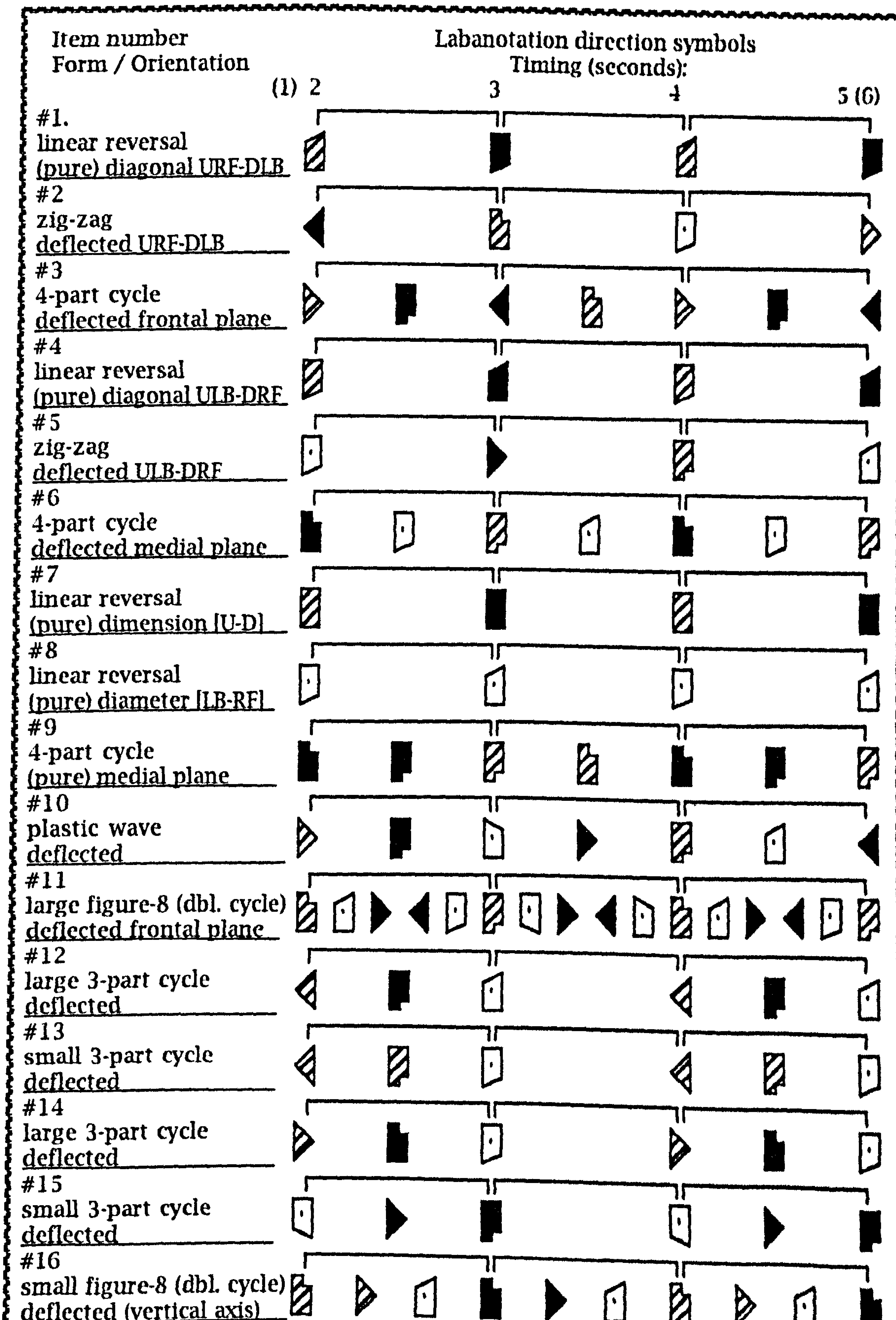


Figure IVB-11. Forms and orientations of the sixteen kinespheric-items.

The "actions" (as defined by Preston-Dunlop, 1979, p. 42; 1980, p. 53; Hutchinson-Guest, 1983, pp. xxiii-xxiv) of each kinespheric-item consisted of a "stillness" on counts 1 and 6 and a "transfer-of-weight" on counts 2, 3, 4, and 5. The actions of "condensing", "expanding", "twisting", and "balancing" varied for each of the items depending on what was required by the different pathways. The actions of "turning", "falling", "traveling" and "jumping" were not present in any of the items. Body poses were also not controlled (except for the starting position) and these varied according to what was required to fulfill the pathway.

IVB.54d Video tape of the kinespheric-items.

A dancer was video-taped demonstrating the kinespheric-items. He was viewed from the back (ie. facing away from the camera) so that there would be no requirement for Subjects to mentally rotate the movement during learning. This also eliminated any facial characteristics which might inadvertently serve as memory cues.

The demonstrator was guided by a metronome which sounded once each second. Each kinespheric-item lasted for 6 seconds and consisted of the following:

second 1:	The demonstrator was pictured in stillness in a neutral position, standing with arms down to the side and legs slightly apart.
seconds 2-5:	The demonstrator performed the movement pathway.
second 6:	The demonstrator held the last position in stillness.

The video-taped kinespheric-items were edited into five different random learning sequences with the constraints that two items never occurred in the same adjacent order more than once and no item ever occurred as the very first or the very last item in the sequence more than once (see Appendix XVII.30).

As discussed above, the kinespheric-items were abstract and were not recognisable as any well known movement pattern. Consequently, in pre-experimental trials Subjects reported great difficulty in quickly learning the unfamiliar movements. Therefore, each item was presented three-times in a row to give Subjects longer encoding time and to decrease the anxiety which often occurred since Subjects could not stop the video tape or ask to see a particular movement again. The series of kinespheric-items was edited into the following sequence:

2 seconds:	A grid of white squares on a black background was presented to alert the Subject that a new item was about to be presented.
6 seconds:	The first presentation of the kinespheric-item.
6 seconds:	The second presentation of the same kinespheric-item.
6 seconds:	The third presentation of the same kinespheric-item.

This sequence was repeated 16 times (for the 16 items). After the last item had finished the grid appeared on the screen three times (2 seconds each time separated by 2 seconds of blackness) to indicate that the learning sequence was over. Thus, the entire learning sequence lasted for approximately 5.5 minutes.

IVB.55 Procedure.

Subjects were scheduled for an individual experimental session depending on convenient availability times. Subjects were told only that this was an experiment on "movement memory".

On arrival, Subjects were given written general information about the experiment and instructions (see Appendix XVII.10). The instructions included: "You will be required to learn 16 different body-movements." "Please physically perform the movements along with the video tape." "Please do not make a continuous sequence by joining all the movements together." "You can recall the movements in any order in which you remember them." Subjects were allowed to ask questions until the task was understood.

To aid in maintaining the separateness of each kinespheric-item, Subjects were instructed to follow the following procedure during recall:

1) Think of the movement;
2) Say "Here's one" (or anything similar to this);
3) Demonstrate the movement.
Continue 1), 2), 3), etc.

Subjects were then acquainted with the procedure by learning three practice movements from a video tape of three kinespheric-items (recorded exactly like the experimental items). The Experimenter observed each Subject rehearsing and then recalling the three practice items. All Subjects were able to successfully accomplish this. These three practice items were not used again in the experiment.

When the Subject indicated that she was ready to proceed with each learning trial the Experimenter started the video player and then left the room. The Subject was in the room alone during the learning trial. When the video tape had finished the Subject knocked on the door, the Experimenter entered, turned off the video player and pushed it to the side of the room.

Each recall trial followed immediately. The Subject recalled the kinespheric-items at the same place in the room, and facing the same direction, as she had been during the learning trials. When she indicated that she was ready the Experimenter started the video-camera and left the room. The recall trials ended in one of two ways: 1) When the Subject had recalled all the movements that could be remembered then she knocked on the door and the Experimenter would enter and turn off the video-camera; or 2) After four minutes had past the Experimenter would enter the room, tell the Subject to stop, and turn off the video-camera. The next learning trial would then begin immediately.

Each Subject had five learning trials alternating with five recall trials. The five random sequences of the 16 items were presented in a different order to each Subject. Subjects were given no knowledge of their results after each recall trial but proceeded immediately on to the next learning trial. After the fifth recall trial the Subject was congratulated and the experimental session ended.

IVB.56 Results.

The video tapes of Subjects' recall trials were observed and (following Sternberg and Tulving, 1977 [see above]) the number of recalled items, observed intertrial repetitions [O(ITR)s], expected intertrial repetitions [E(ITR)s], and pair frequency (PF) was calculated for each recall trial of each Subject (see Appendix XVII.40).

Recall Trials:	1st	2nd	3rd	4th	5th
Mean Recalls (S.D.)	4.42 (1.83)	7.42 (2.64)	9.83 (3.16)	11.00 (5.27)	12.17 (2.59)
Mean O(ITR)s (S.D.)	----	0.58 (0.79)	1.08 (1.00)	1.67 (2.06)	2.58 (2.15)
Mean E(ITR)s (S.D.)	----	0.33 (0.32)	0.80 (0.35)	1.09 (0.35)	1.16 (0.34)
Mean PF (S.D.)	----	0.26 (0.66)	0.29 (0.87)	0.58 (1.85)	1.42 (1.95)

Table IV-11. Performance measures: Mean number recalled; Mean Observed intertrial repetitions [O(ITR)s]; Mean expected intertrial repetitions [E(ITR)s]; Mean pair frequency (PF).

NOTE: Data for O(ITR)s, E(ITR)s and PF for the 2nd recall trial refers to the repetitions of S-units from the 1st-to-2nd trials, data for the 3rd trial refers to repetitions from the 2nd-to-3rd trials, etc.

IVB.56a Number of recalled items.

The mean number of recalled items (12 Subjects, 16 items) for recall trials 1, 2, 3, 4, and 5 were 4.42, 7.42, 9.83, 11.0, and 12.17 respectively (see Table IV-11). Paired sample t-tests showed this increase to be significant across the 1st-to-2nd trials ($t=5.2$, $p<.0001$), 2nd-to-3rd trials ($t=5.16$, $p<.0001$), and the 4th-to-5th trials ($t=3.39$, $p<.006$). Only the increase across the 3rd-to-4th trials failed to reach significance ($t=1.9$, $p<.08$, n.s.).

IVB.56b Observed and expected intertrial repetitions.

The number of mean O(ITR)s for the 1st-to-2nd, 2nd-to-3rd, 3rd-to-4th, and 4th-to-5th trials were 0.58, 1.08, 1.67, and 2.58 respectively. The number of mean E(ITR)s (ie. chance) for the 1st-2nd, 2nd-3rd, 3rd-4th, and 4th-5th trials were 0.33, 0.80, 1.09, and 1.16 respectively (see Table IV-11).

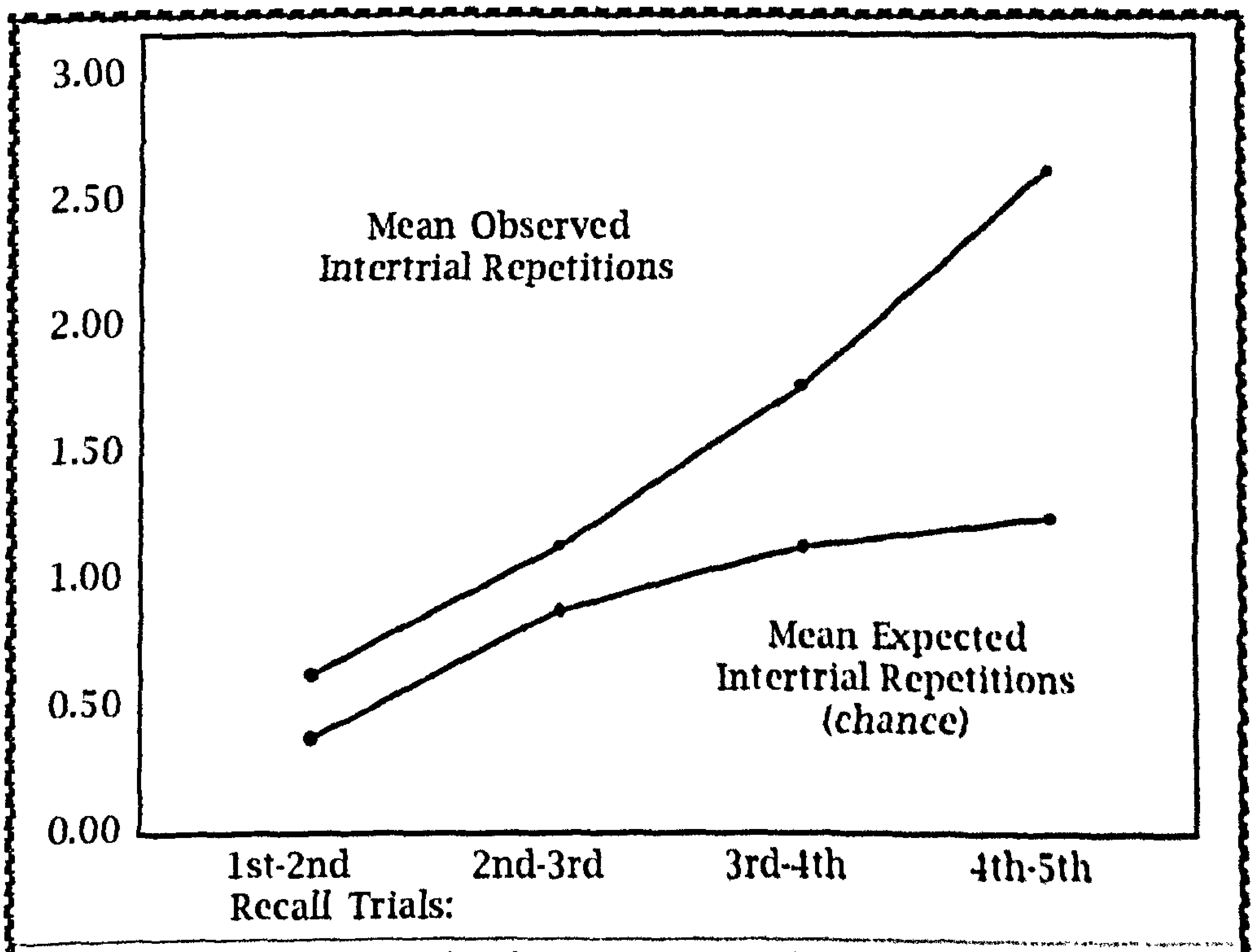


Figure IVB-12. Relationship between mean observed and mean expected intertrial repetitions.

A multi-subject analysis of variance was carried out. The first factor was intertrial repetitions (ITRs) with two levels (observed and expected), and the second factor was recall performance across consecutive recall trials which had four levels (1st-2nd trials, 2nd-3rd trials, 3rd-4th trials, and 4th-5th trials). Results of the ANOVA showed that the main effect of the first factor (ITRs) was marginally significant, which indicates that observed (ITR)s were significantly more frequent than expected (ITR)s

($F_{1/11}$ = 4.22, $p<.06$). The second factor of recall performance across consecutive trials was highly significant ($F_{3/33}$ = 11.29, $p<.0001$). This indicates that the number of ITRs significantly increased over the five recall trials. The interaction between the performance across trials and the pattern of O(ITR)s and E(ITR)s was also significant ($F_{3/33}$ = 2.79, $p<.05$). This shows that as trials continued, the difference between O(ITR)s and E(ITR)s significantly increased (see Fig. IVB-12).

IVB.56c Pair frequency.

To look more closely at this interaction, paired frequency (PF) across trials was calculated by subtracting E(ITR)s from O(ITR)s. This is therefore a measure of the ITRs which are not expected by chance (Sternberg and Tulving, 1977). Mean PF for the 1st-to-2nd, 2nd-to-3rd, 3rd-to-4th, and 4th-to-5th recall trials were 0.26, 0.29, 0.58, and 1.42 respectively (see Table IV-11). Paired sample t-tests showed that the PF scores across the 1st-to-2nd and the 2nd-to-3rd trials significantly increased to the PF score across the 4th-to-5th trials ($t=2.95$, $p<.01$). This reaffirms that subjective organisation is occurring during kinesthetic recall and also confirms that the amount of organisation increases with additional recall trials.

IVB.57 Characteristics of Subjective-units.

Since the occurrence and increase in the subjective organisation of kinespheric-items was verified, the next step was to analyse the composition of subjective-units (S-units) to identify observable criteria (if any) for this clustering. Each of the 16 kinespheric-items exhibits a particular pathway and orientation. These form and orientation attributes were used to analyse the contents of S-units in an effort to determine if they are related to how the item is subjectively organised.

IVB.57a Survey of S-unit occurrences.

A total of 37 different S-units occurred in Subjects' recall orders (see Appendix XVII.50). Some S-units occurred in as many as 11 ITRs produced by five different Subjects while others occurred in only 1 ITR produced by only one Subject. All S-units produced by at least two Subjects were considered to be the strongest S-units occurring in this experiment and were selected for further analysis. Intertrial repetitions are defined for statistical purposes as repetitions across consecutive recall trials, but if a well established S-unit is repeated in non-consecutive recall trials there is no reason to believe that these non-consecutive ITRs are not also indicative of memory organisation. To provide more data for analysis these non-consecutive

ITRs are also included with the occurrences of consecutive ITRs (see Table IV-12).

A descriptive analysis of the form and orientation of the two items within each of the 12 strongest S-units was conducted (for details see Appendix XVII.60). It was found that 63% of the S-units contained two items with similar forms whereas 31% of the S-units contained two items with similar orientations. All of the 12 S-units were not equally robust since some occurred more than others. To correct for the unequal strength of different S-units the number of ITRs for the entire set of 12 S-units were considered as a whole. Of the total number of 47 ITRs, 76% contained two items with similar forms whereas 34% contained two items with similar orientations.

S-unit	Total #Os	Total #ITRs	Specific Occurrences
1/7	4	2	A1-A2 L4-L5
2/5	9	6	B3-B4-B5 D3-D4-D5 E3-E4-E5
3/14	6	3	E4-E5 F3;F5 H2-H3
4/8	7	4	B4-B5 E3-E4-E5 I3;I5
5/8	4	2	B2-B3 H4-H5
5/14	4	2	I4-I5 L4-L5
5/15	4	2	B4-B5 L1-L2
6/9	18	12	B1-B2-B3-B4-B5 E2-E3-E4-E5 F4-F5 G3-G4 I3;I5 L3-L4-L5
7/13	7	4	B2-B3 E1-E2;E5 L2-L3
9/11	7	4	A2-A3 D3-D4-D5 H1;H5
9/15	4	2	D2-D3 E3-E4
13/15	6	4	A3-A4-A5 E3-E4-E5

Table IV-12. Frequency of occurrence for each of the 12 strongest S-units (non-consecutive ITRs included).

ABBREVIATIONS:

S-units are abbreviated by the numbers of the two component kinespheric-items (see Fig. IVB-11). For easy indexing the lower number is always listed first but it is understood that either item might be recalled first.

Total #0s refers to the number of occurrences of the kinespheric-item within the S-unit. Total #ITRs refers to the number of intertrial repetitions of the S-unit.

Specific occurrences of S-units are abbreviated by a letter representing each subject, followed by the number of the recall trial (eg. B4 refers to the 4th recall trial of subject B, etc.). Consecutive ITRs are represented by a dash (-) and non-consecutive ITRs are represented with a semi-colon (;)

This analysis reveals that form attributes are greater descriptors of kinespheric clustering than orientation attributes. This indicates that the composition of kinespheric categories is determined more by the forms of items than by their orientation.

IVB.57b Directionality of S-units.

The two items within an S-unit can be recalled with either item first, this is referred to as the "directionality" (Anderson and Watts, 1969; Sternberg and Tulving, 1977). An S-unit's directionality can be an indicator of category prototypicality since prototypical category members tend to be recalled before members which are less prototypical of the category (Battig and Montague, 1969; Bousfield and Sedgewick, 1944; Palmer et al., 1981; Rosch et al., 1976). Another question is whether attributes of form or orientation describe S-unit directionality.

Five of the 12 strongest S-units were identified as being primarily unidirectional (see Appendix XVII.70). Three rules were derived which describe their pattern of directionality: 1) Small kinespheric-items are recalled before larger items (S-units 5/15 and 9/15); 2) If both items are small the higher item is recalled first (S-unit 13/15); 3) One-dimensional oriented items are recalled first, two-dimensional items are recalled second, and three-dimensional oriented items are recalled last. This last rule conforms to the prototype/deflection hypothesis (see IVA) and describes the uni-directionality of S-units 4/8 and 6/9 and also describes the marginal uni-directionality of the S-units 1/7 and 5/8 (for numbers of kinespheric-items, see Fig. IVB-11).

Several other S-units occurred equally often with either item recalled first (bidirectional). This bidirectionality can also be described by these three rules. For S-units 2/5, 3/14, and 5/14 none of the rules applies and so neither item tended to be recalled first. The bidirectionality of the S-unit 7/13 may result from a conflict between Rule 1 and Rule 3. The bidirectionality of the S-unit 9/11 may occur since item #11 does not have any obvious deflected component, but may instead be remembered as a frontal plane moving around a sagittal axis, thus neutralising the effect of Rule 3.

This description of the components of unidirectional and bidirectional S-units indicates that orientation may play a role in directionality. Dimensional oriented movements tend to be recalled before other orientations. This is in accordance with the prototype/deflection hypothesis (see IVA) which posits that dimensional orientations serve as cognitive prototypes for other orientations within the same kinespheric category.

IVB.57c First and Last recall position ITRs.

Some measures of subjective organisation include the organisation of items which are recalled in the very first or the very last recall position on two consecutive recall trials (Tulving, 1962). In this experiment last-position ITRs did not appear to be an important factor since only two occurred (item #7 for Subject E; item #11 for Subject C) and so were not considered further. However 12 first-position ITRs occurred and so these appeared to be a prominent factor in organisation of recall orders. Items organised into first-position ITRs are referred to here as "first-units" (F-units) (see Appendix XVII.80).

Orientation of kinespheric-items		Number of F-unit occurrences:
1-D:	#7	A1 A2 G2 G3 G4 G5 I2 I3 I5 J3 J4 J5
2-D:	#8	H1 H2 H3 H4 H5
	#9	B1 B2 B4 L1 L2 L3 L5
3-D pure:	#1	J1 J2
	#4	
3-D deflected:	#2	
	#3	
	#5	
	#6	
	#10	
	#11	
	#12	
	#13	E3 E4
	#14	
	#15	
	#16	

Table IV-13. Kinespheric-item orientation and number of F-unit occurrences (reversed F/S-units and non-consecutive ITRs included).

Out of the 12 F-unit ITRs, 10 of these contained one-dimensional and two-dimensional oriented kinespheric-items (items #7, #8, #9). A closer scrutiny also revealed that in 9 out of the 12 F-unit ITRs it was not a single item which was organised into the first recall position but it was an entire S-unit. That is, if an item was organised into an F-unit it also tended to be organised into an S-unit. These S-units organised into the first recall position are referred to here as "first/subjective-units" (F/S-units) and they appear to be indicative of a higher level of organisation. The only case that this was not true was for item #7 which consisted of a vertically oriented line. It may be that the extreme prototypicality of this item allowed it to be easily organised into an F-unit on its own without the more extensive processing involved in the formation of an S-unit. This is supported by the result that more F-units contained item #7 than any other item.

When an F/S-unit occurred, the same Kinespheric-item did not always occur first. For example, Subject L recalls item #9 first in the F-unit 9/8 for the first two recall trials, then on the third recall trial recalls it (in the opposite order) as 8/9. These both appear to be examples of the same F/S-unit and so reversed F/S-units were also included in the data analysis (see Appendix XVII.90). In addition it was evident that non-consecutive ITRs occurred for well established F-units. When non-consecutive ITRs occurred for a Subject who also produced consecutive ITRs of the F-unit, then these non-consecutive ITRs were included in the data analysis.

A histogram representing the number of times which particular kinespheric-items occurred as F-units reveals that one-dimensional items occurred as F-units most frequently, followed by two-dimensional items less frequently, and three-dimensional items are rarely organised into the first recall position (Table IV-13). This recall of one- and two-dimensional oriented movements in the first recall position supports the prototype/deflection hypothesis (see IVA).

IVB.58 Discussion and Directions for Future Research.

The results of this experiment can be interpreted relative to the structure of kinespheric categories. It was first confirmed that subjective organisation occurred during kinespheric free recall and that this organisation increased significantly across the five recall trials. Since the occurrence of subjective organisation was statistically verified it was then justifiable to analyse the composition of the subjective-units (S-units) and infer the structure of kinespheric categories from these.

In this experiment the composition of S-units was better described by the form of the kinespheric-items rather than by their orientation. This leads to a hypothesis that kinespheric-items with the same form tend to be organised into the same category.

Studies of category prototypes have shown that prototypical members of categories tend to be recalled before less-typical members of the category (Palmer et al., 1981; Rosch et al., 1976b; see IVA.32). If this holds true for kinespheric categories then it can be inferred that if one item within an S-unit is more frequently recalled before the other item within the S-unit, that the former item is more typical of the kinespheric category than the latter item.

In this experiment several S-units were identified as unidirectional (ie. one item is usually recalled first). An analysis of the attributes of the firstly recalled items revealed that they were either small forms, or exhibited a one- or two-dimensional orientation. Kinespheric forms with either a one- or two-dimensional orientation were also recalled in the first recall position more often than three-dimensionally oriented forms. These effects associated with the orientation of kinespheric-items leads to the hypothesis that one- and two-dimensional oriented items are perceived to be more prototypical of their categories than three-dimensional oriented items.

Thus, the results of this experiment suggest a twofold hypothesis: Kinespheric categories are distinguished according to the form, and prototypicality within a category is defined by the orientation. This is also in accord with the prototype/deflection hypothesis (see IVA). However, the data presented in this experiment do not give an unequivocal support for this hypothesis. The orientation of the kinespheric form also appeared to contribute towards distinguishing the category, and the size of the form appeared to contribute towards defining the prototypicality. However the twofold form and orientation hypothesis derived here provides a starting place for future experiments.

In the current experiment there was no clue whatsoever about the type of kinesthetic clustering which might occur. To reduce the variable kinesthetic attributes which might contribute to clustering the stimuli were limited to kinesthetic spatial, that is "kinespheric"- items. However, even within the restricted range of kinespheric stimuli there are still multiple variables which each may be effecting the results. For example, many of the kinespheric-items were extremely complex in which several orientations occurred during a single pathway. In these cases it was impossible to determine which orientations the Subject was using for categorisation. The size of the form also appears to effect how it is encoded and categorised. In addition, clustering will always be relative to the contents of a particular stimulus list. That is, the items may be clustered in one way within one stimulus list but clustered in another way within a different stimulus list.

What is necessary in future research is to drastically isolate kinesthetic attributes so that their cognitive significance can be assessed independently. Stimuli lists need to be composed of items which differ from each other along one or two controlled attributes which are being tested one at a time, rather than having multiple attributes varying from item to item. The twofold form and orientation hypothesis for kinespheric categories and prototypes derived from the results of this experiment gives a potential starting place for creating stimuli lists.

This experiment has shown that the paradigm of subjective organisation in kinesthetic recall produces an abundance of data and so can be a valuable method through which to probe the structure of the mental representations of kinesthetic knowledge.

IVB.59 Summary: Subjective Organisation in Kinesthetic Recall.

A movement memory experiment was devised with the purpose of identifying whether categories of kinesthetic spatial information are actually used in cognitive processes. Subjects learned sixteen discrete kinespheric-items and were allowed to recall these in any order over five learning and free recall trials. Measurements of "subjective organisation" indicated that kinespheric-items were organised into categories during learning and recall. An analysis of the categories led to a twofold hypothesis of category membership defined by the form (ie. movements with the same form were clustered together regardless of their orientation) and category prototypicality defined by the orientation (ie. movements oriented along a pure dimension or a Cartesian plane were recalled at the beginning of a cluster). Identifying kinesthetic spatial categories in this way has not been heretofore undertaken in psychological research and so constitutes additional new knowledge.

V. SUMMARY AND CONCLUSIONS

In Section I. a brief biography of Rudolf Laban is given and the "choreutic", "effort", and "Labanotation-kinetography" components of his life-long work with human body movement are identified. Compared to effort and Labanotation, the choreutic system for the conception and embodiment of spatial forms in body movements has remained largely undeveloped. Indeed, choreutics has been ridiculed on philosophical grounds (Langer, 1953, p. 186) without any consideration of its possible relevance to the perception and execution of human movement. This thesis undertook a reevaluation of the choreutic conception according to current scientific knowledge about spatial cognition (eg. perception, imagery) and the control of human body movement. (See I.10-.20.)

An initial step was to determine which fields of scientific study consider the same subject matter as choreutics. Three core components of choreutics were identified relative to dance and movement education: 1) Space is conceptualised by imagining various polyhedral-shaped networks which surround the body and serve as a grid for mapping the locations of body movements and positions. 2) The conceptual image of the form can be mentally manipulated by various rotations and reflections. 3) These imagined spatial forms are physically enacted or "embodied". These three cognitive and physical processes have also been studied in psychological studies of spatial perception (eg. McGee, 1979; Sedgwick, 1986) and motor skill learning (eg. Newell, 1991). Thus, cognitive psychology and motor control studies were reviewed in an attempt to identify current scientific knowledge about spatial cognitive processes for use as a standard against which to reevaluate the choreutic conception. (See I.30.)

In Section II. the concept of "kinesthetic spatial cognition" (analogous to the psychological concept of "visual spatial cognition"; eg. Phillips, 1983) was developed to define an overall realm in cognitive and motor control studies according to which the choreutic conception can be reevaluated.

In Section IIA. kinesthesia was identified as arising from sensory stimulations via receptors in muscles, tendons, joints, skin, vestibular apparatus, eyes, ears, and also from an interior knowledge of motor commands (efferent data). This assortment of stimulations from throughout the body are derived into perceptions of balance and equilibrium, self-motion, limb-motion, limb position, and force or exertion.

In Section IIB. "kinesthetic space" was defined as spatial information which is perceived and/or recalled through the kinesthetic perceptual-motor system. A multitude of types of environmental, bodily, and conceptual "spaces" were considered and concepts such as kinesthetic-motor space, work space, reach space, and movement space are seen as relatively synonymous with Laban's (1966) concept of the "kinesphere"; referring to the space within immediate reach of body movements.

In Section IIC. "kinesthetic spatial cognition" is defined as cognitive processes (eg. perception, imagery, mental manipulations) which are performed on kinesthetic spatial information. Support for this concept is built-up from psychological theory. A great deal of research has distinguished spatial cognition from verbal cognition as using separate cognitive resources (eg. Baddeley, 1986). Spatial information can arise from separate visual, audio, and kinesthetic perceptual-motor systems but is eventually represented in a unitary spatial memory system (eg. Baddeley and Lieberman, 1980; Solso and Raynis, 1979). Kinesthetic-motor knowledge is considered by many researchers to inherently require cognitive processing rather than consisting solely of sensory-motor responding. Kinesthetic-motor activity has long been identified as being at the basis of all spatial learning (eg. Piaget and Inhelder, 1967) and is hypothesised to function as a spatial rehearsal mechanism (eg. eye movements) (Baddeley, 1983). Body movements also appear to serve as a mechanism whereby spatial information arising from different receptors is compared and calibrated so that the various spatial sensations "read" the same. Many theorists also purport that kinesthetic-motor information is at the basis of all types of cognitive processes (including verbal). This concept of "kinesthetic spatial cognition" has not been heretofore explicitly developed in cognitive psychology and so constitutes new knowledge. This provides a cognitive and motor control context in which to reevaluate choreutics.

The choreutic conception can be reevaluated according to knowledge about kinesthetic spatial cognition. In Section III. four cognitive structures* used in choreutics were identified as having also been well developed in studies of spatial cognition and motor control. Briefly stated these are: 1) Spatial information is interpreted according to various systems of reference. 2) Mental representations of

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* A "cognitive structure" refers to the way in which knowledge is organised or structured during cognitive processes (eg. Thorndyke, 1977).

kinesthetic spatial knowledge are based on a code of elemental locations. 3) Individual locations are eventually collected into cognitive map-like spatial images of an entire environment. 4) Symmetrical transformations are often performed on spatial information. The explicit identification of these cognitive structures in spatial cognition research gives psychological validity to their fundamental role within the choreutic conception.

Section IIIA. considers how spatial information must be defined relative to a system of reference. Types of egocentric (body-relative) and exocentric (environment-relative) reference systems have been identified in cognitive studies. Reference systems distinguished in Labanotation and choreutics are validated by the identification of similar reference systems within spatial cognition research. This similarity has not been heretofore explicitly identified and so constitutes new knowledge. A great deal of differentiation is provided in the Labanotation and choreutic reference systems which could serve as tools in spatial cognition research.

In Section IIIB. a variety of research is considered which indicates that the mental representation of spatial information is based on individual locations. For example, the final location of a body movement can be recalled better than the distance moved and the location of one body-part can be recalled (virtually) just as well with a *different* body-part. These effects indicate that spatial locations are recalled rather than particular movements. (See IIIB.10.)

The mass-spring model for motor control provides a theoretical basis for a location code. The elemental unit of body-movement is thought to be a single motion toward a new "equilibrium point" where there is equal tension between agonist and antagonist muscles (Bizzi and Mussa-Ivaldi, 1989; Jordan and Rosenbaum, 1989). Each equilibrium point comprises one elemental location in the mental representation of a body movement. (See IIIB.20.)

A location code is also evident in studies of "trajectory formation" where measurements of the degree of path curvature and velocity of movement revealed that a path was divided into several "path segments" separated by "curvature peaks" (Abend et al., 1982; Morasso, 1983b). A model for the production of complex paths was developed in which the "primitive movements in the motor repertoire" consist of the path segments, identified as "strokes", and the curvature peaks identified as "guiding points" for the production of the trajectory. Angular transitions between strokes occur when they are performed in a discontinuous manner, whereas a partial time overlap between consecutive strokes causes one stroke to be blended or "superimposed" with the next stroke, creating a smoothly curving movement. This model of trajectory formation is identified as being similar to "spline functions" which generate curved lines from a series of straight vectors in computer graphics (Morasso, 1986, pp. 38-44). The "abstract representations" of a body movement are posited to be cognitively planned according to a series of locations in which "the desired shape is approximated by means of a polygon" (one location at each polygonal corner), and then "the sides of the polygon are generated and superimposed" in actual body movement (Morasso et al., 1983, pp. 86, 97). (See IIIB.30.)

Similar location-based models have been developed for handwriting production, motor control of speech, stimulus-response compatibility, spatial motor preprogramming, and in visual and verbal memory. (See IIIB.50, .70.) Coordinative structures are identified as the body-level counterpart to the spatial-level of the location code. A library of reflexive movements allow the entire body to automatically accommodate to the planned trajectory of an individual body-part. (See IIIB.60.)

These location-based models of motor control and spatial cognition give validity to the virtually identical conceptual structure used in choreutics where Laban (1966, pp. 27-28) identified the same movement attributes as the trajectory formation model and referred to them as "'peaks' within the trace-form" and "phases of its pathway". Kinespheric paths and poses are conceived as being polygonal-shaped. Curved or angular trajectories are produced depending on whether successive strokes are smoothly blended together or if the guiding points are abruptly accented. This choreutic conception is virtually identical to the trajectory formation model. (See IIIB.40.)

Section IIIC reviewed how sequences of locations which have been well learned will be conceptually joined together into map-like images which simultaneously represent an entire spatial environment. A great deal of "cognitive map" research has explored characteristics of these spatial images for environments ranging from small page-sized spaces accessible to eye and arm movements through to large country-sized spaces accessible by traveling. This provides psychological validity for Laban's use of geometric map-like images of the kinesphere (termed grids, networks, or scaffolding). Similar geometric kinespheric maps have been depicted by artists and architects (eg. Leonardo Da Vinci; Le Corbusier). In the choreutic conception bodily paths and poses are represented as groups of locations within polyhedral-shaped conceptual map-like images of the kinespheric network.

Section IIID reviewed the variety of symmetrical transformations (eg. mental rotation, reflection, imagined self-translation) which are used within spatial cognition tasks. Many motor control studies have also revealed that kinesthetic spatial information (eg. an arm movement) can easily be transformed (eg. reflected, rotated) or performed by different body parts. This ability to perform symmetrical operations is identified as being critical for effective everyday use of spatial knowledge (eg. when reading a map which is not in alignment with the actual physical environment). Five types of symmetrical transformations are identified within spatial cognition and motor control studies and referred to here as translation (including body transfer), reflection, rotation, size scaling, and retrogradation. These symmetries and their notation symbols can help clarify and make explicit the transformations in spatial cognitive tasks and dance practice. A large part of choreutic practice also consists of transforming spatial forms into new orientations and performing them with different body parts. Choreutic "scales" are composed of paths and poses with three-dimensional symmetry which are described identically to spatial patterns used while maintaining dynamic equilibrium in three dimensions. Because of this, the mental conception and physical execution of choreutic scales and rings can be considered to be cognitive and bodily practice in symmetrical transformations and varieties of dynamic equilibrium adjustments.

The four cognitive structures of kinesthetic space identified here (reference systems, location code, map-like images, symmetrical transformations) have been well developed within psychology and motor control research and so this provides a validation for their use in choreutics. These parallel spatial conceptions developed in choreutics and identified in spatial cognition and motor control research have not been heretofore identified and so constitute new knowledge about the psychological validity of the choreutic conception.

In Section IV. two components of choreutics were identified and reevaluated more closely. These include a prototype/deflection hypothesis for the mental conception and bodily action of kinespheric forms (IVA), and varieties of taxonomy-schemes for distinguishing between categories of kinespheric information (IVB). Perceptual/memory experiments were devised from previous psychological experimental methods for probing these choreutic components. Both experiments demonstrated the advantageous use of choreutic material and Labanotation symbols as stimuli in experimental research. This has not heretofore been explicitly identified and so constitutes new knowledge.

In Section IVA a choreutic prototype/deflection hypothesis was identified which posits that kinespheric dimensional and diagonal orientations serve as idealised conceptual prototypes of pure stability and pure mobility, while actual bodily movements occur as deflections ("inclinations") between nearby dimensional and diagonal directions. (See IVA.20,.40.)

Similar spatial prototypes are evident in the English language where dimensions are given the greatest conceptual specificity, diagonals (45°) are given less, and off-diagonal inclines are given the least specificity. Prototype effects are also demonstrated in spatial cognition research where (for example) dimensional orientations are perceived and responded to more readily than diagonal orientations ("oblique effect") and lines or angles are perceived/remembered to be more dimensional, or to be closer to 90°, than they actually are. (See IVA.30,.50.)

Anatomical constraints are identified as a principal source of deflections. Measurements of ranges of motion at single-joints did not support the deflection hypothesis but these are not ecologically valid measures of whole-body kinespheric structure. Kinesiological analyses of joint structures and muscular lines-of-pull both supported the hypothesis that body movements tend to move out of pure dimensionally-oriented Cartesian planes and into obliquely tilting paths. Therefore, oblique directions must be considered to be kinesiologically simpler than dimensional and Cartesian planar paths. (See IVA.70.)

Deflections are described in choreutics as arising from many sources including; rotary joint articulations which take the motion out of a pure Cartesian plane; effects arising from the physical forces generated during a movement (eg. momentum): and also from the desire by the mover to produce a particular expression or communication. The physical forces and expressive qualities of moving within Cartesian planes are flat, rigid, and contained, compared with the physics and expression of movement along inclined planes. Laban (1951, p. 11) made a similar observation that the inclinations are "most obvious in the expressions of emotional excitement" when the dynamism of inclinational slopes would be overtly exhibited. (See IVA.80.)

The hypothesised deflected inclinations create an icosahedral-shaped kinespheric structure with rectangular-shaped Cartesian planes. This is remarkably similar to ergonomic measurements of the shape of the workspace or "kinetosphere" (eg. Dempster et al., 1959; Squires, 1956). (See IVA.90.)

The choreutic conception can be considered to be a counter-part to the ballet conception. Ballet is based on a conception of dimensions which are implicitly deflected towards nearby diagonals during actual body movement. In contrast to this, choreutics is based on a conception of diagonals which are explicitly deflected towards nearby dimensions during actual body movement. Laban (1926, p. 64) summarises that ballet is "oriented in dimensional stability" while the "new dance" is "oriented in diagonal lability" and so Laban used the choreutic diagonal scale as the principal exercise in his dance technique classes (Bodmer and Huxley, 1982, p. 18). A few examples of ballet movements deflecting into inclinations are given here. The further development of a choreutic diagonally-based para-ballet movement technique is possible with an understanding of organic deflections into inclinational directions. This is a direction for future research. (See IVA.60,.80.)

An experiment was devised with the purpose of identifying cognitive prototypes in kinesthetic spatial cognition. Subjects made distance judgements between pairs of kinespheric directions (with Labanotation symbols used as stimuli) by drawing a symbol at an appropriate distance within a semi-circular grid (once with stimulus 1 fixed at the origin of a semi-circular grid, and once with stimulus 2 fixed at the origin of the grid). These were measured and scrutinised for the presence of asymmetrical distance judgements which are an indication of cognitive reference points (following Rosch, 1975a; Sadalla et al., 1980). Distance judgements were not significantly different regardless of which Labanotation symbol was fixed at the origin of the grid and so this did not support the hypothesis of reference points in cognitive maps of the kinesphere. However, it appeared that Subjects may have been estimating the static length of a line or the size of an angle rather than a distance along a particular direction *from* one location and *towards* another location. Alternative procedures for identifying reference points in kinespheric cognitive maps are suggested. (See IVA.110.)

In Section IVB hypothetical categories of kinesthetic spatial information are distinguished in dance and choreutics. These can possibly contribute to the need for defining a "class" of movement which has been identified as a fundamental problem in evaluating the schema theory for motor learning. Spatial perception research indicates that the primitive element of kinespheric poses is the straight body segment (eg. as in a "stick figure" representation of an animal's body) (Marr, 1980; Marr and Nishihara, 1978). Individual segments are organised into higher-order groupings (eg. ball-like, pentagon-shaped, "X"-shaped) according to the Gestalt principles of perceptual grouping. Motor control research indicates that the primitive element of kinespheric paths is the curved stroke between locations (eg. Morasso, 1986). Individual curved strokes can be organised into higher-order groupings (eg. straight paths, angles, loops, figure-8) according the possibilities afforded by kinesiological constraints. A method for developing a kinesiologically valid taxonomy of kinespheric forms is presented. Further refinements to an initial taxonomy developed here is a matter for future research. (See IVB.10-.30.)

Since visual and kinesthetic spatial forms can be easily recognised or produced regardless of metric variations, Bernstein (1984) asserts that they are mentally represented as "topological categories" (pp. 105, 108) which are embodied with slightly different metric variations on each successive physical execution yet the essential topological form is unchanged. Thus, Bernstein describes the "co-ordinational net of the motor field . . . as oscillating like a cobweb in the wind" (p. 109). This is virtually identical to the choreutic conception where kinespheric "natural sequences" are based on a contrast of "axial" versus "equatorial" shapes of motion, together with an intermediary "hybrid" (Laban, 1966, pp. 68-72) and these topological forms are conceived to deflect across various polyhedral-shaped cognitive map-like images of the kinespheric network. (See IVB.34.)

A movement memory experiment was devised with the purpose of identifying whether categories of kinesthetic spatial information are actually used in cognitive processes. Subjects learned sixteen discrete kinespheric-items and were allowed to recall these in any order over five learning and free recall trials. Measurements of "subjective organisation" indicated that kinespheric-items were organised into categories during learning and recall. An analysis of the categories led to a twofold hypothesis of category membership defined by the form (ie. movements with the same form were clustered together regardless of their orientation) and category prototypicality defined by the orientation (ie. movements oriented along a pure dimension or a Cartesian plane were recalled at the beginning of a cluster). Identifying kinesthetic spatial categories in this way has not been heretofore undertaken in psychological research and so constitutes additional new knowledge. (See IVB.50.)

In summary, new knowledge has been identified in this research relevant to dance education. There is a lack of verified knowledge about kinesthetic spatial cognitive structures by dance theorists and educators. This gap in the knowledge is addressed by this thesis which presents psychologically valid knowledge about cognitive structures of kinesthetic space written for dancers, movement educators, and others with no previous experience with cognitive theories.

New knowledge is also presented relative to the choreutic conception. A principal realm of the subject matter of choreutics was identified within the psychological concept of kinesthetic spatial cognition. Cognitive structures which are used in choreutics were psychologically validated by their well established identification in spatial cognition and motor control research. Choreutic conceptions of organic deflections and varieties of kinespheric categories were identified in this research and were supported with anatomical/kinesiological analysis and by psychological experiments.

In addition, new knowledge identified in this research is relevant to the fields of psychology and motor control. Whiting (1986) reviews the importance of human body movement within psychology and probes the question of why a subfield of psychology concerned with human movement has not been differentiated. It is pointed out that since virtually all behavioral and cognitive processes involve body movement that there is a "dualistic thinking implicit in trying to separate out movement from cognition" (p. 116). Whiting (1986) reasons that one factor leading to this neglect in studying body movements in psychology may be the methodological difficulties involved in trying to quantify their attributes. Even though body movement is familiar to everyone it is also elusive and its "vocabulary is difficult to codify" (p. 124). Likewise, In Morasso's (1983b, p. 187) attempts to use verbal descriptions of three-dimensional arm/hand trajectories in motor control research, it is noted that "simple experiments of this kind reveal the dramatic inadequacy of natural language to express movements and spatial relations".

This problem has also been identified by Golani (1986) who asserts that movements must be considered in their entire three-dimensional plastic form rather than the incomplete planar analyses typically found in motor control studies. Another good example can be seen in the lexicon of "motor knowledge", or "motor language" presented by Cammurri and Colleagues (1986, pp. 104, 116-124) which consists of an assemblage of dance and movement terms without any consistent underlying analysis of their interrelationships. The necessity for a taxonomy of kinesthetic-motor knowledge has also been identified as essential for determining what constitutes a "class" of movements in studies of the schema theory for motor learning.

This problem of a lack of penetrating terminology for forms and orientations of body movements in psychology and motor control can be informed by the movement categories and terminology developed in choreutics and Labanotation. The first steps toward a more explicit taxonomy of motor knowledge is taken in this present research and directions for future inquiries are given. This research has also demonstrated the new knowledge that choreutic material and accompanying Labanotation symbols can be advantageously used as stimuli in psychological and motor control experiments.

This research has only been a beginning in defining the range of kinesthetic spatial knowledge. The foundation has been provided by firmly rooting choreutics within the context of spatial cognition and motor control. Future research can continue this process by continuing to clarify spatial cognitive structures within the study of dance and choreutics, and by utilising choreutic concepts and material within research into spatial cognition and motor control.