Citation: Fane, B. (2002). Androgens and Gender Development in Children with Congenital Adrenal Hyperplasia: Studies of Spatial Cognition and Social Mechanisms Influencing Gender-Typed Behaviour. (Unpublished Doctoral thesis, City, University of London)

ANDROGENS AND GENDER DEVELOPMENT IN CHILDREN WITH CONGENITAL ADRENAL HYPERPLASIA: STUDIES OF SPATIAL COGNITION AND SOCIAL MECHANISMS INFLUENCING GENDER-TYPED BEHAVIOUR

Briony Fane

Thesis submitted in fulfillment of requirements for the degree of Doctor of Philosophy

Department of Psychology
City University

April 2002

CONTENTS

Page No.

PART ONE- GENERAL

PART TWO – SPATIAL COGNITION

PART THREE – GENDER TYPED BEHAVIOUR

Appendices:

Appendix 1: Pre-School Activities Inventory
Appendix 2: Study Test Battery
Appendix 3: Sex Differences in Mental Rotations and Targeting Ability in very young Children: Their magnitude and relationship to Nationality and Culture. Fane, Collins & Hines (2002, in preparation).
Appendix 4: Example of Mental Rotations Task
Appendix 5: Example of JLO Spatial Perception Task
Appendix 6: Example of JLO Spatial Perception Task
Appendix 7: Targeting Task
Appendix 8: Example of Targeting
Appendix 9: Modelling Study – list of item pairs
Appendix 10: Examples of gender-labelling cards
Appendix 11: Pictures of Gender-labelling neutral toys
Appendix 12: The Role of Peers and Adult in Same-sex Imitation by Boys and Girls. Fane, Blair & Hines (2002, submitted for publication).

LIST OF TABLES

LIST OF FIGURES

DECLARATION

"I grant powers of discretion to the University Librarian to allow this thesis to be copied in whole or in part without further reference to me. This permission covers only single copies made for study purposes, subject to normal conditions of acknowledgement".

ACKNOWLEDGEMENTS

Many people have helped me to complete this study, and I am very grateful to all of them. However, I would like to give special thanks to the following:

- *The CAH patients* and their families who took part in the study.

- *Professor Melissa Hines* for her invaluable guidance and expert direction. This study could not have been completed without your help. Thank you!

- *The CAH Support Group*, in particular, Sue Elford, Honorary Secretary, who helped enormously with recruitment of patients and their families.

- *All my friends* who have given me so much encouragement and support and provided me with inspiration.

PREFACE

The research outlined in this thesis stems from empirical work carried out on individuals with a genetic condition known as Congenital Adrenal Hyperplasia (CAH), which causes an overproduction of adrenal androgens beginning prenatally. Individuals with CAH are exposed to high levels of adrenal androgens in the prenatal and neonatal periods. In females, the excessive prenatal androgen production causes masculinisation of the external genitalia to varying degrees.

Previous studies of individuals with CAH have suggested that exposure to high levels of androgens prenatally has a masculinising influence on some aspects of sexually differentiated behaviour. In regard to psychosocial behaviour, for example, girls with CAH have shown preferences for male-typical compared to female-typical toys and activities, for male playmates compared to female playmates, and have shown a reduced interest in infants, compared to unaffected female relatives. Boys with CAH have not been studied as extensively as girls. However, studies in which patterns of behaviour of CAH boys are also examined generally show few behavioural differences compared to unaffected boys.

Previous attempts to identify unique patterns of cognitive functioning in children with CAH have not been as successful. The present research was prompted by the recognition that empirical investigations on aspects of cognitive behaviour (e.g., spatial cognition), which have not been studied as extensively as psychosocial behaviour, have produced inconsistent results. Moreover, often participating individuals have also been exposed to the influence of later androgens, and studies have not always used measures that show robust sex differences. The research also included an assessment of the relationship between the early hormone environment and targeting ability, an aspect of spatial cognition that has not previously been investigated in children with CAH.

Furthermore. it is not clear whether hormones influence all behaviours that show sex differences. There is no research to date investigating the possibility that masculinising hormones might also influence social influences governing gender role development in the same way that they influence other aspects of psychosocial behaviour in females with CAH. This research sought to extend the research literature by including a study of social behaviour to assess whether prenatal androgens might also act on social influences involved in gender role development.

The main premise of this research is that if prenatal androgens masculinise aspects of sexually differentiated behaviour, then girls with CAH might be expected to show more male-typical patterns of behaviour compared to unaffected girls, and behaviour more similar to that of unaffected boys on the dimensions under investigation. Outcomes for boys with CAH are less clear, however their behaviour is assessed to ascertain whether high levels of adrenal androgens alter later behaviour.

CHAPTER ONE

INTRODUCTION

Males and females differ systematically on tests of spatial cognition. For example, many studies have revealed that males have an advantage over females on certain aspects of visual-spatial ability in which the sex differences observed are some of the largest in the cognitive realm (see Voyer, Voyer, & Bryden, 1995). Targeting ability is another aspect of spatial cognition in which males have an advantage (Jardine & Martin, 1983; Watson & Kimura, 1991). These differences have also been observed in children, (e.g., Kerns & Berenbaum, 1991; Thomas & French, 1985; Levine, Huttenlocher, Taylor & Langrock, 1999). However, the size of the sex difference for visual-spatial ability is smaller in children than it is in adults. For targeting ability, the magnitude of the difference between boys and girls is as large as that seen for adults.

Sex differences are also observed in gender role behaviour. Children show gender-typical toy and activity choices from a very early age (e.g., Maccoby & Jacklin, 1974; Caldera, Huston & O'Brien, 1989; Lytton & Romney, 1991). Boys consistently choose masculine-typical toys and activities and girls consistently choose feminine-typical toys and activities. The display of gender-typical behaviour has been the subject of an enormous amount of research, and many researchers have argued that the origins of the sex differences are due to psychosocial factors, including socialization practices within the family, peer relationships, and sex segregation in childhood (Block, 1983; Lytton & Romney, 1991; Harris, 1995; Maccoby, 1998).

It has also been suggested that sex differences in certain aspects of spatial cognition and childhood play and activities may be influenced by masculinizing hormones (see Berenbaum, 1990 for review). Early research carried out in non-human species led to this suggestion (e.g., Goy & Phoenix, 1971; Goy & McEwen, 1980; Williams & Meck, 1991).

Direct evidence for effects of androgens on behaviour comes from the manipulation of these hormones in experimental animals, such as rats, guinea-pigs, and non-human primates. In females, administration of androgens at certain times during sensitive periods of prenatal and neonatal development produces long lasting changes in the structure of the brain, and influences both reproductive and non-reproductive behaviour in a masculine direction (Phoenix et al., 1959; Arnold & Gorski, 1984) (see Chapter Two). The prenatal and neonatal periods are thought to be important times for determining this because it is during weeks 8-24 of gestation that sexual differentiation of the genitalia takes place (Warnes, Faiman, Reyes, & Winter, 1977) and it is during these periods that hormone concentrations are at their highest.

Over the past few decades, the investigation of individuals who have experienced unusual hormone environments during prenatal and neonatal development have contributed greatly to our understanding of human behavioural development (see Collaer & Hines, 1995, for review). Because it is unethical to manipulate hormones in human beings, people with unusual hormone histories provide an opportunity to study the effects of high levels of prenatal and neonatal androgens on subsequent behaviour. Individuals with congenital adrenal hyperplasia (CAH) are one such group. CAH is a genetic condition inherited as an autosomal recessive disorder. Individuals are exposed to high levels of androgens during early development caused by a deficiency in one of the adrenal enzymes, which in turn causes an overproduction of adrenal androgens (Chapter Three). Behavioural studies in children and adults with CAH show that females differ from unaffected same-sex controls on a number of psychosocial dimensions, including gender identity, gender role, and sexual orientation (Money & Ehrhardt, 1972; Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Hines & Kaufman, 1994; Berenbaum & Snyder, 1995; Zucker et al., 1996), (Chapter Three and Chapter Four).

In addition to psychosocial behaviour, aspects of cognitive functioning have also been the subject of research in CAH. Evidence has accumulated from studies of females with CAH that there is an androgenising influence on gender role behaviour (Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Berenbaum & Snyder, 1995; Hines, Fane, Pasterski, Mathews, Conway, & Brook, 2002, submitted for publication). There is also evidence that specific cognitive abilities are altered in females with CAH, although this evidence is more equivocal. In particular, some studies have reported that certain aspects of visual-spatial ability have been found to be enhanced in CAH females compared to same-sex controls (Perlman, 1973; Resnick, Berenbaum, Gottesman, & Bouchard, 1986; Hampson, Rovet, & Altmann, 1998). Other studies, however, have not observed these differences (Ehrhardt & Baker, 1974; McGuire, Ryan, & Omenn, 1975, Helleday, Bartfai, Ritzen, & Forsman, 1994; Hines et al., 2002), (Chapter Five).

Males with CAH generally show male-typical behaviour (Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Berenbaum & Snyder, 1995). This pattern of behaviour is consistent with studies in non-human species in which high levels of androgens have varying behavioural effects, but generally few differences are observed (Baum & Schretlen, 1975; Diamond, Llacuna, & Wong, 1973). In males with CAH, differences that are occasionally reported tend to be inconsistent from study to study (Ehrhardt & Baker, 1974; Resnick et al., 1986; Hines & Kaufman, 1994). It has been suggested that males with CAH may not experience elevated androgens. Because of an increase in the production of adrenal androgens it is thought that the production of testicular androgens down-regulates in order to compensate for this (Pang, Levine, Chow, Faiman, & New, 1979) (see Chapter Three). Thus, on this basis, it might be expected that behaviour would not differ from unaffected males. However, they are of interest because of the elevated levels of adrenal androgens, and because of the inconsistent reports of demasculinisation in behaviour.

Social influences play an active role in shaping gender-role behaviour in boys and girls (see Maccoby & Jacklin, 1974), (Chapter Seven). Studies examining responses to social influences, such as modelling and gender-labelling, have revealed that children are more likely to attend differentially to same-sex information and behave in accord with this information (e.g., Masters, Ford, Arend, Grotevant, & Clark, 1979; Perry & Bussey, 1979; Bussey & Bandura, 1984).

It is not known whether androgens might also exert effects on gender-role behaviour indirectly, through these social mechanisms. There is extensive research exploring the possibility that sex differences in this aspect of human behaviour are the result of socialization factors and thus argue for a social learning explanation for differences observed (e.g., Bandura, 1977; Bussey & Bandura, 1984; Block, 1983; Fagot & Leinbach, 1989). It is also widely known that social mechanisms, such as modelling and gender-labelling, contribute to the development of gender role behaviour (Masters et al., 1979; Perry & Bussey, 1979; Bussey & Bandura, 1984). Furthermore, it is argued that older children are more likely to be more flexible in their gender role behaviour than younger children, who are more likely to be gender traditional (Katz & Boswell, 1985; Fouts, & Liikanen, 1975). The proposition that androgens operate on these social mechanisms, facilitating the development of gender role behaviour, has not been explored in children with CAH, and warrants investigation because information regarding this may provide valuable insight into the processes underlying gender development.

The influence of prenatal androgens on both spatial cognition and social mechanisms (modelling and gender-labelling) governing the development of gender role behaviour are empirically investigated in studies in this thesis (Chapter Six and Chapter Eight). One of the primary goals is to examine whether prenatal androgens enhance performance on aspects of spatial cognition in which males typically excel, and whether responses to social information manipulating gender are altered in a masculine direction, in girls with CAH. In respect of spatial cognition, no studies have examined effects of prenatal androgens on targeting ability in young children, and there is only one other study investigating androgens on performance in an exclusively pre-adolescent sample of CAH children and unaffected relatives (Hampson, et. al, 1998). Furthermore, no studies to date have investigated prenatal androgens and social factors influencing gender role development in CAH children.

Thus, this research seeks to clarify the role that masculinising hormones play in the development of these behaviours, and to inspire further research in the quest for causes of sex differences in human behavioural development.

CHAPTER TWO

SEXUALLY DIFFERENTIATED BEHAVIOUR IN ANIMALS AND HUMANS: AN OVERVIEW OF RESEARCH

2.1 CHAPTER SUMMARY

In non-human species, studies have shown that sex hormones (e.g., testosterone and its metabolites, dihydrotestosterone, and estradiol) play a major role in the development of sex differences in behaviour (e.g., Phoenix, et al., 1959; Goy & McEwen, 1980; Arnold & Gorski, 1984; Breedlove, 1994). They also influence the organization of neural regions in the brain in a masculine direction during critical periods (prenatally and neonatally) in early development (e.g., MacLusky, Clark, Naftolin, & Goldman-Rakic, 1987; Juraska, 1991; Hines, Allen, & Gorski, 1992). It is thought that the organising influences of androgens during the prenatal and neonatal periods underlie behavioural sex differences (see Collaer & Hines, 1995). This chapter will give a short review of some of the evidence for these findings in both reproductive and non-reproductive behaviour in non-human species. Moreover, because androgens influence behaviours that show sex differences in non-human species, research has also investigated the proposition that human behaviour that shows sex differences may be similarly influenced by exposure to androgens. Thus, some of the evidence that early androgens affect human behavioural development will also be reviewed.

2.2 REPRODUCTIVE AND NON-REPRODUCTIVE BEHAVIOUR IN NON-HUMAN SPECIES

2.2.1 Reproductive Behaviour

The current understanding of the processes of sexual differentiation of the brain and subsequent behaviour comes from many years of research investigating the action of masculinising hormones (e.g., androgens), during sensitive periods in early development.

Early research investigating the effects of hormones on brain-behaviour relationships was first carried out in non-human species (Phoenix, et al.,1959; Goy & McEwen, 1980). Experiments revealed that sexually dimorphic behaviours could be modified by exposure to androgens during critical periods of early development while the central nervous system was differentiating. Animal studies demonstrated that androgens typically produced some masculinisation and defeminisation of certain reproductive behaviours (e.g., Arnold & Gorski, 1984; Goy & McEwen, 1980).

For example, it was found that female rodents exposed to high levels of androgens prenatally and neonatally were more likely than unexposed females to mount other females as sex partners and were less likely to be sexually receptive to males. Further, male rodents who were deprived of androgens during critical periods of early development showed the opposite pattern of male sexual behaviour (e.g., Breedlove, 1992).

Studies investigating effects of hormones on subsequent reproductive behaviour in non-human species, were pioneered by Phoenix, et al., (1959). These researchers specifically investigated the sexual behaviour of rodents to assess whether androgens exert a masculinizing influence when manipulated in females during sensitive periods of development. For example, Phoenix et al., (1959) found that in female guinea pigs, exposure to testosterone prenatally (despite subsequent exposure to estrogen in adulthood) prevented induction of female sexual receptivity (known as lordosis). Conversely, genetic males deprived of androgens during neonatal life were found to be permanently feminised and demasculinised in adulthood (Grady, Phoenix, & Young, 1965). This is possible because sexual differentiation is conceptualized as two-dimensional, with one dimension ranging from masculinisation to demasculinisation and the other ranging from feminisation to defeminisation. Thus, it is possible to be high on one dimension and low on the other dimension (see Collaer & Hines, 1995).

These early findings inspired what is known as the organisational hypothesis (Goy & McEwen, 1982), which proposed that early exposure to androgens can have lifelong and permanent effects on the brain, causing it to function in a masculine direction in adulthood. The organisational hypothesis further hypothesised that the brain was sensitive to the masculinising effects of hormones for only a short time during early development, such that if androgens were present during the sensitive period, neural and behavioural development would occur in a male direction, but if absent, development would occur in a female direction (Arnold & Breedlove, 1985). For example, female rats injected with testosterone on the day of birth, or up to the tenth day of life, were unlikely to show lordosis (female sexual receptivity). However, if they were given injections of testosterone on the twelfth day, this had no effect on lordosis, and they showed sexual receptivity in a typical female manner during their ovulatory cycle.

The organisational hypothesis has guided much of the research carried out on reproductive behaviour in non-human species, providing evidence that the exposure of young animals to androgens results in more masculine sexual behaviour in adulthood. Moreover, that the removal of androgens results in more feminine sexual behaviour (Arnold & Gorski, 1984). Further, different behaviours are affected at different times during these early periods of development. Thus, it is possible for an animal to show both feminine and masculine behaviours by administering testosterone during the sensitive period for masculinisation, but withholding it during the sensitive period for defeminisation (see Collaer & Hines, 1995).

The model described above for prenatal and neonatal hormone influences on sexually differentiated behaviour has been supported not only in rodents, but also in other mammalian species including gerbils (Turner, 1975), dogs (Beach & Kuehn, 1970), sheep (Short, 1974) and rhesus monkeys (Goy, 1968).

As well as organisational influences, androgens also exert what are known as activational influences. These influences occur later, in adulthood. They are called activational because it is thought that they activate existing brain regions. They also tend to be more transient, waxing and waning with hormonal fluctuations (see Collaer & Hines, 1995). They generally occur in sexually mature animals. An example would be the behavioural changes that are observed across the oestrous cycle in rats.

2.2.2 Non-Reproductive Behaviour

Hormones also influence some non-reproductive behaviours. Findings from research conducted on reproductive behaviour in non-human species led to a number of studies investigating the influence of androgens on the development of non-reproductive behaviours that show sex differences in animals, to examine whether this aspect of behavioural development was similarly influenced, or even determined, in the same way by the organisational influence of early androgens (e.g., Goy & Resko, 1972; Beatty, 1992; Meaney, 1988).

Thus, given the findings for reproductive behaviour, it was predicted that early exposure to androgens should cause masculinisation of certain non-reproductive behaviours in adulthood, and that in the absence of androgens, subsequent behaviour should be more feminine. It was also predicted that different behaviours could only be influenced during critical periods of brain development, and that the timing of this sensitivity was variable depending on the behaviour in question.

These predictions have been upheld for those non-reproductive behaviours investigated. For example, sex differences are evident in aggressive behaviour (Beatty, 1979), in rough and tumble play (Meaney, 1988), and in certain visual-spatial skills, such as maze learning (Williams & Meck, 1991), in visual discrimination learning in primates (Bachavelier & Hagger, 1991), and in object discrimination reversal (Clark & Goldman-Rakic, 1989).

Investigation of performance on certain aspects of visual-spatial ability in non-human species (rodents in particular), have found that normal males outperform normal females (e.g., Beatty, 1979; Gaulin & Fitzgerald, 1986). In addition, it has been demonstrated that administration of testosterone to newborn female rats improves their adult performance in a water maze task and that castration of newborn male rates decreases this performance (Dawson, Cheung, & Lau, 1975). Further, Williams and Meck (1991) manipulated estradiol, a metabolite of androgen, in newborn female rats in the first 10 days of postnatal life and castrated male rats on the first day of life, to examine whether early exposure to high levels of estradiol in female newborn rats and deprivation of the same hormone in male rats alters spatial ability in adult life. At 70 days of age, the male control rats (not castrated) and female rats exposed to estradiol, performed more accurately on a radial-arm maze task, while female control rats and male castrated rats performed less accurately. Williams and Meck's (1991) study clearly demonstrated that early exposure to hormones improves performance in certain aspects of visual-spatial functioning. Furthermore, because the rats had no circulating androgens at the time of testing, it supported the view that the organisational effects of androgens are important in determining the sexual differentiation of visual-spatial functioning. In a later study, reinforcing these findings, Roof and Havens (1992) also found improvements in both the water-maze and radial-arm maze tasks in female rats treated neonatally with testosterone, and found the reverse effects in male rats deprived of testosterone.

Thus, on the basis of the evidence from non-human species, there is support for the organisational hypothesis in non-reproductive behaviour, that is, exposure to testosterone and its metabolites during early sensitive periods of development leads to sexual differentiation in a masculine direction of reproductive and non-reproductive behaviour in non-human species.

2.2.3 Sex Differences in Neural Regions

Levels of androgens during early development also influence structural sex differences in the brain. A number of brain regions are sexually dimorphic (for a review see Arnold & Gorski, 1984; Collaer & Hines, 1995) and show physical changes as a consequence of the manipulation of androgens during early development. It is thought that these brain regions, which are sensitive to hormones, mediate behaviours which show sex differences.

For example, Raisman and Field, (1973) demonstrated that females had a greater number of synapses than males in the preoptic area, an area in the hypothamalus which is larger in males than females, and is known to be involved in reproductive behaviour. The preoptic area has been examined in some detail with respect to the influence of hormones. Sex differences have been found in the gross volume and shape of this area in rats (Gorski, Harlan, Jacobsen, Shryne, & Southam, 1980). It has been reported that the difference in the size of a nuclear region in the preoptic area, labelled the sexually dimorphic nucleus of the preoptic area (SDN-POA), in adult animals could be reversed by the administration of androgens during early development (Gorski, Gordon, Shryne, & Southam, 1978). Gorski et al (1978) also demonstrated that early castration of male rats reduced the size of this nucleus while administration of testosterone during early development, increased its size. Further, Denenburg, Berrebi, and Fitch (1988) found that the administration of testosterone to female rats neonatally increases the size of the corpus callosum, another sexually dimorphic brain region which is thought to contribute to sex differences in non-reproductive behaviour.

The hippocampus, a region of the brain involved with learning, memory and, in particular, spatial memory, has been shown to be sensitive to the organisational influences of androgens in some non-human species (e.g., Juraska, 1991). Moreover, Williams, Cohen, and Meck (1990) have produced findings suggesting that both the hippocampus and the frontal cortex are neural sites which are involved in the organization of sexual differentiation of visual-spatial abilities in rats. These areas of the brain contain receptors for sex hormones in rats during the first week of life (e.g., MacLusky, Lieberburg, & McEwen, 1979). Data suggest that sexual differentiation of the cortex and the hippocampus may be regulated by early exposure to androgens. Further, cognitive abilities that are sexually dimorphic and which are controlled by these brain regions, may be modified by effects of androgens (Williams & Meck, 1991).

2.3 HUMAN RESEARCH

In humans, it is possible to assess more complex behaviour patterns than is possible in animals. For example, reproductive behaviours such as lordosis in females and mounting in males that are influenced by hormones in non-human species do not provide definitive models of sexual orientation, which in humans include both cognitive and affective as well as behavioural components (Hines, 1982). Thus, it is not possible to extrapolate outcomes of studies of hormone influences on brain structure and subsequent behavioural functioning in non-human species directly to human behavioural functioning because the significance of such brain behaviour relationships is still not completely determined in humans. Furthermore, the effects of masculinising hormones on the brain and subsequent behaviour in animals may not be identical in humans. Given this, a wider range of behaviours must be studied before conclusions can be drawn relating to effects of hormones (for review, see Collaer & Hines, 1995). However, it might be expected that the general principles would be similar. One outcome of this hypothesis has been to test the notion that the same sex differences found in the behaviour of non-human species might also be found in human behavioural functioning.

The existence of differences in brain-behaviour relationships in animals raises the possibility that the human brain is influenced in similar ways by the organisational effects of androgens during critical periods of early development. Moreover, those behaviours that are influenced by early exposure to androgens will be most evident in behaviours that show consistent sex differences. This has been inferred from the commonly held belief that behaviours that are sexually differentiated are influenced by sex hormones, while behaviours that do not show sex differences are not thought to be sensitive to the influence of hormones. Although it is not possible to rule out the possibility that activational effects of later hormones, such as those observed in adolescence and adulthood, or that psychosocial factors also have powerful effects on human behavioural development, it is clear that the early hormone environment is important in determining brain-behaviour relationships.

Although it is evident that structural differences in neural regions are, in part, dependent on the organisational influences of sex hormones in non-human species, evidence for this has not been found in humans, but it is likely that similar effects do occur in regions of the human brain. In support of this conjecture, anatomical studies have revealed that structural differences do exist in neural regions of the human brain, and that these regions contain receptors for androgens.

For example, Wada, Clarke, and Hamm (1975) found that females, more than males, showed a larger planum temporale on the right hemisphere than on the left hemisphere, an area of the brain thought to be involved in speech. Sex differences in the major pathways connecting the two hemispheres have also been reported. In a review of studies investigating sex differences in the size of the corpus callosum, Hines (1990) found that the majority of studies reported that a particular region of the corpus callosum is larger (relative to brain weight) in females. Allen and Gorski (1991) found that the anterior commissure was larger in females than in males, although, this finding has not been replicated. Swaab and Fliers (1985) reported a sex difference in the preoptic area of the hypothalamus (INAH1) such that the volume and cell number was approximately 2½ times greater in males than in females. However, this has not been replicated (e.g., Byne, Lasco, Kemether, Shinwari, Edgar, Morgello, Jones & Tobet, 2000). Further, Allen, Hines, Shryne, and Gorski (1989) found the presence of two other sexually dimorphic cell groups in the preoptic area of the hypothalamus which are twice as large in males as in females. This area is associated with sexual behaviour in humans (LeVay, 1991). These latter two findings are of particular interest because the preoptic area of the hypothalamus has been found to be sexually dimorphic in several non-human species and sensitive to the early hormone environment. Sex differences have also been reported in different areas of the corpus callosum. the main connecting tract between the two cerebral hemispheres. The corpus callosum has been related to sex differences in aspects of cognitive functioning (Hines, Chiu, McAdams, Bentler, Lipcamon (1992).

Although sex differences in neural regions have been reported, findings for humans are more controversial than they are for non-human species, and there is no direct evidence that these differences result from the action of sex hormones on neural tissue. However, a number of sex differences in brain organization have been reported in humans and these sex differences may provide the anatomical substrate for sex differences observed in behaviour. However it is not known whether they are a direct result of organisational influences of sex hormones in the human brain (Hampson & Kimura, 1992).

The evidence for early androgens influencing aspects of human behaviour (more detailed reviews can be found in later chapters) comes mainly from studies involving females exposed to high levels of masculinizing hormones during early development because of a genetic condition, known as congenital adrenal hyperplasia (CAH) (see chapter 3). Females with CAH have been found to be more masculine than unaffected female controls on a variety of behaviours, including childhood play behaviour (Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Berenbaum & Snyder, 1995), sexual orientation (Ehrhardt, Epstein, & Money, 1968; Money, Schwartz, & Lewis, 1984; Dittman, Kappes, & Kappes, 1992; Zucker, 1996), and aggression (Reinisch, 1981; Dabbs, Hopper, & Jurkovic, 1990; Berenbaum & Resnick, 1997) (see Collaer & Hines, 1995 for review). The evidence is more prominent in some areas than in others. For example, with respect to cognitive functioning, effects of androgens on visual-spatial abilities have been identified in some studies, (Resnick, Berenbaum, & Gottesman, & Bouchard, 1986; Hampson, Rovet, & Altman, 1998); however, other studies have not substantiated these findings (Baker & Ehrhardt, 1974; McGuire, Ryan, & Omenn, 1975; Helleday et al., 1994). Thus, the existence of effects of androgen on visual-spatial ability because of CAH are still largely inconclusive, (see Chapter 5 for a critique).

The implications for an androgenic influence on aspects of spatial cognition and gender role behaviour will be reviewed and empirically tested in the following chapters. At present it is only possible to speculate about possible hormonal mechanisms that might influence these abilities. However, despite this, many of the findings from studies of individuals with atypical hormone exposure, converge with findings in animals suggesting that prenatal sex hormones have an important influence on later behaviour and provide a valuable insight into the role that masculinizing hormones play in development.

CHAPTER THREE

CONGENITAL ADRENAL HYPERPLASIA AND BEHAVIOUR: AN OVERVIEW

3.1 INTRODUCTION

In this chapter, information regarding the significance of individuals exposed to a genetically based hormonal abnormality, congenital adrenal hyperplasia (CAH), will be reviewed. Studying the behaviour of individuals with CAH has increased our understanding of the role that sex hormones play in human behavioural development. Given that it is unethical to manipulate hormones in humans, research is limited to the study of clinical endocrine conditions such as CAH, in which there is a known abnormal hormone milieu. These conditions allow assessment of the hypothesis derived from animal models, that androgens influence the development of sexually differentiated behaviour.

3.2 CAH: An Overview

CAH is a group of inherited autosomal recessive disorders in which a defect occurs in one of the enzymatic steps required to synthesize cortisol from cholesterol, resulting in an increased production of adrenal androgens (New & Levine, 1984). In the most common form of CAH (New & Speiser, 1986), there is an adrenal enzyme deficit in 21-hydroxylase (21-OH). In this form of CAH, individuals are unable to produce sufficient quantities of cortisol to inhibit the release of adrenocorticotropic hormones (ACTH). ACTH levels rise via a negative feedback system, which results in hyperplasia of the adrenal gland, and an increase in production of cortisol precursors and sex hormones (androstenedione and testosterone) in response to ACTH. In 21-OH deficiency, which is responsible for about 90-95% of all CAH cases, there is an accumulation of cortisol precursors resulting in an increased production of adrenal androgens prenatally, and postnatally before detection and treatment.

There are three forms of 21-OH deficiency that present at birth: (i) a salt losing form of the disorder; ii) a classic simple virilising form of the disorder in which no salt lost occurs; and, (iii) a non-classical, mild form of the disorder in which the onset occurs later in life. The two major variants, however, are classic simple virilising and salt-losing forms.

The salt-losing form of the disorder occurs in approximately 80% of patients with 21-OH deficiency (Conway, 2000). It is characterized by excess adrenal androgen secretion that causes progressive virilization, accelerated growth, and advanced bone age. In addition to the excess adrenal androgen production, there is an aldosterone deficiency that causes low serum sodium and high serum potassium levels. Females with both this form of CAH and the simple virilising form (see next paragraph) have ambiguity of the external genitalia to varying degrees. Diagnosis at birth of a female with salt-losing CAH is usually made immediately because of the apparent genital ambiguity. However, in both males and females with the salt-losing form, they are subject to life-threatening, salt losing crises within the first few weeks of life if left untreated. Surgical reconstruction of the virilized genitalia in females may be necessary, though, optimally, glucorticoid therapy usually prevents any further virilization postnatally. Treatment includes lifelong glucocorticoid therapy to regulate the production of cortisol and androgen levels. For those individuals who are salt-losers, mineralocorticoid therapy is also required, in addition to the glucocorticoid therapy, to regulate production of aldosterone thus preventing salt losing crises (Miller & Levine, 1987).

In approximately 20% of children with less severe CAH, the classic simple virilising form of the disorder, the sodium balance is normal. However, like the salt losing form of the disorder, it is characterized by excess adrenal androgen secretion causing progressive virilization, accelerated growth, and advanced bone age because of the excess androgens. As in the salt losing form of CAH, females with simple virilising CAH also have ambiguity of the external genitalia to varying degrees. Diagnosis at birth of a female with simple virilising CAH is usually made immediately because of the apparent genital ambiguity. For newborn males with this form of the disorder, because the external genitalia are not affected, diagnosis often depends on screening. However, males are usually diagnosed in infancy because they experience salt-losing crises. If left untreated postnatally, because of the excess androgens, there can be progressive penile or clitoral enlargement, precocious puberty, and advancement in bone age. This can accelerate growth in early childhood, producing an unusually tall and muscular child. Boys with the simple virilising from of CAH are often diagnosed at this point. This early growth is followed by premature retardation of bone growth resulting in a final height that is below what might be expected. Consequently, patients are typically tall children but short adults. Treatment includes lifelong glucocorticoid therapy to regulate the production of cortisol and androgen levels.

In summary, more than 90% of cases of virilising CAH are caused by 21-OH deficiency. Females with severe, classic 21-OH deficiency are exposed to excess androgens prenatally, and postnatally until detection, and are born with masculinisation of the external genitalia. Approximately 80% of patients cannot synthesize sufficient aldosterone to maintain sodium balance and may develop potentially fatal salt wasting crises if left untreated. The incidence of CAH due to 21-OH deficiency in the population is 1 in 5-15,000 live births (New & Levine, 1984)

3.3 CAH FEMALES AND BEHAVIOUR

The most prominent feature of 21-OH deficiency in females is virilization of the genitalia. Adrenocortical function begins in the 3rd month of gestation and a foetus with 21-OH is exposed to oversecreted adrenal androgens at the critical time of sexual differentiation. In the case of females, the excessive adrenal androgen production masculinizes the external genitalia causing, in particular, clitoral enlargement and partial fusion of the labia.

Females with CAH have been repeatedly used as a model to test the hypothesis that the prenatal hormone environment affects sexual differentiation of the brain and behaviour in humans, as it does in non-human species. This is because development of the brain and behaviour is likely to be influenced in a masculine direction by the high levels of prenatal androgens. In particular, hypotheses have been tested evaluating the impact of prenatal androgen exposure on psychological, psychosocial, and psychosexual development. Studies that have been carried out have addressed the question of how prenatal androgen exposure impacts on development (e.g., Ehrhardt, Epstein & Money, 1968; Ehrhardt & Baker, 1974; Reinisch & Sanders, 1984; Berenbaum & Hines, 1992; Resnick, Berenbaum, Gottesman & Bouchard, 1986; Hines & Kaufman, 1994; Berenbaum & Snyder, 1995).

Typically, studies testing the prenatal androgen hypothesis in females with CAH have investigated gender identity, gender role behaviour, sexual orientation and aspects of cognitive functioning. With regard to gender identity (a person's identification with one or the other sex), some studies suggest a less certain female gender identity in girls with CAH (Ehrhardt, Epstein & Money, 1968, Ehrhardt & Baker, 1974) compared to control girls. Others suggest a normal gender identity in line with sex of rearing (Ehrhardt & Meyer-Bahlburg, 1981; Berenbaum & Snyder, 1995). However, researchers have concluded that although in the majority of cases gender identity accords with sex of rearing, it is less well established than in control girls. (see Zucker, 2001, for review).

With respect to gender role behaviour (traits that are culturally associated with being male or female), typically gender-typed play activities, interests, and playmate preferences are the behaviours of interest. Studies have found that CAH girls differ from unaffected girls in preferring boys' toys to girls' toys, a preference for male rather than female playmates, greater tomboyism, reduced interest in infants and a preference for male items of clothing as opposed to female items of clothing (Ehrhardt, Epstein, & Money, 1968; Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Resnick et al., 1986; Hines & Kaufman, 1994; Berenbaum & Snyder, 1995; Leveroni & Berenbaum, 1998).

The effects of prenatal androgens on cognitive abilities have been assessed in CAH females by examining IQ, mathematical ability, verbal ability, and visual-spatial ability (Perlman, 1973, Baker & Ehrhardt, 1974; McGuire et al., 1976; Resnick et al., 1986; Benbow, 1988; Sinforiani, Livieri, Maufi, Bisio, Sibilla, Chiesa, & Martelli, 1994). With regard to IQ, the elevated levels of IQ that were initially found in CAH females compared to unaffected same-sex relatives (Money & Lewis, 1966; Lewis, Money & Epstein, 1968; McGuire & Omenn, 1975) were subsequently explained by a sampling bias rather than because of high levels of androgens, because unaffected siblings of CAH patients also showed elevated IQs. Further, individuals with high intelligence were more likely to enrol in research projects (see reviews by Berenbaum, 1990 and Collaer & Hines, 1995).

With regard to other cognitive abilities, if prenatal levels of androgens do contribute to cognitive sex differences, then females exposed to prenatal androgens might be expected to show increased performance on those abilities that on average favour males. In respect of visual-spatial ability, findings to date have produced an inconsistent pattern of results.

A study carried out by Resnick, et al., (1986) reported that the performance of 17 CAH females on both two- and three-dimensional tests of mental rotations and on the Card Rotations Test was significantly better than that of 13 unaffected same-sex relatives. Similarly, Hampson, et al., (1998) found that 7 girls with CAH, aged 8-12 years, achieved significantly higher spatial scores than 5 relative control girls on the Spatial Relations test of the Primary Mental Abilities, a spatial visualization task.

These latter studies provide the strongest evidence to date in favour of an enhancing effect of prenatal androgens on visual-spatial ability.

In contrast, other studies have found no differences, or even decreased performance in females with CAH. For example, McGuire et al., (1975) in a study of 15 females with CAH, ages 5 to 30 years did not find any significant differences between CAH females and matched same-sex controls using the Embedded Figures Test or the Block Design Test. Similarly, Baker and Ehrhardt (1974), investigated performance on the spatial subtest of the Primary Mental Abilities battery of tests in 13 females with CAH and 11 female relatives aged from 4 to 26 years, and found that females with CAH performed similarly to female relatives. A further study (Helleday, Bartfai, Ritzen, & Forsham, 1994) of 22, 17 to 34 year old females with CAH and 22 matched controls also found no differences on a mental rotations task or on the Block Design Test and The Hidden figures Test. The latter two tasks are spatial visualization tasks. However, this study did find that CAH females scored lower than controls on a spatial perception task (the Rod and Frame Test).

Studies that have assessed the verbal abilities of females with CAH have found no differences (Baker & Ehrhardt, 1974; McGuire et al., 1975; Resnick et al., 1986). With respect to maths abilities, two studies have reported decreased performance on arithmetic tests in females with CAH compared to female controls (Resnick, et al., 1986; Baker & Ehrhardt, 1974). These findings seem paradoxical given that mathematical reasoning is a skill in which males normally excel. However, it has been suggested that these two studies which found a deficit in performance in CAH females, used simple mathematics tests that did not tap the kind of mathematical skill which typically shows a male advantage (see Collaer & Hines, 1995).

Research on other non-hormonal influences that might explain the behavioural changes in females with CAH have also been examined. The relationship between factors such as degree of virilization influencing self- or parental-perceptions (Quadagno, Briscoe, & Quadagno, 1977), the illness history associated with CAH (Slijper, 1984) and the salt-losing versus simple virilising status, (Dittmann, et al., 1990a) have been explored. Differences have been observed between salt-losing and simple virilising females with CAH, such that gender related behaviour in females with salt losing CAH was reported to be more masculine than for females with simple virilising CAH (Dittmann, et al., 1992; Slijper, 1984). However, the outcome of studies assessing other illness factors, suggest that they are less likely to influence behaviour than that of the early hormone environment.

3.4 CAH MALES AND BEHAVIOUR

Males with CAH have normal appearing genitalia at birth. However, they are treated pharmacologically in the same way as females, in order to prevent early onset of puberty.

It is unclear whether CAH males experience excessive androgen exposure. It is also unclear whether elevated androgens, beyond normal levels, increase or decrease masculine behaviour beyond that seen in normal males. Animal studies have produced inconsistent findings (e.g., Baum & Shretlen, 1975; Pang, Levine, Chow, Faiman, & New, 1979). Some studies have found evidence of increased masculinisation, while other studies have found no such effects, or a reduction in masculine-typical behaviour (Diamond, Llacuna, & Wong, 1973). One hypothesis put forward to account for this is in relation to the compensating mechanisms from the testicular production of androgens. It is thought that the over-production of androgens from the adrenal glands due to CAH may result in a down-regulation of testicular androgen production as a result of a negative feed back effect system caused by excessive production of adrenal androgens (Pang, Levine, Chow, Faiman, & New, 1979).

Males with CAH have not been studied as extensively as females. However, studies assessing behaviour in males with CAH have generally reported very few differences in behaviour compared to unaffected males. Ehrhardt and Baker (1974) found no differences between CAH males and unaffected male relatives on measures of gender-related behaviour, except that CAH males manifested higher energy expenditure than unaffected male relatives. Further, Berenbaum and Hines, (1992) found that 11 boys with CAH did not differ from 18 unaffected male relatives in play with boys' or girls' toys. Hines and Kaufman (1994) found no differences in sex of preferred playmate in 11 boys with CAH compared to 18 unaffected same-sex relatives. However, unlike Ehrhardt and Baker (1974), they did find that boys with CAH showed reduced rough and tumble play compared to control boys. Further, Berenbaum and Snyder (1995) found similar results in 19 CAH compared to 25 unaffected male relatives of individuals with CAH in which no differences in activity and playmate preferences were observed.

With respect to cognitive abilities, Perlman (1973) found that CAH males did not differ from control boys on a battery of cognitive tests. Baker and Ehrhardt (1974) found no differences between 8 males with CAH and 14 male relatives on the Spatial Relations Test. McGuire et al., (1975) also found no differences between 16 males with CAH and 16 matched controls on two tests of visual-spatial ability (Block Design Test and Embedded Figures Test). Further, Resnick et al., (1986) found no differences between the performance 8 CAH males and 14 unaffected male relatives on two tests of mental rotations and on the Hidden Patterns Test, a spatial visualization task. However, Hampson et al., (1998) did find that boys with CAH scored lower than unaffected male relatives on a spatial relations test. Similarly, after controlling for general intellectual ability, Hines, Fane, Pasterski, Mathews, Conway and Brook (2002, submitted for publication) also found that the performance of CAH males was decreased compared to that of unaffected male relatives on both tests of two and three-dimensional mental rotations.

To conclude, although individuals with CAH provide a relevant patient group for the study of human behavioural sex differences, it is unlikely that the relationship between androgens and subsequent behaviour is a simple one. Moreover, hormones other than androgens are also abnormal in these individuals, and the extent of their effects on behaviour, if any, is yet known. Furthermore, hormonal and psychosocial influences interacting together may contribute to some of the sex differences in human behaviour. Thus although prenatal androgens may play a role independently, it is also likely that their effects operate in tandem with socialization factors.

CHAPTER FOUR

GENDER ROLE BEHAVIOUR IN CHILDREN WITH CONGENITAL ADRENAL HYPERPLASIA: EMPIRICAL EVIDENCE

4.1 FOREWARD

This chapter presents data on the gender role behaviour of boys and girls with CAH and unaffected relatives. Assessment of whether this sample of CAH children is typical of others with CAH in respect to their gender role behaviour is examined. The data are relevant to empirical investigations reported on in later chapters and thus have been analysed separately. This will allow findings to be discussed in relation to both spatial cognition and the influence of social information in gender role development.

4.2 INTRODUCTION

Several studies have reported that females with CAH prefer to engage in more masculine play and activities than other girls (Ehrhardt, Epstein & Money, 1968; Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Dittmann, Kappes, Kappes, Börger, Willig, & Wallis; 1990; Hines & Kaufman, 1994; Berenbaum & Snyder, 1995). However, because other studies have found behaviour to be altered in CAH females, and because protocols investigating responses to social influences carried out in this thesis have not been tested in CAH children before, gender role behaviour was measured. This enabled an assessment of whether CAH girls in this study, like other samples, are more masculine in their gender role behaviour than unaffected girls. Studies of boys with CAH have produced inconsistent findings in regard to the development of childhood play and activities (Ehrhardt & Baker, 1974; Hines & Kaufman, 1994; Berenbaum & Snyder, 1995), with few differences being reported. Their gender role behaviour is assessed to confirm that this aspect of behavioural functioning is similar to that seen in other CAH boys.

4.3 HYPOTHESES

Sex differences in gender role behaviour are predicted. Unaffected boys are predicted to adopt more masculine gender role behaviour than unaffected girls, who are predicted to adopt more feminine gender role behaviour. CAH girls' gender role behaviour is predicted to be more masculine than that of unaffected girls, and more similar to that of unaffected boys. No specific predictions are made for CAH boys.

4.4 METHOD

4.4.1 Participants

Ninety-four children, 50 CAH children (27 girls and 23 boys) and 44 unaffected relatives (22 girls and 22 boys), aged 3-11 years, took part. Children with CAH were recruited through Paediatric Endocrine Consultants at Great Ormond Street Hospital in London and via a CAH Support Group in the UK. Forty nine patients were 21-hydroxylase (21-0H) and salt-losing and one was 21-0H and non salt losing (simple virilising). Unaffected siblings and cousins (40 siblings and 4 cousins) served as control participants. Cousins were asked to participate when siblings were not available. Table 4.1 sets out the frequency of patients with sibling and/or cousin control participants.

Table 4.1. Frequency of CAH patients with one or more sibling and/or cousin control participants.

	One unaffected sister	Two unaffected sisters	One unaffected brother	Two unaffected brothers	One Unaffected female cousin	Two Unaffected female cousins	No relative controls
CAH girls	6	0	6	1	3	1	13
CAH Boys	7	0	9	0	1	0	8

Relatives represent a good comparison group when random assignment to groups is not possible because they are similar to patients on factors such as genetic make-up, socioeconomic status, and family background (Reinsich & Gandelman, 1978). Although they cannot be matched individually on age they generally do match on this. Unaffected relative controls were also recruited from a similar study examining some of the same behaviours and traits in adolescents and adults with CAH (see Table 4.2).

Table 4.2. Frequency of sibling controls with a CAH brother or sister participating in adolescent and adult study.

	CAH sister	CAH brother
Unaffected girls with CAH brother and/or sister in adult study	1	3
Unaffected boys with CAH brother and/or sister in adult study	2	1

All children were white Caucasian. Parents provided written consent for children's participation. In this sample, patient and control groups were comparable in age at the time of testing (see Table 4.3).

Table 4.3. Age of CAH and unaffected boys and girls at time of testing.

	CAH girls		**Unaffected Girls**		**CAH Boys**		**Unaffected Boys**	
	M	SD	M	SD	M	SD	M	SD
Mean age	7.6	2.48	7.0	2.40	7.2	2.68	7.5	2.13

It was not possible to calculate participation rate in the study. Because of ethical considerations, no information was given from Great Ormond Street Hospital when families did not consent to participate. With respect to recruitment from the CAH Support Group, all families with CAH children were contacted but not all of the families had CAH children in the 3-11 year old age range. Further, because of confidentiality, it was not possible to find out how many families replied following the invitation to participate.

4.4.2 Materials

The Pre-school Activities Inventory (PSAI) (Golombok & Rust, 1993a, 1993b) measures gender role behaviour in young children. The Inventory has been standardised across several samples in different countries, including a sample of 939 boys and 704 girls in the UK; 170 girls and 178 boys in the Netherlands; and 96 boys and 115 girls in Minnesota. It has also been tested for reliability, using both test-retest reliability (.64 across the sexes) and split-half reliability (.88 for the sexes combined). It has been subjected to validation in which scores on the test were found to correlate with teachers' blind ratings of the children's 'boyish' and 'girlish' behaviour.

The PSAI is designed for use with children aged from 2 to 7 years, and is completed by a parent or caretaker. Parents or caretakers of older children (8-11 years) participating in the study were asked to complete the Inventory retrospectively, thinking back to the time when their child was between the ages of 2 to 7 years.

The PSAI consists of 24 items in 3 content categories: toys (7 items), activities (11 items) and personality characteristics (6 items) and measures frequency of play in each category (see Appendix 1). All questions are designed to discriminate masculine from feminine gender role behaviour. Higher scores reflect more masculine gender role behaviour and lower scores indicate more feminine gender role behaviour.

4.4.3 Procedure

Parents completed the PSAI (Golombok & Rust, 1988) whilst children completed a battery of tests, some of which are reported on in other chapters of this thesis (see Appendix 2). Instructions informed respondents that each question on the Inventory asks how frequently their child plays with particular toys, engages in particular activities, or shows particular characteristics. There were 5 response categories: N = never; HE = hardly ever; S = sometimes; O = often; VO = very often. Respondents were told to circle the response which best described their child's behaviour, and to answer all of the questions.

4.5 RESULTS

Initial analysis

As the PSAI was designed for use with children between the age of 2-7 years, an initial analysis was carried out to ascertain difference in scores for younger children in the study (3-7 year olds) for whom the inventory was completed concurrently, and older children for whom the Inventory was completed retrospectively (8-11 year olds). A three-way, sex (girls, boys) by diagnosis (CAH, unaffected children) by completion (retrospective, concurrent) analysis of variance (ANOVA) revealed significant main effects of sex, F (1,86) = 118.86, p < .001, and diagnosis, F (1,86) = 22.98, p < .001. Boys' scores were higher (more masculine) than girls' scores (which were lower, indicating they were more feminine in gender role behaviour), and children with CAH revealed more masculine scores than unaffected children. A two-way interaction between sex and diagnosis was also significant, F (1,86) = 35.77, p < .001, revealing that CAH girls scores were higher (more masculine) than unaffected girls scores, however, CAH and unaffected boys did not differ. The main effect of time of completion was not significant, F (1,86) = 0.01, p = .98. None of the interactions between completion, sex and diagnosis were significant either. The significant interaction between sex and diagnosis is explored further in the planned comparisons below.

Correlation of PSAI and age

The correlation between PSAI scores and age was examined however, no association was found, r = 0.086, p = .41.

Planned Comparisons

The main ANOVA was followed by a series of planned comparisons, to test the specific hypotheses relating to CAH. Independent analyses of variance were conducted for each of the planned comparisons, comparing gender role behaviour in unaffected boys and girls, CAH girls and unaffected girls, CAH girls and unaffected boys and CAH boys and unaffected boys. Given that the PSAI has been standardised for age and that there were no differences for retrospective versus concurrent completion, age was not included as a factor in these analyses. Effect sizes were also calculated using Cohen's 'd' statistic (Cohen, 1977).

Table 4.4. PSAI scores for CAH and control comparison Groups, as a function of concurrent and retrospective completion.

	PSAI Score	
	M	SD
CAH girls		
Concurrent 3-7 years (N=15)	57.64	17.97
Retrospective 8-11 years (N=12)	57.78	12.90
Total (N=27)	57.70	15.63
Unaffected girls		
Concurrent 3-7 years (N=13)	32.43	10.62
Retrospective 8-11 years (N=9)	28.21	12.90
Total (N=22)	30.70	11.50
CAH Boys		
Concurrent 3-7 years (N = 13)	70.08	8.64
Retrospective 8-11 years (N =10)	70.36	10.14
Total (N=23)	70.20	9.10
Unaffected boys		
Concurrent 3-7 years (N=10)	71.46	12.30
Retrospective 8-11 years (N=12)	75.02	6.90
Total (N=22)	73.40	9.64

As predicted mean PSAI scores differed for unaffected girls and boys, *F* (1, 42) = 178.25, *p* < .001. Boys' scores were significantly higher (more masculine), than girls' scores which were lower (more feminine). The size of this difference was large (d = 4.03). Differences were also observed between CAH girls and unaffected girls, *F* (1, 47) = 45.52, *p* < .001. CAH girls' scores were significantly higher (more masculine), than unaffected girls' scores which were lower and indicated feminine gender role behaviour. The size of the difference was also large (d = 2.0). CAH girls' and unaffected boys' scores also differed, *F* (1,47) = 16.91, *p* < .001. CAH girls' scores were less masculine than unaffected boys' scores. The size of the difference was moderate (d = 0.6). PSAI scores for CAH boys and unaffected boys did not differ, *F*

(1, 43) = 1.31, p = .26, and the size of the difference was small (d = 0.3). (See Table 4.4).

Frequency of Play with Girls

One of the questions in the PSAI relates to frequency of play with other girls and was subjected to a separate analysis ('how often the child engages in play with girls') in order to test for group differences on this dimension, specifically, testing the hypothesis that CAH girls will be reported to play less with other girls than unaffected girls.

Independent t-tests were carried out for each of the specific CAH and control group comparisons. Unaffected girls were reported to play with other girls significantly more often than unaffected boys, t (42) = 8.05, p < .001. CAH girls were reported to play with other girls significantly less often than unaffected girls, t (47) = 4.39, p < .001, but more often than unaffected boys, t (47) = 3.54, p = .001. CAH boys were reported to play with girls significantly more often than unaffected boys, t (43) = 2.31, p < .03. (See Table 4.5).

Table 4.5 Frequency of play with girls by CAH and control comparison groups.

	CAH girls		**Unaffected girls**		**CAH boys**		**Unaffected boys**	
	M	SD	M	SD	M	SD	M	SD
Frequency of play with girls	3.04	1.00	3.86	0.35	2.74	0.92	2.10	1.00

4.6 DISCUSSION

The data reveal large differences between unaffected boys and girls, as expected, indicating that unaffected boys are masculine in their gender role behaviour and unaffected girls are feminine in their gender role behaviour. The data further indicate masculinising effects in girls with CAH. They scored somewhere in between unaffected girls and boys, suggesting that they are more masculinised in their gender role behaviour than unaffected girls, but are not as masculinised as unaffected boys. No changes in gender role behaviour in boys with CAH compared to other boys were observed, and this finding is consistent with previous studies which have reported no differences in childhood play behaviour (Ehrhardt & Baker, 1974; McGuire, Ryan & Omenn, 1975; Berenbaum & Snyder, 1995).

The findings are consistent with other studies (Money & Ehrhardt, 1972; Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Hines & Kaufman, 1994) in which CAH girls have been reported by their mothers in some studies, and observed directly in other studies, to be more masculine in their play behaviour. They are reported to prefer boys as playmates, and toys such as cars and trucks as opposed to dolls. Thus the data from this sample of CAH girls indicate that, like other samples of CAH girls, early hormone exposure has a masculinising effect on gender role behaviour.

Furthermore, when frequency of play with girls was analysed separately, similar findings were revealed for girls with CAH and unaffected female relatives. As expected, unaffected girls were reported to play with other girls more often than unaffected boys. CAH girls, however were reported to be less likely to play with girls than unaffected girls, but more likely to play with girls than unaffected boys. Again these findings for CAH girls are similar to previous findings in regard to masculinisation of play behaviour (Berenbaum & Hines, 1992; Ehrhardt & Baker, 1974; Berenbaum & Snyder, 1995).

The finding that boys with CAH were reported to play with girls more often than unaffected boys was unexpected. Past research has generally not suggested behavioural change as a result of CAH. However, there are a small number of studies which have reported demasculinisation in other areas (Hines & Kaufman, 1994; Hampson et al., 1998; Hines et al., 2002, submitted for publication). Although unexpected, the reporting of increased play with girls compared to unaffected boys may explain Hines and Kaufman's (1994) observation that CAH boys were less likely to engage in rough and tumble play than unaffected boys. Generally, girls do not engage in this type of play behaviour, and as a result of this social situation CAH boys may co-operate by inhibiting this behaviour. As a consequence this may then impact on their play with other boys. However, caution is exercised in this interpretation as only a single item has been measured to assess this aspect of behaviour.

In conclusion, the results from this study are relevant to other studies carried out in this thesis. It is well known that certain dimensions of spatial cognition show a male advantage, and some studies have shown that females with CAH perform better than other females, suggesting an influence of androgens. It is also possible that this advantage might be related to childhood gender role behaviour. Moreover, social influences in gender role development, such as modelling and gender-labelling, clearly show an impact of sex of model or gender label of stimuli on boys and girls' subsequent response behaviour. However, it is not known if sex-typical responses to social mechanisms influencing gender role development are altered in girls with CAH. Thus, knowledge of CAH girls' gender role behaviour will allow an assessment of the relationship between play behaviour and social influences, and may provide evidence for separable or different effects of androgen on these processes.

Finally, the results suggest that the PSAI is a useful measure of gender role behaviour in children with CAH and that this is the case whether used concurrently or retrospectively.

CHAPTER FIVE

EARLY SEX DIFFERENCES IN SPATIAL COGNITION AND EVIDENCE FOR AN INFLUENCE OF HORMONES: A REVIEW

5.1 INTRODUCTION

Sex differences in aspects of spatial cognition, such as visual-spatial and targeting ability, are widely acknowledged (Jardine & Martin, 1983; Lunn & Kimura, 1989; Watson & Kimura, 1991; also see Voyer, Voyer, & Bryden, 1995, for review), however the basis for these differences remains at issue, and the age at which differences can be detected is still questioned. Although robust sex differences favouring males in visual-spatial abilities such as mental rotations and spatial perception are well documented in adolescents and adults, the existence of such sex differences in children remains controversial (see Voyer et al., 1995, for review). However, in respect of targeting ability, robust sex differences are observed from as early as 3 years and continue into adulthood (Thomas & Thomas, 1988, Lunn & Kimura, 1989, Jardine & Martin, 1991).

One explanation put forward to account for sex differences observed in visual-spatial ability is that of the early hormone environment. Rats exposed prenatally to high levels of androgens prenatally and neonatally show enhanced spatial abilities. As a consequence of this, it has been hypothesised that androgens similarly influence visual-spatial functioning in humans. However, evidence for this is inconsistent (Perlman, 1973; Ehrhardt & Baker, 1974; Resnick, Berenbaum Gottesman, & Bouchard, 1986; Hampson, Rovet & Altmann, 1998; Hines et al., 2002, submitted for publication). With regard to targeting ability, there is only one study reporting an effect of hormones (Hines et al., 2002 submitted for publication) on performance. At present, research conducted in the human literature that relates to the early hormone environment as a mechanism by which sex differences mediate these skills is relatively sparse.

5.2 VISUAL-SPATIAL ABILITY

One aspect of spatial cognition widely recognized as typically showing a sex difference in humans is visual-spatial ability. It is an important component of human cognition and a sex difference, with males on average outperforming females, has been extensively demonstrated (see Voyer et al., 1995; Linn & Petersen, 1985, Maccoby & Jacklin, 1974, for reviews). The sex difference has also been found to occur in some non-human species (e.g., Williams & Meck, 1991). The size of the sex difference in humans, however, is often relatively small compared to the size of difference seen in the behaviour of non-human species. The demonstration of hormonal contributions to performance on visual-spatial ability is mixed. Some studies have only produced suggestive results, with factors such as lack of statistical power, and methodological shortcomings such as small sample size and lack of appropriate measures to detect sex differences, preventing more definitive conclusions (e.g., Ehrhardt & Baker, 1974; Resnick et al., 1986).

Visual-spatial ability is not an easy term to define. However, it is generally referred to as the ability to imagine what an irregular figure would look like if it were rotated in space, or the ability to determine the relationship between shapes and objects (Halpern, 1992). Visual-spatial ability is typically measured using a variety of psychometric tests. For example, they may require individuals to imagine the rotation of a depicted object, or to imagine what an object would like when folded together or seen from a different perspective without the physical changes actually taking place, but rather, taking place in the mind (Hampson & Kimura, 1992). Other tests might require individuals to recognise shapes embedded within a more complex visual array, or to solve a maze problem, or imagine changes in the relative positions of objects. Meta analytic studies, which have surveyed the published data, have shown that there are at least 3 distinct subtypes of visual-spatial ability, referred to as mental rotations, spatial perception and spatial visualisation (see Linn & Petersen, 1985; Voyer et al., 1995, for reviews). Research from a cognitive perspective identified the three general categories of visual-spatial ability (e.g., Carpenter & Just, 1981; Shepard & Cooper, 1982). These categories were arrived at by focusing on similarities in the processes that respondents used to carry out individual items within each of the three perspectives (Linn & Petersen, 1985).

The sex differences in each of these categories of visual-spatial ability vary in size, with the largest and most reliable sex difference being reported for tests involving mental rotations. Mental rotation involves the imaginal rotation of two- or three-dimensional objects in space, requiring participants to make a comparison between a rotated figure and its standard form, and to decide whether the rotated figure is the same as the standard, or whether it is a mirror image. Differences as large as almost one standard deviation, favouring males, have been reported (mean effect size = 0.73) on a variety of these tests, involving both two- and three-dimensions, the stimuli of which can be either familiar or unfamiliar.

Tasks involving spatial perception require the ability to determine spatial relations despite distracting information. The differences in terms of effect size for tests involving spatial perception are smaller than that for mental rotations but still in the moderate range, (mean effect size = 0.44) (Voyer, et al., 1995). Tests typically involve individuals discriminating between the direction or orientation of lines with or without distracting information.

The third category, spatial visualisation, is defined as the ability to manipulate complex information, and shows a much smaller sex difference (mean effect size = 0.13), and not of significant magnitude. Tests in this latter category are more heterogeneous and include tasks such as those in which individuals have to decide which one, of an array of drawings, can be made out of a set of fragmented parts, or what an unfolded shape would look like when folded. Other tests involve individuals reconstructing a shape using three-dimensional blocks, or finding a simple figure embedded within a complex pattern (Voyer, et al., 1995). Tasks within this latter domain are more diverse in their cognitive requirements and, thus Voyer et al., (1995) conclude, that it may be a 'catchall' category for tasks that do not fit well in the other categories.

Visual-spatial ability is important, not only in our understanding of human intelligence, of which it is a component, but also in understanding the different representations of males and females in occupational life. In a real world setting it is important because performance in a number of occupations including, architecture, engineering, carpentry, mechanics, and other occupations that require competence in visual-spatial ability, are typically work domains in which males often excel (Govier & Feldman, 1999). Demands on spatial skill are also made by various technical tasks such as interpretation of graphs, and X-rays, and often require the ability to mentally transform images. Moreover, tests of visual-spatial ability have also been used to predict success in first year undergraduate engineering courses (Poole & Stanley, 1972).

A large body of the research investigating the development of visual-spatial ability has been carried out over the last three decades (Maccoby & Jacklin, 1974; Linn & Petersen, 1985; Voyer et al.,1995). Reviews have brought to attention that in general, males tend to outperform females on these tasks. However, in spite of the evidence indicating an overall male advantage on visual-spatial functioning, issues relating to the causes of these differences, the age at which these differences are thought to emerge, and their significance are still not entirely clear. Among pre-adolescent boys and girls, there are inconsistent findings of sex differences on all three sub-types of visual-spatial tasks. Several studies have failed to produce reliable sex differences in pre-adolescent children (see Maccoby & Jacklin, 1974; Waber, 1976) and some researchers have proposed that this is because differences do not fully emerge before adolescence (e.g., Nash, 1975, Waber, 1976).

These inconclusive findings have led to disagreement as to the developmental course that visual-spatial skills take for boys and girls. Other researchers, however, argue that sex differences in some aspects of visual-spatial ability can be detected in pre-adolescent children (eg, Newcombe, 1982; Johnson & Meade, 1987). Studies investigating mental rotations in children have shown that reliable sex differences do emerge when age appropriate tests are administered (Rosser, Rosser, Ensing, Glider & Lane, 1984; Levine, Huttenlocher, Taylor & Langrock, 1999; Vederhus & Krekling, 1996, Fane, Collins & Hines, 2002, in preparation).

5.2.1 Early Sex Differences and Visual-Spatial Ability

Several different measures are available for examining visual-spatial ability in children. However, the developmental pattern is probably different for each type of visual-spatial ability (Halpern, 1992). Linn and Petersen (1986), in their meta analysis, concluded that sex differences in mental rotations cannot be measured reliably until around 10 or 11 years of age, and for spatial perception concluded that sex differences are not detected until approximately 7 years of age. In a more recent meta analysis of sex differences in spatial abilities, Voyer et al., (1995) concluded that sex differences in young children are inconsistent but argue that most of the measures of spatial performance used in young children were developed for use with adults, thus making tasks very difficult for young children and producing floor effects which might mask detection of sex differences in young age-groups.

Studies assessing visual-spatial functioning in children, in which sex differences have been found, have often used tasks which involve mental rotations to demonstrate developmental trends and sex differences, and predominantly use an outcome measure of response accuracy. Rosser et al., (1984) used a mental rotations task, which required children to rotate line drawings, similar in shape to teardrops, with differing numbers of cues to orientation. They found that 4 and 5 year old girls lagged behind boys when there were at least 2 cues to orientation on the stimuli. Johnson and Meade (1987) demonstrated sex differences in children as young as 6 years on a two-dimensional mental rotations task. Kerns and Berenbaum (1991) found that in 9-13 year olds, boys were faster, and performed better on a three-dimensional mental rotations test than girls. Their test was similar to that used by Vandenberg and Kuse (1978), although it was modified by the use of actual three-dimensional objects rather than the pictorial two-dimensional representations of three-dimensional objects typically used with adults. Vederhus and Krekling (1996) found near adult effect sizes in 9 year olds ($d = 0.6$) on both the PMA Spatial Relations test (Thurstone, 1962) ($d = 0.79$), and on a modified three-dimensional mental rotations test (Vandenberg and Kuse, 1978) ($d = .56$), with boys outperforming girls. Fane, Collins and Hines, 2002 (in preparation) found a sex difference favouring boys on a two-dimensional mental rotations task, originally used by Marmor (1975, 1977) in children aged 3-8 years ($d = 0.95$) and on a modification of the same task in children aged 4 and 5 years ($d = 1.13$). Levine, Huttenlocher and Langrock (1999) found that boys performed better than girls as early as 4½ years of age on a spatial transformation task with a mental rotations component. Interestingly, the three-dimensional mental rotations task used in Vederhus et als., (1996) study, which observed a sex difference, is a modified version of the standard mental rotations task used with adults, normally considered too difficult for young children.

The studies showing sex differences favouring boys in pre-adolescent children all used modifications of the standard Shepard and Metzler (1971) mental rotations paradigm which shows the largest and most consistent sex difference in adults. The mental rotations tasks have been validated in the experimental and developmental literature as a useful technique for assessing visual-spatial ability in children, and is one of the most commonly used experimental paradigms. It is possible that one of the main reasons why little reliable data exist on sex differences in children is due to the fact that some of the measures used to test visual-spatial ability, are not appropriate and do not show large sex differences, even in adults.

The developmental pattern for tests of spatial perception is more complicated. Generally, differences favouring males are not detected until about 7 years of age, accelerating to adult levels at about 11-13 years (Halpern, 1992). Studies of spatial perception in pre-adolescent children are fewer than studies of mental rotations. Tasks typically used to assess spatial perception in children have been the Rod and Frame Task, which requires the ability to position a rod vertically within a tilted frame, and the Water level Task, which requires participants to draw in the water level of a tilted glass that has been half filled with water. The investigation of spatial perception in children, however, is replete with contradictory findings. Only a few studies have found sex differences (Witkin, Goodenough, & Karp, 1967; Maxwell, Croake, & Biddle, 1977; Vederhus & Krekling, 1996). Others have found no differences (Willemsen, 1974; McGillicuddy-DeLisi, Delisi, & Young, 1978; Kenyon, 1984; Pennings, 1991).

A line orientation task, Judgment of Line Orientation (Benton, Varney & Hamsher, 1978), is a task that also measures spatial perception. It is a test that measures the accuracy of judgements of the slope of visually presented lines. Participants are required to match target stimuli consisting of pairs of lines, with identical lines in a multiple choice array. It is a test which has shown a sex difference (Lindgren & Benton, 1980) but has not been used extensively to test healthy individuals, having been originally designed as a neuropsychological assessment tool to assess spatial deficits in brain damaged patients. However, given its ease of use, and its limited demands on memory capacity, it is regarded as being suitable for children as young as 7 years. Furthermore, given that it is a relatively new 'addition' within the visual-spatial domain, and given that it shows a sex difference, it merits further investigation as to the developmental course it takes and whether the test is suitable for children younger than 7 years.

5.2.2 Hormones and Visual-Spatial Ability in Atypical Development

Early masculinizing hormones play an important role in postnatal behaviour in animal studies (e.g., Goy & Phoenix, 1982). As a consequence of this it has been proposed that the same hormones are one influence on sex-related differences in humans too (see Collaer & Hines, 1995). This hypothesis has not received extensive investigation in children because of the difficulties in measuring hormonal status, and the timing of the measurement of hormone levels. However, some research has been conducted specifically to examine the effects of the early hormone environment on the development of visual-spatial functioning by assessing behaviour in individuals exposed to high levels of androgens prenatally (Baker & Ehrhardt, 1974; Resnick, Berenbaum, Gottesman, & Bouchard, 1986; Hampson et al., 1998). If the prenatal hormone environment does contribute to sex differences, then it might be expected that females with CAH who are exposed to high levels of prenatal androgens, will show an enhancement in visual-spatial functioning similar to the performance of males.

Testing this hypothesis has produced mixed findings. For example, an early study (Perlman, 1973) reported that 11 females with CAH performed better than 11 unaffected matched control girls (aged from 3 to 15 years old), on the Healey Picture Completion Test, a spatial visualization task. Further, Resnick, Berenbaum,Gottesman, and Bouchard (1986) investigated cognitive abilities in 17 females and 8 males with CAH (with ages ranging from 11 to 18 years), and found significantly enhanced performance in females with CAH compared to 13 unaffected female relatives on three mental rotations tasks: two-dimensional mental rotations, three-dimensional mental rotations (Vandenberg & Kuse, 1978), and The Card Rotation Test (Ekstrom, French, Harman & Derman, 1976). This study has found the strongest evidence to date of an enhancing effect of prenatal androgens on mental rotations in females with CAH. Similarly, in a more recent study, Hampson, Rovet, and Altmann (1998) reported that 7 girls with CAH aged from 8-12 years, achieved significantly higher scores than 5 unaffected female relatives of girls with CAH on the PMA Spatial Relations Test, a test of spatial visualisation.

In contrast, in an earlier study, Baker and Ehrhardt (1974) reported that 13 CAH females did not differ from 11 unaffected female relatives on the spatial subtest of the Primary Mental Abilities test battery. The age range in this sample was 4-26 years.

Similarly, McGuire, Ryan and Omenn (1975) did not find differences between the performance of 15 females with CAH (aged from 5-30 years) and matched control females on the Block Design Test and the Embedded Figures Test, both tests of spatial visualisation. Helleday, Bartfai, Ritzen and Forsman, (1994) found no differences on a mental rotations task or on the Block Design Test and the Hidden Figures Test (both tests of spatial visualization) but did observe impaired performance in CAH females compared to control females. These studies, however, did not separate out those individuals who were pre-adolescent, adolescent and post-adolescent, and thus drawing any conclusions with regard to prenatal androgens and visual spatial performance in CAH individuals is difficult. Further, in a more recent study, Hines et al., 2002 (submitted for publication), found no differences between 40 CAH females and 29 unaffected relatives, aged from 12 to 45 years, on both two- and three-dimensional tests of mental rotations.

Findings with regard to males with CAH show fewer differences. Hines et al., (2002, submitted for publication) reported impaired performance in 29 males with CAH compared to 30 unaffected male relatives on two-and three-dimensional mental rotations. This finding is similar to that reported by Hampson et al., (1998) who found that CAH males scored lower than unaffected male relatives on a spatial visualization task. Resnick et al., (1986), however, found no differences between 8 males with CAH and 14 unaffected relatives. Similarly, Baker and Ehrhardt (1974) found no differences between 8 males with CAH compared to 14 unaffected male relatives on the spatial relations subtest of Thurstone's test battery. There were also no differences between 16 CAH males and 14 male relatives on the Block Design Test or the Embedded Figures Test in McGuire et als., (1975) study.

Thus, some studies provide evidence for the influence of early androgens on visual-spatial ability, while others do not. However, the age range of the sample tested in Resnick et als., (1986) study which reported an effect of CAH in females, precludes any definitive conclusions from being drawn in regard to the influence of the prenatal hormone environment, because later hormones might also be influencing visual-spatial performance. In order to clarify the extent to which hormones contribute to sex differences in visual-spatial ability, studies would need to assess this functioning in pre-adolescent children, before the activation of later hormones.

5.2.3 Hormones and Visual-Spatial Ability in Normal Development

Another approach taken to investigate the relationship between hormones and visual-spatial ability has involved measuring hormone levels during early development and relating these to subsequent visual-spatial functioning in normally developing individuals. These studies, however, do not clarify the inconsistencies that have been found in studies of CAH individuals and preclude conclusions. For example, Jacklin, Wilcox and Maccoby (1988), found a significant inverse relationship between levels of neonatal androgens (testosterone and androstenodione) and the spatial component of the Primary Mental Abilities (PMA) test in girls at 6½ years of age. No relationship was observed in boys. Nor was any significant difference found between the performance of boys and girls on this task. The authors did note, however, that the levels of hormones found neonatally in umbilical cord blood might not be representative of the androgen levels present prenatally during the sensitive period for sexual differentiation of the brain. Furthermore, the spatial component of the PMA test does not typically show a large or consistent sex difference and this may account for the lack of a sex difference and lack of a positive relationship with androgen.

Finegan, Niccols, and Sitarenios (1992) investigated the relationship between prenatal testosterone, as measured at 14 weeks gestation in amniotic fluid, and visual-spatial ability at age 4 years. They found that those girls who had lower prenatal testosterone levels achieved higher scores on a block-building task. This observation is the opposite of what would be predicted. However, in a study by Grimshaw, Sitarenios, and Finegan (1995), a positive relation was found between rates of mental rotation in 7-year old girls and prenatal testosterone levels (measured using second trimester amniotic fluid). Girls with higher levels of prenatal testosterone were faster at mental rotations than girls with lower levels of prenatal testosterone. The opposite pattern was found in boys. These findings led the authors to conclude that testosterone acts prenatally on the brain to influence later visual-spatial ability. However, it is unclear whether the performance of girls with higher levels of prenatal testosterone was also better.

There are two possible explanations for the disparate findings in both the Jacklin et al., (1988) and Finegan et al., (1992) studies. First, the measures used to assess visual-spatial functioning in both studies do not typically show a large sex difference. Second, in Jacklin et als., (1988) study, measures of testosterone were recorded using neonatal cord blood and it is unclear how reliable this is as a measure of circulating hormone levels prenatally. These methodological limitations preclude any firm conclusions being drawn in regard to how much, or whether early sex hormones influence visual-spatial ability, especially as in both studies for girls, the findings were the opposite of those expected.

It is evident that inconsistencies in the research literature highlight the necessity for a systematic approach to be taken in the investigation of the relationship between the early hormone environment and visual-spatial functioning. Two things are clear, however. Firstly, that it is important to use measures of visual-spatial ability that show reliable sex differences in children. Many studies have used measures showing negligible or unknown sex differences. Secondly, the predicted sex differences in healthy boys and girls should be investigated concurrently in those studies that explore differences between individuals with hormonal abnormalities. This is important for confirmation that tasks under investigation do (or do not) show the expected sex differences in healthy individuals. It is of particular importance in studies investigating sex differences in children because findings are not as clear as they are in adults, and reliable measures of visual-spatial ability have to date not been identified. Further, without an assessment of sex differences it is not possible to draw conclusions with respect to the influence of androgens on visual-spatial performance.

Thus far, it has been demonstrated that in animals (Chapter Two) there is support for an underlying effect of early androgens on certain aspects of visual-spatial ability, but in humans this has not been clearly demonstrated. However, one general finding of note, is that the types of visual-spatial ability that have been used to assess behaviour in humans and animals, differ dramatically. In animals visual-spatial ability typically involves a kind of navigational learning, whereas in humans, tasks used to assess performance involve paper and pencil tests of mental rotations, spatial perception and spatial visualisation. Therefore, extrapolating findings from animals to humans is difficult. Further, as Hampson (2000) brings to attention, although in humans, visual-spatial abilities most probably have different neurological substrates, the hippocampus (implicated in the animal research) has not emerged as significant in tasks that show reliable sex differences in humans. For example, tasks such as mental rotations appear to rely in part on parietal and right hemisphere cortical processes (Kosslyn & Koenig, 1992; Kosslyn, Digirolamo, Thompson & Alpert, 1998). However, Williams and Meck (1991) do provide some convergent evidence from their research, reporting that the frontal cortex is involved in visual-spatial functioning in rats.

In an attempt to address the issue of comparability across spatial tasks used in animals and humans, Hampson (2000) gave human participants a 'virtual' maze task and found a large sex difference favouring males. The author also found that scores on this task correlate highly with scores on the Vandenberg and Kuse (1978) mental rotations task, thus indicating some common variance.

5.3 TARGETING ABILITY

A second aspect of spatial cognition that shows a large and reliable sex difference favouring males is throwing accuracy, commonly called targeting. Sex differences favouring males in targeting are widely recognized (e.g., Watson & Kimura, 1989). The differences between males and females in throwing accuracy, are as large as those found in mental rotations (Kimura, 1999) and are reported to exist in children as young as 3 years of age (Thomas & Thomas, 1988; Lunn & Kimura, 1989).

Research carried out in this domain is not as extensive as it is for visual-spatial ability, and to date there is only one other study investigating the effects of hormones on targeting ability in a sample of adolescent and adult CAH individuals (Hines, et al., 2002, submitted for publication). Given that it is unlikely that the sex differences observed in this aspect of spatial cognition are due solely to experiential factors, it is believed that biological factors may also be involved (see Brinkmann, 1966). Further, the fact that neither height nor weight account for the large sex difference that is typically apparent (Watson & Kimura, 1991; Thomas & French, 1988) suggests it requires some kind of spatiomotor analysis and co-ordination that is not totally reducible to muscle characteristics (Kimura, 1999). Moreover, when sports history is taken into account, it explains only a negligible portion of the difference between the sexes (Watson & Kimura, 1991). Thus, the sex difference for targeting is important in view of this research which shows consistently that males throw more accurately than females independent of the above factors. This suggests that a hormonal influence may provide a viable explanation accounting for variation between the sexes.

A meta analysis carried out by Thomas and French (1985), highlighted that differences between boys and girls for throwing are 1.5 standard deviation units at 3 years of age, and increases throughout the elementary school years. The authors argue that the size of the sex difference precludes a total environmental explanation as it is unlikely that 3 year old boys would have had the degree of throwing experience needed to attain such a large difference.

However, experiential influences may go some way in explaining the increasing advantage that boys gain over girls, as there are data which indicate that elementary school boys practice their throwing skills more often than girls (e.g., Halverson, Roberton & Langdorfer, 1982). Thomas and French (1985) argue that although the sex difference in throwing performance can be reduced by providing equal reinforcement for boys and girls, the fact that the differences are not totally eliminated means that there has to be other factors that are important prior to puberty.

The suggestion that the early hormone environment influences the development of targeting ability before puberty has not been considered. It is argued that later hormones activated during puberty result in increased muscle mass in boys giving them an advantage over girls (Kimura, 1999). However, because the male advantage is apparent at such an early age, it also suggests the possibility that the early hormone environment is important. In addition, the physical characteristics of boys and girls are very similar in childhood. So although at adolescence boys will have a biological advantage in performance compared to girls, because boys are larger and have more muscle at this time, later hormones activated at puberty, cannot explain the early differences that are observed.

In terms of a cognitive involvement in targeting ability, clearly some kind of spatial analysis must be involved in conjunction with the necessary motor sequence, in order for a stimulus to be directed accurately at a target (Watson & Kimura, 1991). However, as Watson and Kimura (1991) point out, the spatial functions involved in skills such as targeting may be separable from the spatial functions involved in a typical paper and pencil measure of visual-spatial ability.

Other studies have also confirmed the male advantage in targeting. Jardine and Martin (1983) studied the targeting performance of 83 pairs of adolescent twins, aged from 13 to 19 years of age. Individuals were required to throw tennis balls, using overarm, at a vertical target and using underarm, at a horizontal target (laid out on the floor). Males performed significantly better than females on both tasks. Lunn and Kimura (1989) also investigated targeting ability in boys and girls between the ages of three and five years and found that after minimising the contribution of physical sex differences (using underarm throwing), boys were significantly more accurate than girls in their throwing ability on a horizontal throwing task. Butterfield and Loovis (1993) reported similar findings in a study of 381 boys and 338 girls aged between 4 and 14 years. They found that in all grades between kindergarten and Grade 8, boys had a more mature throwing pattern than girls. Moore & Reeve (1987) carried out a throwing accuracy task in which they varied the size of the target. They found that across all ages (5-10 years) boys were more accurate at targeting than girls. Although testing an older sample, Watson and Kimura (1991) found that for 24 males and 24 females aged between 17-27 years, there was a large difference in the male direction for throwing accuracy. These authors further report that the male advantage is not obviously related to experience, as partialling out the effects of previous sports experience did not reduce the size of the difference.

It has been proposed that socialization factors such as parental reinforcement contribute to the male advantage in targeting performance. The suggestion is that the sex differences found in targeting have been caused by the differential treatment of boys and girls by parents, especially fathers. For example, fathers are more likely to react negatively when boys engage in female-typical play (Fagot & Hagan, 1991). It is also the case that parents tend to send subtle messages that some types of toys and gross motor activities are more acceptable for boys (Fagot, 1978). The differences are thought to increase developmentally, because this differential treatment of boys and girls continues throughout childhood.

Finally, there is only one known comparative study of targeting performance. Westergaard, Liv, Hay and Suomi, (2000) compared targeting performance in humans and non-human primates. A sex difference was observed in humans, males were more accurate than females, but this sex difference did not extend to non-human primates.

To date, there is no convergent evidence, from animal or human studies that provide clear predictions for hormonal effects on targeting ability. Thus it is not yet clear whether there is a convergent pattern of evidence suggesting hormonal influences on the development of targeting skill.

This chapter has described some of the evidence for sex differences in visual-spatial and targeting ability in children and evidence that early hormones may be implicated in visual-spatial ability. Sex differences in these aspects of spatial cognition are widely acknowledged in adolescents and adults, however for children it is a more complex arena. Finally, with regard to visual-spatial ability, the question still remains as to whether early sex differences are evident and what influences contribute to the development of these skills.

CHAPTER SIX

PRENATAL ANDROGEN EXPOSURE AND SPATIAL COGNITION IN CHILDREN WITH CONGENITAL ADRENAL HYPERPLASIA: EMPIRICAL EVIDENCE

6.1 ABSTRACT

In this study empirical evidence for prenatal androgens influencing spatial cognition was investigated in children. 27 girls with CAH and 23 boys with CAH, and 22 unaffected female and 22 unaffected male relatives aged from 3-11 years took part. Performance on two tests of visual-spatial ability (mental rotations and spatial perception), and two targeting tasks (ball throwing and dart throwing), was assessed. Performance was compared to examine whether aspects of spatial cognition are enhanced in girls with CAH, who have been exposed to high levels of androgens prenatally. The spatial tasks used have shown sex differences with boys outperforming girls in the general population.

Results revealed mixed findings. For visual-spatial ability, some differences were observed in unaffected children. Boys were faster than girls at spatial perception but not mental rotations and there were no significant differences in accuracy of performance for either task. In respect of targeting, boys were better than girls at dart throwing, but statistical significance was not quite reached for ball throwing. The

findings for girls with CAH were less clear. CAH girls did not differ from unaffected girls in speed or accuracy of performance for spatial perception or mental rotations. For targeting, CAH girls' performance was better than unaffected girls', and similar to that of unaffected boys. The performance of CAH boys did not differ from unaffected boys on any of the tasks.

Results suggest that targeting but not visual-spatial ability may be influenced by prenatal androgens. Results also suggest that aspects of visual-spatial functioning may be differentially sensitive to sex differences. Findings are discussed in relation to the impact of both hormonal and environmental factors on spatial cognition and to methodological limitations evident in the study of visual-spatial ability in young children.

6.2 INTRODUCTION

It has been hypothesised that sex related differences in postnatal development may in part be attributed to prenatal androgens (e.g., Breedlove, 1994). In non-human species, hormones bring into active operation powerful effects on behaviour during early critical periods of development when androgen levels are elevated in males (Phoenix, et al., 1959; Goy & McEwen, 1980). During these periods, administration of androgens (testosterone, and its metabolites) to females increases male-typical behaviour and decreases female-typical behaviour. There is some evidence that there are similar hormonal influences on the development of human behaviours that show sex differences (for review, see Collaer & Hines, 1995). Much of this evidence is still equivocal, and the mechanisms responsible for the sex differences are still not entirely clear. However, when human behaviours show sex differences, it is thought that they too may be influenced, in part, by androgens during early development.

Given that it is unethical to administer hormones to humans in order to study behaviour, information about the role of hormones has been obtained from individuals exposed to abnormal hormone environments as a consequence of naturally occurring endocrinological disorders. One such group of individuals are those with congenital adrenal hyperplasia (CAH) (see Chapter 3). As a consequence of the early exposure to high levels of androgens in females with the disorder, CAH provides an opportunity to examine the effects of hormones on the development of sex differentiated behaviour.

Females with CAH have frequently been studied in order to determine the impact of prenatal exposure to androgens on various aspects of psychological development. Studies include childhood play behaviour (e.g., Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Hines & Kaufman, 1994) where it has been found that girls with CAH show an increased interest in male-typical toys and activities. They also show reduced interest in infants compared to unaffected girls (Leveroni & Berenbaum, 1998). Specific aspects of cognitive ability, such as visual-spatial functioning, have also been subject to investigation in individuals with CAH. However, findings in this domain are mixed. Some studies have revealed enhanced performance in CAH females compared to unaffected females. For example, Resnick, Berenbaum, Gottesman, and Bouchard (1986) compared the performance of 17 females with CAH to that of 13 unaffected female relatives, aged 11-18 years, on a battery of five cognitive tests. Three of these tasks assessed visual-spatial functioning and differed for CAH females versus female relatives. These were a three-dimensional mental rotations task, a two-dimensional mental rotations task, and the Card Rotations Task. They found that females with CAH obtained significantly higher scores than unaffected females. The performance of 8 CAH males was also compared to 14 of their unaffected male relatives, but no differences were found. Similarly, in a study of 7 CAH girls and 5 CAH boys aged 8-12 years, Hampson, Rovet, and Altmann (1998) found that after controlling for general intelligence girls with CAH achieved significantly higher spatial scores than unaffected female relatives on the PMA spatial relations test, a test of spatial visualisation. However, CAH boys showed a detriment in performance compared to unaffected male relatives. Further, although an older sample, Helleday et al (1994) examined the relationship between hormones and spatial perception and found that CAH females scored lower than female controls on the Rod and Frame Task.

In contrast, other studies have found no differences between females with CAH and their unaffected same-sex relatives. For example, an early study by Baker and Ehrhardt (1974) did not find any differences between 13 females with CAH and 11 unaffected same-sex relatives aged from 4-26 years on a spatial visualization task. Similarly, no differences were found between the performance of 8 males with CAH and 14 unaffected male relatives. Further, McGuire, Ryan, and Omenn (1975) tested 15 females with CAH comparing their performance to control females on tests of spatial visualization, but did not find altered performance in CAH females, and no differences were found between 16 CAH males and 16 male relatives. Consistent with Baker & Ehrhardt's (1974) and McGuire et als., (1975) findings, a more recent study using a much larger sample than has previously been investigated, Hines et al., (2002) also reported no differences between 40 CAH females and 29 unaffected female relatives on a thee-dimensional test of mental rotations ($d = 0.17$) and the spatial relations test ($d = 0.12$). However, impaired performance was reported in 29 males with CAH compared to 30 unaffected male relatives on both spatial tests ($d = 0.58$ and $d = 0.42$, respectively). General intelligence was controlled for in these analyses using the vocabulary sub-test of the Wechsler Intelligence Scale for Children (WISC) and Wechsler Adult Intelligence Scale (WAIS).

The relationship between levels of androgens and spatial abilities in healthy children does not clarify the inconsistencies that have been found in studies of CAH individuals. A study by Jacklin, Wilcox, and Maccoby (1988) found a negative relationship between levels of testosterone and spatial ability in normal girls aged 6½ years. Higher testosterone levels were associated with lower scores on the spatial component of the Primary Mental Abilities Test in healthy girls. No relationship was found in boys. Similarly, Finegan, Niccols, and Sitarenios (1992) also found an inverse relationship between second trimester testosterone and spatial scores. These studies used a test of spatial visualisation, which shows a negligible sex difference (Voyer et al., 1995). Grimshaw, Sitarenios, and Finegan (1995), however, did find a positive correlation between prenatal testosterone and mental rotations. Specifically, they found that in girls, higher levels of prenatal testosterone were associated with faster rates of rotation, but not enhanced performance. For boys, higher levels of testosterone were associated with slower rates of rotation.

Two possible explanations may account for the inconsistency of findings in these studies. First, there may be methodological problems in obtaining reliable measures of prenatal androgens, in terms of how representative they are of levels of circulating androgens at the time of collection. For example, Grimshaw et al., (1995) examined second trimester testosterone levels taken from amniotic fluid, whereas in the Jacklin et al (1988) study, testosterone levels were assessed neonatally from umbilical cord blood, which has been argued to be less reflective of foetal exposure than amniotic fluid (Greenspan & Forsham, 1986). Secondly, Finegan et al., (1992) used a spatial visualisation task which may not be a suitable marker of hormonal influences because it typically shows a negligible sex difference.

Sex differences in visual-spatial performance are specific to certain subtypes of visual-spatial ability that have been identified (Linn & Petersen, 1985; Voyer, Voyer

& Bryden, 1995). This ability is no longer thought of as a unitary concept, but rather, as three distinct subtypes tapping three diverse components, namely, spatial perception, mental rotations, and spatial visualisation (Linn & Petersen, 1985, Voyer, et al.,1995). Mental rotations is defined as the ability to rotate quickly and accurately two- or three-dimensional figures in the imagination. Tests typically require participants to make comparisons between a figure and its rotated form. Stimuli are usually two-dimensional representations of two-or three-dimensional figures. Spatial perception is defined as the ability to determine spatial relations among stimuli despite distracting information (e.g., a frame of reference, or a distracting array of lines). Finally, spatial visualisation is defined as the ability to manipulate complex information when there are different stages to produce the correct solution (Voyer et al., 1995). Of the three categories, sex differences in spatial perception and mental rotation are the most robust in adolescents and adults, with mental rotations producing the largest sex difference (Voyer et al., 1995). Effect sizes showing the magnitude of the differences between males and females are typically largest for mental rotations ($d = 0.73$), moderate for spatial perception ($d = 0.44$), and small for spatial visualization ($d = 0.13$), revealing that the size of the difference depends on the subtype of task used.

Early studies concluded that the sex differences found on tests of mental rotations do not reliably appear until puberty (see Maccoby & Jacklin, 1974). However, more recently, where sex differences on mental rotations tests have been reported in pre-adolescent children, boys have been reported to show better performance than girls (e.g., Levine, Huttenlocher, & Langrock,1999; Vederhus & Krekling, 1996), although not all studies have found such differences (Courbois, 2000; Karadi, Szabo, &

Szepesi, 1999). One possible explanation for this discrepancy is that different task demands may be required to carry out mental rotations in the latter studies. For example Courbois' (2000) study used representations of stimuli with and without salient cues to orientation thus making half of the task more difficult, and results revealed that children had more difficulty performing the task when there were no salient cues.

The evidence for sex differences in spatial perception in pre-adolescent children is equivocal and more sparse than for mental rotations. Studies examining performance on tasks such as the Rod and Frame Task, Water Level Task, and Judgment of Line Orientation (JLO) task are typically used, and studies have produced mixed findings. A male advantage in children has been reported in some studies (Witkin, Goodenough, & Karp, 1967; Maxwell, Croake, & Biddle, 1975; Lindgren & Benton, 1980; Vederhus & Krekling, 1996), but not in others (Willemsen, 1974; Kenyon, 1984; Pennings, 1991). In Lindgren and Benton's (1980) study, the Judgment of Line Orientation task was used with 7-14 year old boys and girls. They found that boys outperformed girls at all ages, but that this difference became more pronounced at age 13. Thus, although the sex difference may be more apparent at puberty, differences in pre-adolescent children are still evident. Lunn and Kimura (1989), however, found a sex difference favouring 3-4 year old girls on a modification of the JLO. The female advantage is the converse of what might be expected and the authors suggest that the modified version may not be equivalent to the original JLO (Benton et al., 1983).

Given that the evidence has produced mixed findings in regard to sex differences in tests of spatial perception and mental rotations in pre-adolescent children, it does not necessarily mean that sex differences do not exist. Many tests that have been used with young children have been found to be inadequate for detecting such differences. For example, in some tests children may be unable to understand what is required of them, thus producing floor effects. In a typical paradigm in mental rotations whereby children are shown abstract representations of three-dimensional objects, the task at hand is often very difficult for young children, who do not hold their attention well. For example, different tasks may reveal different performance levels in children depending on the geometrical characteristics of the stimuli. When salient cues are present they may help children to encode the stimulus thus making mental rotation less difficult. Conversely, when the stimulus has no salient cues to axis, the task may be more difficult thus masking sex differences. Furthermore, sex differences have been reported to emerge at different ages for different tests (Voyer et al., 1995).

A further aspect of spatial cognition, targeting ability, also shows sex differences. To date, only one other study has investigated the relationship between the early hormone environment and targeting performance. Using an adolescent and adult sample aged from 12-45 years, Hines et al., (2002, submitted for publication) compared the performance of 30 unaffected males and 29 unaffected females and found that males showed enhanced targeting performance compared to females. The performance of 40 females with CAH was also compared to the 29 unaffected female relatives revealing enhanced performance in CAH females'. No differences were found in targeting between 29 males with CAH and 30 male relatives. In healthy individuals, targeting shows one of the most reliable sex differences, larger than that reported for mental rotations (Watson & Kimura, 1994; Kimura, 1999). The large sex difference is also apparent in children as young as 3 years (Thomas & French, 1985), and thus an examination of the extent to which it is sensitive to the hormone environment warrants investigation in children.

A meta analysis carried out by Thomas and French (1985) found targeting differences of 1.5 standard deviation units at 3 years of age between boys and girls, a difference found to increase throughout the elementary school years. The authors argue that the size of the sex difference precludes a total environmental explanation as 3 year old boys would not have had the degree of throwing experience required in order to attain such a large difference.

However, environmental influences may go some way to explain the increasing advantage that boys gain over girls, as there are data indicating that elementary school boys practice their throwing skills more than girls (e.g., Halverson, Roberton & Langdorfer, 1982). On the basis of their meta analysis, Thomas and French (1985) argue that although the sex difference can be reduced by providing equal reinforcement for boys and girls, the fact that the differences are not totally eliminated, means that other factors, such as the prenatal hormone environment, might be important prior to puberty. The suggestion that hormones are influential in the development of targeting ability has not been considered in individuals who have not yet reached puberty. It has been suggested that pubertal hormones result in increased muscle mass in boys giving them an advantage over girls (Thomas & French, 1985). But given that the male advantage is seen at such an early age, there is also the possibility that hormones are implicated.

It is also argued that targeting ability has a strong a cognitive component. According to Kimura (1999), the fact that neither height nor weight account for the sex difference suggests that it requires some kind of rapid spatiomotor analysis and co-ordination which cannot be reduced to muscular activity.

Jardine and Martin (1983) studied targeting performance in 83 pairs of adolescent twins, aged between 13 and 19 years of age. Participants were required to throw tennis balls overarm, at a vertical target, and underarm at a horizontal target (laid out on the floor). Males' performed significantly better than females on both tasks. Lunn and Kimura (1989) investigated targeting ability in boys and girls between the ages of three and five years. They found that after minimising the contribution of physical sex differences by using underarm throwing, boys were significantly more accurate than girls in their throwing ability on a horizontal throwing task. Butterfield and Loovis (1993) reported similar findings in a study of 381 boys and 338 girls aged between 4 and 14 years. They found that at all grades between kindergarten and Grade 8, boys had a more mature throwing pattern than girls. Testing an older sample of 24 males and 24 females aged between 17-27 years, Watson and Kimura (1991) found that there was a large difference for throwing accuracy, with males outperforming females, demonstrating that the trend continues through to adulthood.

This chapter reports on a study of spatial cognition in boys and girls with CAH and their unaffected relatives. From the preceding review, two main points were noted. Firstly, that some studies have demonstrated that exposure to high levels of prenatal androgens in females with CAH induces changes in a masculine direction while others have not. Secondly, that studies investigating sex differences in visual-spatial ability in preadolescent children have revealed inconsistent findings. In the present study, therefore, patterns of visual-spatial functioning and targeting ability in girls with CAH are compared to unaffected same-sex relatives, and to unaffected male relatives to determine if prenatal androgens enhance functioning on these tasks. Although it is unlikely that boys with CAH generally experience elevated androgens prenatally, their performance is compared to unaffected boys to assess whether the elevated adrenal androgens affects performance as other studies have observed impaired visual-spatial performance. The performance of unaffected girls and boys is also compared to test for sex differences in visual-spatial ability and targeting ability.

Performance on two visual-spatial tasks is assessed using a two-dimensional mental-rotations task and a test of spatial perception. The Marmor mental rotations task (Marmor, 1975) (modified) was chosen because a sex difference has been shown in young children (Fane, Collins, & Hines, in preparation) (see Appendix 3). Further, it is a task which resembles the standard mental rotations paradigm (Shepard & Metzler, 1971) in two-dimensional form and is designed for use with children. The Judgment of Line Orientation Task was chosen as a test of spatial perception because it shows a sex difference favouring males from age 7 years (Benton, Hamsher, Varney, & Spreen, 1983). Moreover, spatial perception has not been investigated extensively in young children and has not been examined in very young boys and girls, or in boys and girls with CAH. However, it may be an aspect of visual-spatial ability that is altered in CAH individuals and thus will be examined. Targeting ability is assessed using ball throwing and dart throwing tasks.

The vocabulary subtest of the Wechsler Intelligence Scales (WPPSI and WISC) is included to rule out the possibility that any male advantage on the spatial tasks is attributable to differences in intellectual skill in CAH or unaffected boys and girls in the sample.

6.3 METHOD

6.3.1 Participants

Ninety-four children, 50 CAH children (27 girls and 23 boys) and 44 unaffected relatives (22 girls and 22 boys), aged 3-11 years, took part. CAH and unaffected children were the same as those in the previous empirical study (see Chapter 4). Children with CAH were recruited through Paediatric Endocrine Consultants at Great Ormond Street Hospital in London and via a CAH Support Group in the UK. Forty nine patients were 21-hydroxylase (21-0H) and salt-losing and one was 21-0H and non salt losing (simple virilising). Unaffected siblings and cousins (40 siblings and 4 cousins) served as control participants. Cousins were asked to participate when siblings were not available. Table 6.1 sets out the frequency of patients with sibling or cousin control participants. Relatives represent a good comparison group when random assignment to groups is not possible, because they are similar to patients on factors such as genetic make-up, socioeconomic status, and family background (Reinsich & Gandelman, 1978). Although they cannot be matched individually on age they generally do match on this. Unaffected relative controls were also recruited from a similar study examining some of the same behaviours and traits in adolescents and adults with CAH (see Table 6.2).

Table 6.1. Frequency of CAH patients with one or more sibling and/or cousin control.

	One unaffected sister	Two unaffected sisters	One unaffected brother	Two unaffected brothers	One Unaffected female cousin	Two Unaffected female cousins	No relative controls
CAH girls	6	0	6	1	3	1	13
CAH Boys	7	0	9	0	1	0	8

Table 6.2. Frequency of unaffected boys and girls with a CAH brother or sister participating in adolescent and adult study.

	CAH sister	CAH brother
Unaffected girls with CAH brother and/or sister in adult study	1	3
Unaffected boys with CAH brother and/or sister in adult study	2	1

All children were white Caucasian. Parents provided written consent for children's participation. In this sample, patient and control groups were comparable in age at the time of testing (see Table 6.3).

Table 6.3. Age of CAH and unaffected boys and girls at time of testing

	CAH girls		**Unaffected Girls**		**CAH Boys**		**Unaffected Boys**	
	M	SD	M	SD	M	SD	M	SD
Mean age	7.6	2.48	7.0	2.40	7.2	2.68	7.5	2.13

It was not possible to calculate participation rate in the study. Because of ethical considerations, no information was given from Great Ormond Street Hospital when families did not consent to participate. With respect to recruitment from the CAH Support Group, all families with CAH children were contacted but not all of the families had CAH children in the 3-11 year old age range. Further, because of confidentiality, it was not possible to find out how many families replied following the invitation to participate.

6.3.2 Measures and Procedure

6.3.2.1 Vocabulary

It is sometimes difficult to detect relationships in cognitive abilities because they can be positively correlated with general intelligence. Therefore the Vocabulary sub-test from the Wechsler Preschool and Primary Scale of Intelligence - Revised UK Edition (WPPSI-R^{UK}), for 3-5 year olds, and Wechsler Intelligence Scale for Children Third Edition UK, (WISC-III^{UK}) for 6-11 year olds, was administered for control purposes. This sub-test is often used as a measure of general intelligence in children and controlled for when testing other aspects of cognition. Controlling for general intelligence using the Vocabulary subtest is more suitable than controlling for overall IQ when investigating the effects of hormones on behaviour, as it is possible that some subtests of the Wechsler scales (e.g., digit span) might be influenced by androgens, and therefore could potentially distort outcomes. Analysis of the scaled vocabulary score indicated comparability of male and female groups (see Table 6.4). There were no significant main effects of sex, F (1, 90) = 0.35, p = .85, or diagnosis, F (1, 90) = 0.74, p = .40, and the interaction between sex and diagnosis was non-significant, F (1, 90) = 1.65, p = .20 . Like other samples of CAH males and females (e.g., Perlman, 1973; McGuire et al., 1975) they do not differ from unaffected relative controls and thus, in terms of general intellectual functioning, constitute a typical sample of children.

Table 6.4. Mean scaled vocabulary scores as a function of CAH and control comparison groups.

	CAH girls (N=27)		**Unaffected girls (N=22)**		**CAH boys (N=23)**		**Unaffected boys (N=22)**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Total	11.19	3.70	11.55	3.46	12.00	3.75	10.41	3.35

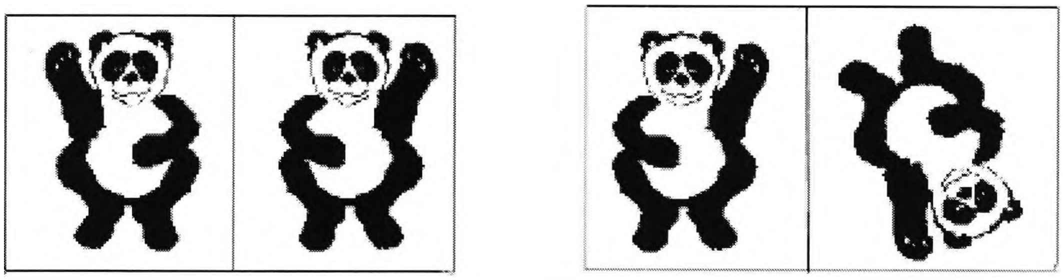
6.3.2.2. Marmor Mental Rotations Task (modified)

The original Marmor Task (1975) was piloted in an earlier study of healthy children in the general population, in order to test for sex differences (Fane, Collins & Hines, 2002, in preparation). A sex differences favouring boys was observed in children as young as 3 years of age (see Appendix 3).

A slightly modified version of the original Marmor mental rotations task was used to assess mental rotations performance in this study. The task was modified to include two extra angles of orientation (90^0 and 180^0). Tests of two-dimensional mental rotations typically use figures rotated around one half of a 360^0 axis, from 0^0 to 180^0. This is because it has been found that from 180^0 to 360^0 response times decrease and accuracy increases at the same rate to as response times increase and accuracy decreases from 0^0 to 180^0 (e.g., Niall, 1997).

The Marmor task requires children to view a pair of simultaneously presented figures and decide whether they are the 'same' or 'different,' regardless of the orientation of one of the pair of figures around a horizontal axis. This task is well suited for investigating mental rotations ability in young children because it requires no motor output and the stimuli (Panda bears) are appealing enough to hold a child's attention.

3 sets of stimuli were used. The first set consisted of 2 yellow cards, 8.27 by 11.69 inches, with Panda Bears in the upright position (one with a right arm raised and one with a left arm raised) and one blank card. A separate cut-out Panda Bear could be placed on the blank card. This allowed demonstration of the concepts of matched ('same') versus reflected ('different') stimuli (used for pre-training and criterion test for same-different judgements). In addition, the cut-out Panda Bear could be rotated on the blank 8.27 by 11.69 inch cards and was also used for mental rotations training ("tipping over"). The second set of stimuli consisted of four folders, each 8.27 by 11.69 inches with two Panda Bears in each, set in the upright position. In two of the folders, the Panda Bears were waving with the same arms, and in the remaining two folders the Panda Bears were waving with different arms (see Fig 6.1a where the Panda Bears are in the upright position and waving with different arms).


a. Different

b. Same

Fig. 6.1. Example of mental rotations task. Children decide whether bears have 'same' or 'different' arms raised.

The third set of stimuli consisted of twenty-four 8.27 by 11.69 inch folders, each containing two 8 x 4 inch Panda Bear figures, which were used for the test trials. Panda Bears on the inside left of each folder were fixed in an upright position. 12 folders had upright Panda Bears with their left arms raised and 12 had upright Panda Bears with their right arms raised. On the inside right of each folder, the Panda Bears were fixed at one of 6 angles (30^0, 60^0, 90^0, 120^0, 150^0 and 180^0). 12 of the rotated

Panda Bears had the opposite arm raised to that of the Panda Bear on the inside left of each folder, and 12 had the same arm raised. For each angle of orientation, four sets of two Panda Bears were presented: left-left, left-right, right-right and right-left. (See Fig. 6.1b where the 2 Panda Bears are the 'same'. The Panda Bear on the left is upright with its left arm raised and the Panda Bear on the right has the same arm raised but is rotated to 150^0). These stimuli were used for the fourth part of the procedure–the experimental mental rotations task.

Experimental procedures for this task closely followed Marmor's (1975). However, three major alterations were: 1) that the test stimuli were presented as pictures of Panda Bear shaped figures pasted into 8.27 by 11.69 inch folders, instead of Panda Bears standing upright in front of a plywood backdrop; 2) that the experimental procedures and test trials were carried out in one session, instead of extending over 4 days, and, 3) that responses were verbal throughout the training procedures and test trials, instead of manual (pressing levers that indicated 'same' and 'different'). They consisted of four parts: 1) pre-training for same-different judgements, 2) criterion test for same-different judgements, 3) mental rotations training, and 4) the experimental mental rotations task.

The mental rotations task began approximately 30 seconds following the learning and practice sessions. The first folder was placed unopened in front of the children. The experimenter explained that inside each folder were two Panda Bears, and that sometimes they would be waving with the same arms and sometimes with different arms, and that some would be 'tipping over'(rotated). Children were told that it did not matter if the bears were 'tipping over' because what was important was for the children to tell the researcher as quickly and as accurately as possible, whether the Panda Bears were waving with the ‘same’ or ‘different’ arms. Children were told that the time they took to do this would be recorded so that the difference between boys and girls could be measured. The dependent measures were correct reaction time and the number of correct judgements (response accuracy). All children completed a total of 24 trials, with 4 trials at each angle of rotation. The task required approximately 20-25 minutes to complete (see Appendix 4).

The 24 trials for the mental-rotations task were presented in a fixed random sequence. The criteria for this was that 1) no two orientations could be presented consecutively; 2) same or different pairs were never presented more than four times consecutively; 3) each orientation preceded every other, an equal number of times, and, 4) single and double alternation sequences of same and different pairs were limited to three consecutive alternations.

6.3.2.3 Judgment of Line Orientation (Short Form) Odd

A short version of the individually administered Judgment of Line Orientation Task (JLO) Form V was used (Woodward, Benedict, Roberts, Goldstein, Kinnner, Capruso, & Clark (1996). The short version, known as JLO (Short Form) odd, comprises all the odd items in the standard JLO (Benton, Hamsher, Varney, & Spreen, 1983) and is administered individually. The task is in booklet form and consists of 15 test items and 5 practice items. The items increase in difficulty as the test progresses. The stimulus items are each presented as a pair of target line segments 1.9 cms in length (half the length of the lines in the multiple choice comparison array) and located in the upper part of the booklet. The comparison array, containing 11 numbered lines, is presented in the lower part of the booklet. The comparison lines radiate from a central origin and span an arc of 180^0 with separations of 18^0 intervals between adjacent lines. For the practice items, the line length of the stimulus is the same as the full-length lines (3.8 cms in length) appearing on the comparison array. (See Appendix 5).

The test booklet was placed flat on the table in front of the children in an open position so that the stimulus items in the upper half were positioned at an angle of approximately 45 degrees. Children were asked to study the target lines and match them with the equivalent lines in the multiple choice comparison array below. They were asked to point to the lines that matched the comparison lines (older children aged from 7-11 years, were also asked to verbally state the numbers of the matching comparison lines). Dependent measures were reaction time to correctly identify the two lines for each trial, and number of item pairs correctly identified (response accuracy).

6.3.2.4. Targeting Ability

Two targeting tasks, ball throwing and dart throwing, provided a measure of children's targeting ability. The target (67 by 67 centimetres) was viewed from a distance of 2.25 metres for 3-5 year olds, and 2.75 metres for 6 –11 year olds, and viewed at an angle of 103^o from the horizontal (see Appendices 7 and 8). The bulls eye had a diameter of 2.5 centimetres. There were 3 practice trials and 12 test trials for each task. The balls were ping pong balls covered with Velcro designed to stick to velcro, and the darts had been modified for use with children by replacing the pointed tip with a flat round velcro head. Children who had not played darts before were given instructions on how to hold and aim the darts. All children were given a chance to practice. Parents or caretakers of children were shown the modified darts and were asked for verbal permission before their child(ren) participated in dart throwing. Standing on the appropriate distance marker, children were told to aim at the bulls' eye in the centre of the target. All children threw overarm using the hand with which they were most comfortable. The dependent measure was mean distance (in centimetres) for 'hits' from the centre of the board for the 12 trials, for ball throwing and dart throwing. Scores were reversed so that a higher score indicated better performance. This was done by subtracting scores from the maximum possible distance on the target (48 cms).

Ball throwing and dart throwing scores correlated positively ($r = .763$) and were combined into a composite variable (using standardised z scores) of overall targeting performance.

Administration of the visual-spatial and targeting tasks were counterbalanced to control for possible order effects. There were two orders for the test battery (see Appendix 2) which included tasks investigating androgens and responses to social mechanisms thought to influence gender role behaviour, reported on in a later chapter.

6.4 RESULTS

6.4.1 Marmor Mental Rotations Task

Reliability Testing

Given that the Marmor task used in this study had been modified from the original by the addition of two angles of orientation (90^0 and 180^0), and because it was administered in a different format from the original task, reliability testing was carried out to assess the consistency of the results. Using Cronbach's alpha, the reaction time scores revealed a reliability coefficient of .94. For response accuracy (number of correct judgements out of 24), Cronbach's alpha revealed a reliability coefficient of .86.

Marmor Task - Analyses

Correlations

Correlations of age and vocabulary and reaction times for first and second trial blocks were examined separately for boys and girls. For boys, age and reaction times correlated significantly in a negative direction for both the first trial block, r = -0.539, p < .001, and the second trial block, r = -0.508, p < .001. Vocabulary did not correlate with reaction times in either the first trial block, r = -0.144, p = .34 or second trial block, r = -0.211, p = .16. For girls, age and reaction times correlated significantly in a negative direction in both the first trial block, r = -0.562, p < .001, and the second trial block, r = -0.432, p < .001. Vocabulary did not correlate with reaction times in the first trial block, r = 0.238, p = .09, but did in the second trial block, r = 0.300, p < .04.

Response accuracy variables were also correlated with age and vocabulary, and similar associations were found. For boys, age and response accuracy correlated significantly in a positive direction in both the first trial block, r = 0.761, p < .001, and in the second trial block, r = 0.608, p < .001. However vocabulary did not correlate with response accuracy in either the first trial block, r = 0.143, p = .35 or in the second trial block, r = 1.00, p = .52. For girls, age and response accuracy correlated significantly in a positive direction in both the first half of the trials, r = 0.518, p < .001, and in the second trial block, r = 0.692, p < .001. However, vocabulary did not correlate with response accuracy in either the first trial block, r = 0.102, p = .49 or in the second trial block, r = -0.010, p = .95.

Mental Rotations - correct reaction times
Trial Block (First and second twelve trials)

Three-way (sex x diagnosis x trial block) mixed design analyses of covariance (ANCOVAs) were carried out to determine group differences. Because age and vocabulary correlated with the mental rotations measures, they were entered as the covariates in these analyses. Variables around the 180^0 axis were presented in a fixed random sequence and these analyses provided an assessment of practice effects across the first and second trial blocks.

Table 6.5 Marmor Mental Rotations Task. Reaction times (secs) for correct answers as a function of CAH patients and unaffected relative controls by trial block (trials 1-12 and trials 13-24).

	CAH Girls (N=27)		**Unaffected Girls (N=22)**		**CAH Boys (N=23)**		**Unaffected Boys (N=22)**	
	M	SD	M	SD	M	SD	M	SD
First Trial Block (Trials 1-12)	2.22	0.92	2.66	1.41	2.54	1.66	2.02	1.22
Second Trial Block (Trials 13-24)	1.88	1.02	2.20	1.07	2.42	1.86	1.91	1.12
Total Trials (Trials 1-24)	2.05	0.92	2.42	1.16	2.47	1.70	1.96	1.26

For correct reaction times, there was a significant main effect of trial block, F (1, 89) = 6.85, p = .01, a significant sex by diagnosis interaction, F (1, 89) = 4.00, p = .05, and a significant trial block by sex interaction, F (1, 89) = 4.04, p = .05. There were no main effects of sex, F (1, 89) = 0.01, p = .94, or diagnosis, F (1, 89) = 1.00, p = .76, and no further two- or three-way interactions reached significance [trial block by diagnosis, F (1, 89) = 0.16, p = .69, trial block by sex and diagnosis, F (1, 89) = 0.20, p = .66].

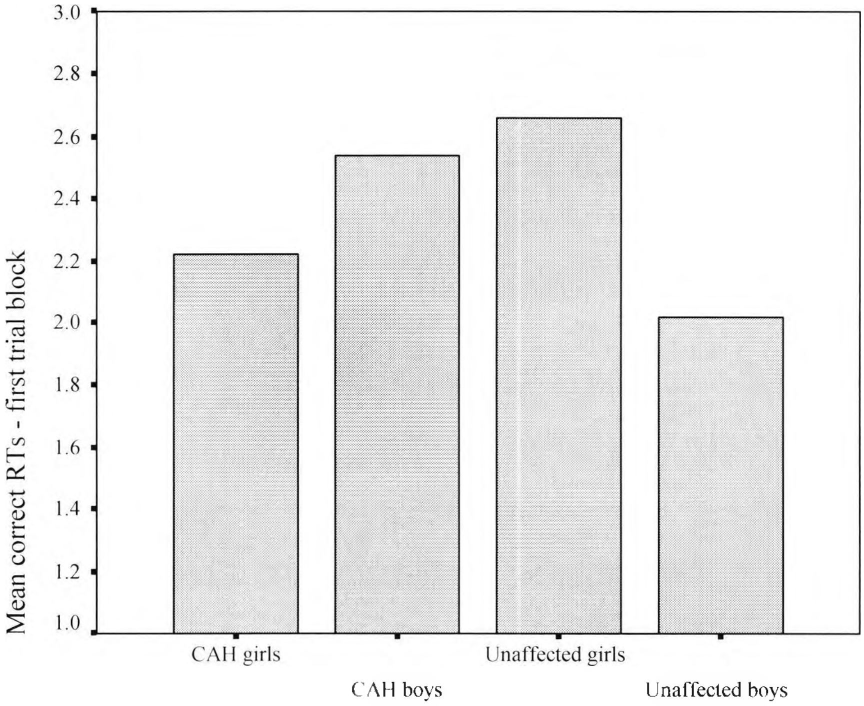
Planned Comparisons

Because of differences in speed of responding for the first and second blocks of trials, planned comparisons were carried out on correct reaction times for the first and second block of trials separately. To test the specific hypotheses relating to CAH, each of the analyses the CAH and control comparison groups were analysed in the following way: the performance of unaffected boys' was compared to unaffected girls. CAH girls' performance was compared to unaffected girls', and then to unaffected boys'. CAH boys' performance was compared to unaffected boys'. Age and vocabulary served as covariates.

First trial block (trials 1-12)

Planned comparisons for the first trial block revealed that the reaction times of unaffected boys did not differ from the reaction times unaffected girls, F (1, 40) = 3.10, p = .08, although there was a trend towards significance. CAH girls did not differ from unaffected girls, F (1, 45) = 2.44, p = .12, and neither did CAH girls reaction times differ from unaffected boys reaction times, F (1, 45) = 0.58, p = .45. CAH boys and unaffected boys also did not differ, F (1, 41) = 2.73, p = .11.

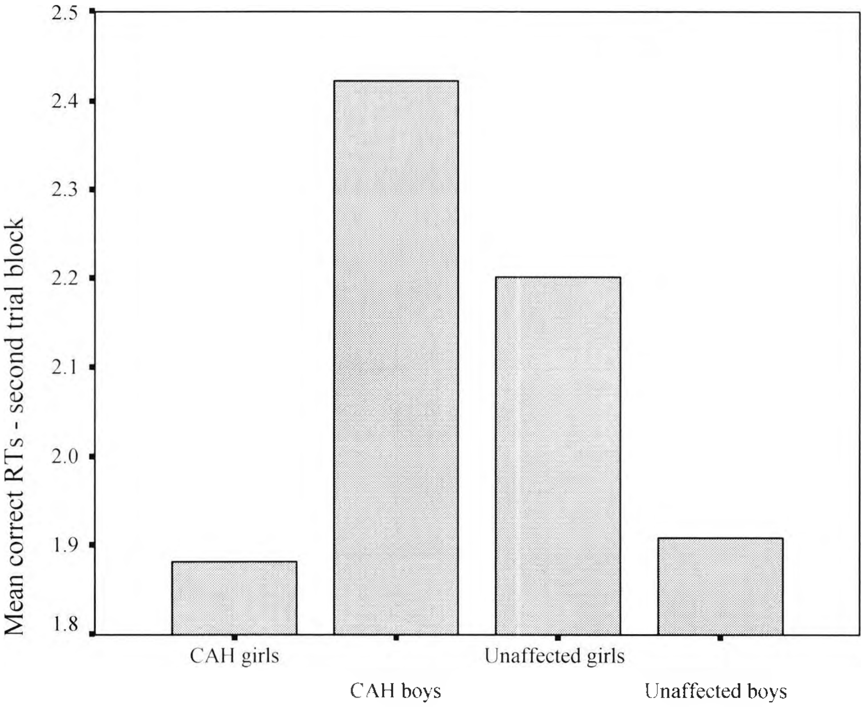
Fig. 6.2 Mental Rotations. Reaction times (secs) for first trial block by CAH and control comparison groups



Second Trial Block (trials 13-24)

Planned comparisons for the second trial block revealed that the reaction times of unaffected boys did not differ from unaffected girls, F (1, 40) = 0.80, p = .37. CAH girls also did not differ from unaffected girls, F (1, 45) = 1.57, p = .22, or from unaffected boys, F (1, 45) = 0.01, p = .94, and neither did CAH boys differ from unaffected boys, F (1, 41) = 2.73, p = .11.

Fig. 6.3 Mental Rotations. Reaction times (secs) for second trial block by CAH and control comparison groups



Mental Rotations - Effect sizes for correct reaction times

In order to calculate the magnitude of the difference between CAH and unaffected relative groups, effect sizes were calculated using Cohen's 'd' procedure (Cohen, 1988), taking the difference between the mean scores and dividing by the pooled standard deviation. Effect sizes were small to moderate between the groups tested (see Table 6.6).

Table 6.6 Mental Rotations task. Effect sizes between CAH and control comparison groups for correct reaction times.

	Trials 1-12	**Trials 13-24**	**Total Trials**
	d	d	d
Unaffected girls vs. unaffected boys	0.5	0.3	0.4
CAH girls vs. unaffected girls	0.7	0.4	0.5
CAH girls vs. unaffected boys	0.2	0.0	0.1
CAH boys vs. unaffected boys	0.2	0.6	0.4

Mental Rotations - Response Accuracy

A three-way (sex x diagnosis x trial block) mixed design analysis of covariance (ANCOVA) was carried out to determine group differences in response accuracy for the first and second trial blocks. Age correlated with accuracy of performance for mental rotations, but vocabulary score did not. Age was entered as the covariate. Variables around the 180^0 axis were presented in a fixed random sequence and these analyses provided an assessment of practice effects in response accuracy across the two trial blocks.

Table 6.7. Mental Rotations total response accuracy as a function of CAH and control comparison groups.

	CAH girls (N=27)		**Unaffected girls (N=22)**		**CAH boys (N=23)**		**Unaffected boys (N=22)**	
	M	SD	M	SD	M	SD	M	SD
First Trial Block (Trials 1-12)	8.84	2.44	9.49	2.14	9.27	2.77	9.29	2.77
Second Trial Block (Trials 13-24)	9.35	2.31	9.82	2.61	9.41	3.24	9.26	2.55
Total Trials (Trials 1-24)	18.19	4.37	19.26	4.20	18.70	5.53	18.70	5.04

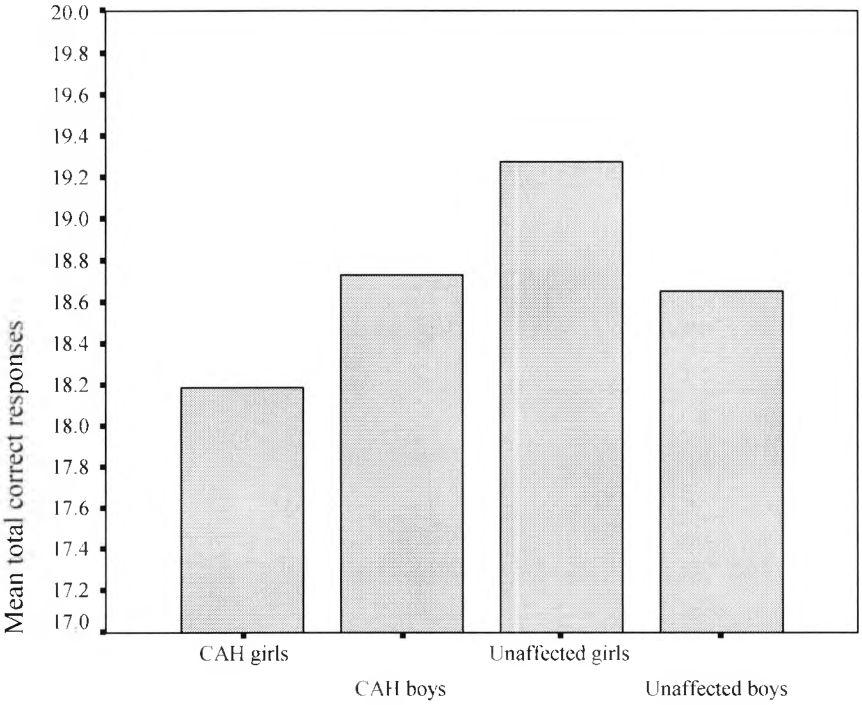
Response accuracy data revealed no main effects of trial block, F (1, 89) = 0.30, p = .86, sex F (1, 89) = 0.75, p = .79, or diagnosis, F (1, 89) = 1.34, p = .25. None of the two- or three-way interactions were significant either: for trial block by sex, F (1, 89) = 0.01, p = .94, trial block by diagnosis, F (1, 89) = 0.13, p = .72, for sex by diagnosis, F (1, 89) = 1.00, p = .70, or for trial block by sex by diagnosis, F (1, 89) = 0.60, p = .44.

Planned comparisons

The ANCOVA revealed no difference in response accuracy between the first and second trial blocks and so the total 24 trials correctly identified were analysed in one block in the planned comparisons. The specific hypotheses relating to CAH were analysed in the same way as for the reaction time data. Age but not vocabulary score correlated with accuracy of performance and served as the covariate in these analyses.

Planned comparisons revealed that the total response accuracy of unaffected boys did not differ from, F (1, 40) = 0.33, p = .57. CAH girls response accuracy did not differ from unaffected girls, F (1, 45) = 1.15, p = .29, or from unaffected boys, F (1, 45) = 0.15, p = .70, and CAH boys did not differ from unaffected boys, F (1, 41) = 0.01, p = .96.

Fig 6.4 Response accuracy for total trials by CAH and control comparison groups.



Mental Rotations - Effect sizes for response accuracy

Cohen's 'd' statistic was used to measure the size of the difference between the CAH and unaffected relative groups. For response accuracy effect sizes were negligible between all groups tested (see Table 6.8).

Table 6.8. Mental Rotations Task. Effect sizes between CAH and control comparison groups for response accuracy.

	Total Trials
	d
Unaffected girls vs. unaffected boys	0.01
CAH girls vs. unaffected girls	0.08
CAH girls vs. unaffected boys	0.00
CAH boys vs. Unaffected boys	0.05

6.4.2 Spatial Perception - Judgment of Line Orientation (Short Form) Odd (JLO)

Children scoring 3 or more correct (of a total of 5) in the JLO practice trials were entered into the analysis. Of the 94 participants, 66 (70%) were entered. Table 6.9

below shows the number and percentage of children in each CAH and control comparison group who passed this criterion.

Table 6.9. Percentage of CAH and unaffected children entered into JLO analysis (3 or more out of 5 practice trials correct).

	CAH Girls (N=27)	**Unaffected Girls (N= 22)**	**CAH Boys (N = 23)**	**Unaffected Boys (N = 22)**
Total included	N = 17 63%	N=17 77%	N=17 74%	N=15 68%

JLO (spatial perception) - Correlations

Correlations of age and vocabulary with JLO performance were examined for boys and girls separately. For boys, age and JLO correct reaction times did not correlate significantly, r = -0.330, p = .065, but age and JLO response accuracy did, r = 0.563, p = .001. Vocabulary did not correlate with either JLO correct reaction times, r = 0.122, p = .506 or JLO response accuracy, r = 0.274, p = .117. For girls, age correlated with JLO correct reaction times, r = 0.483, p = .004 and with JLO response accuracy, r = 0.571, p < .001. Vocabulary did not correlate with either JLO correct reaction times, r = 0.125, p = .481 or JLO response accuracy, r = 0.198, p = .262.

Correlations were also examined between JLO reaction times and JLO response accuracy for boys and girls separately. No correlations were observed between the two outcome measures for boys, r = -0.243, p = .179, or for girls, r = -0.208, p = .237.

JLO (Spatial Perception) – Analyses for reaction times

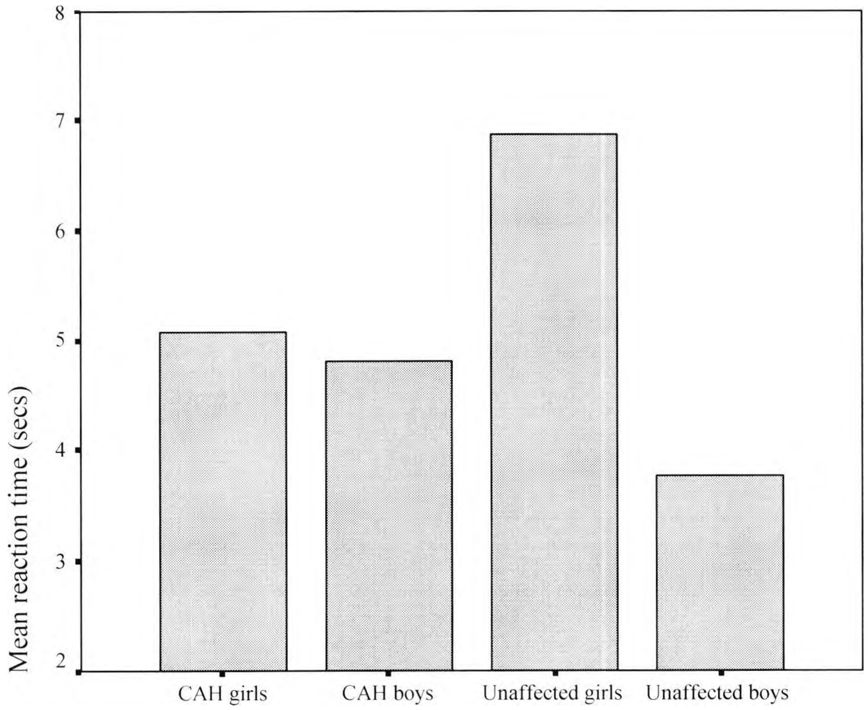
Two-way (sex x diagnosis) analyses of covariance (ANCOVAs) were carried out to determine group differences in JLO correct reaction times and JLO response accuracy. Because age correlated with the JLO, it served as the covariate in these analyses. In addition to the ANCOVAs, four planned comparisons were carried out (unaffected girls versus unaffected boys, CAH girls versus unaffected girls, CAH girls versus unaffected boys and CAH males versus unaffected males). These comparisons allowed testing of the specific hypotheses relating to CAH, and an assessment of sex differences in spatial perception. Age was also entered as covariate in the planned comparisons.

Table 6.10. JLO - mean reaction times (in seconds) for correct scores by CAH and control comparison groups.

	CAH girls N = 17		**Unaffected girls (N=17)**		**CAH boys (N=17)**		**Unaffected boys (N=15)**	
	M	SD	M	SD	M	SD	M	SD
Reaction time for correct performance	5.10	2.17	6.90	3.60	4.74	2.24	3.82	1.12

For correct reaction time, there was a significant main effect of sex, F (1, 61) = 8.91, p = .004, and a significant sex by diagnosis interaction, F (1, 61) = 6.17, p < .02, but no main effect of diagnosis, F (1, 61) = 2.29 p = .51. The planned comparisons revealed that unaffected boys' reaction times were faster than unaffected girls', F (1, 31) = 4.14, p = .05. Although CAH girls' reaction times did not differ from unaffected girls, F (1, 31) = 3.06, p =.09, there was a trend towards significance. CAH girls' and unaffected boys' reaction times also did not differ, F (1, 29) = 3.70, p = .06, however, there was also a trend towards significance. CAH boys and unaffected boys' reaction times did not differ, F (1, 29) = 3.18, p < .10.

Fig. 6.5. JLO mean reaction time (secs) for correct responses, by CAH and control comparison groups.



JLO Effect Sizes for correct reaction times

Effect sizes were calculated and revealed that the magnitude of the differences for reaction times was moderate to large between the groups tested. The greatest difference was seen between unaffected boys and girls, more than one standard deviation unit (see Table 6.11).

Table 6.11 Effect Sizes for JLO correct reaction times by CAH and control comparison groups.

	Effect Sizes
	d
Unaffected girls vs unaffected boys	1.3
CAH girls vs unaffected girls	0.7
CAH girls vs unaffected boys	0.75
CAH boys vs unaffected boys	0.5

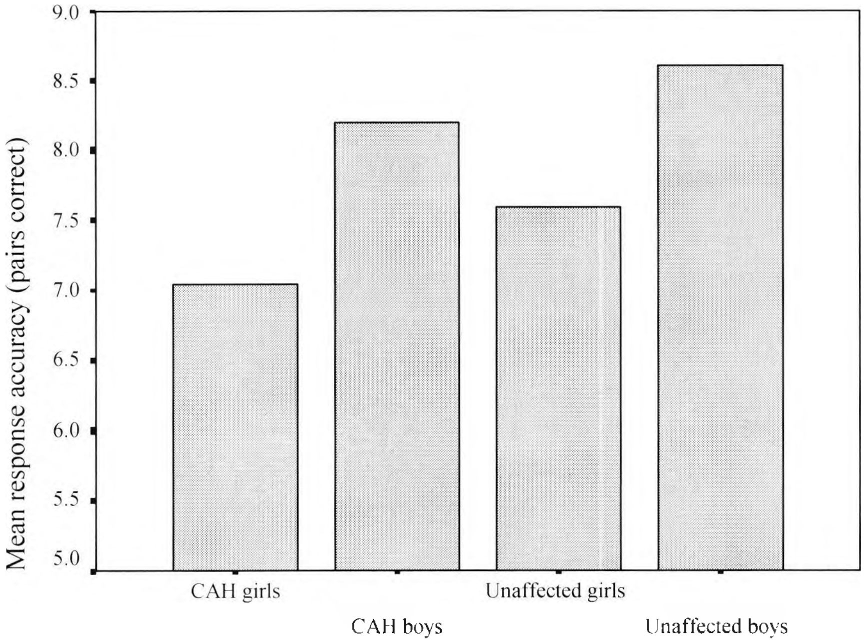
JLO Response Accuracy - Analyses

Table 6.12. Mean response accuracy by CAH and control comparison groups.

	CAH girls N = 17		**Unaffected girls (N=17)**		**CAH boys (N=17)**		**Unaffected boys (N=15)**	
	M	SD	M	SD	M	SD	M	SD
Total Response accuracy (trials 1-15)	7.03	3.61	7.59	2.60	8.20	4.40	8.61	3.40

For response accuracy ANCOVA revealed no significant main effects of sex, F (1, 61) = 2.42, p = .13, or diagnosis, F (1, 61) = 0.47, p = .49, and the two-way interaction between sex and diagnosis was also non-significant, F (1, 61) = 0.01, p = .93. The planned comparisons revealed that unaffected boys' and girls' response accuracy did not differ, F (1, 29) = 1.96, p = .17, CAH girls' response accuracy did not differ from unaffected girls', F (1, 31) = 0.35, p = .56, or from unaffected boys', F (1, 29) = 2.20, p = .15, and CAH and unaffected boys' response accuracy did not differ, F (1, 29) = 0.14, p = .71.

Fig. 6.6. JLO response accuracy (mean number of correctly matched pairs) by CAH and control comparison groups.



GROUP

JLO - Effect Sizes for response accuracy

Effect sizes were calculated, using Cohen's 'd' statistic, and revealed that the magnitude of the differences for JLO response accuracy was moderate between unaffected boys and girls and between CAH girls and unaffected boys. However, for CAH and unaffected girls and CAH and unaffected boys the magnitude of the difference was small (see Table 6.13).

Table 6.13. Effect Sizes for JLO (Short Form) odd response accuracy by CAH and control comparison groups

	Effect Sizes
	d
Unaffected girls vs unaffected boys	0.6
CAH girls vs unaffected girls	0.1
CAH girls vs unaffected boys	0.6
CAH boys vs unaffected boys	0.2

6.4.3 Targeting (Ball And Dart Throwing)

Scores were transformed so that a higher score indicated better performance. This was done by subtracting scores from the maximum possible distance on the target (max. distance = 48 centimetres).

Targeting - Correlations

A partial correlation was calculated between the composite targeting variable and height whilst controlling for age. The correlation did not reach significance, r = .0241, p = .82. Because the effect of height is lost when controlling for age, height is not partialled out in any of the analyses, however, age is entered as a covariate.

Targeting Analyses

Table 6.14. Dart and ball throwing scores and standardised targeting composite scores (reversed) as a function of CAH and control comparison groups.

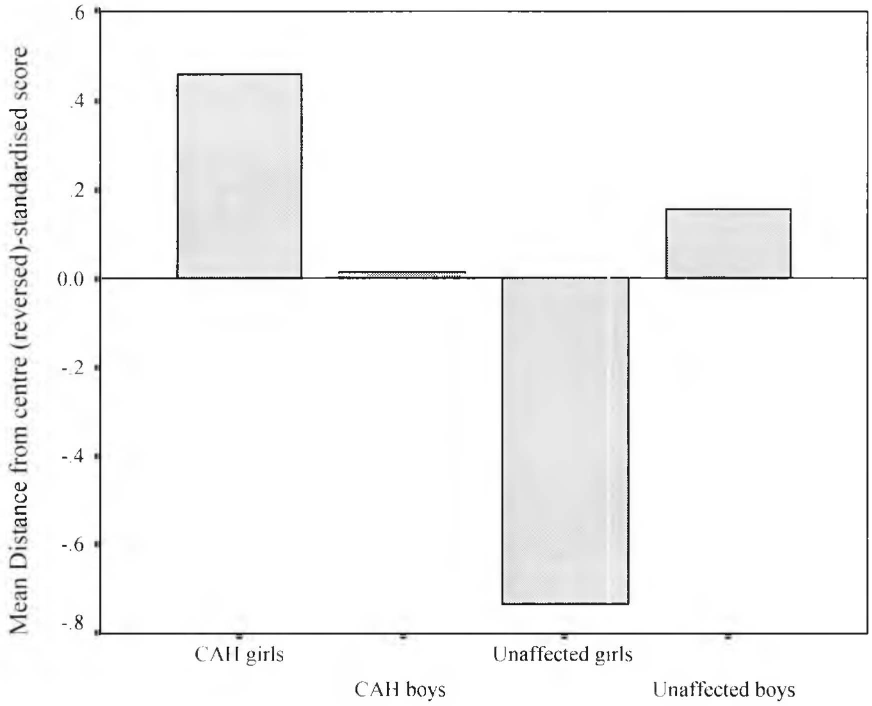
	CAH girls		**Unaffected girls**		**CAH boys**		**Unaffected boys**	
	M	SD	M	SD	M	SD	M	SD
Dart throwing (range = 0-48 cms)	22.23	9.20	15.66	10.05	20.59	10.71	21.05	11.75
Ball throwing (range = 0-48 cms)	25.03	6.90	19.45	8.23	22.54	7.56	22.81	7.25
Targeting composite	0.36	1.23	-0.62	1.42	0.06	1.39	0.11	1.49

Two-way (sex x diagnosis) analyses of covariance (ANCOVAs) were carried out on the targeting composite and each of the two measures of targeting (ball throwing and dart throwing) to detect group differences, with age entered as the covariate. In addition to the ANCOVAs, four planned comparisons were carried out (unaffected girls versus unaffected boys, CAH girls versus unaffected girls, CAH girls versus unaffected boys and CAH males versus unaffected males). These comparisons allowed testing of the specific hypotheses relating to CAH, and also allowed an assessment of sex differences in targeting performance. Age was also entered as a covariate in the planned comparisons.

Targeting Composite

For the targeting composite, there was a main effect of diagnosis, F (1, 89) = 4.91, p = .03, and a significant two-way interaction between sex and diagnosis, F (1, 89) = 5.90, p =.02, but no main effect of sex, F (1, 89) = 1.01, p = .32. The planned comparisons revealed that unaffected boys were better at targeting than unaffected girls, F (1, 41) = 5.50, p < .03, and CAH girls were better at targeting than unaffected girls, F (1, 46) = 11.18, p = .002. The targeting performance of CAH girls did not differ from unaffected boys, F (1, 46) = 0.80, p = .38, and CAH boys and unaffected boys also did not differ, F (1, 42) = 0.12, p = .91.

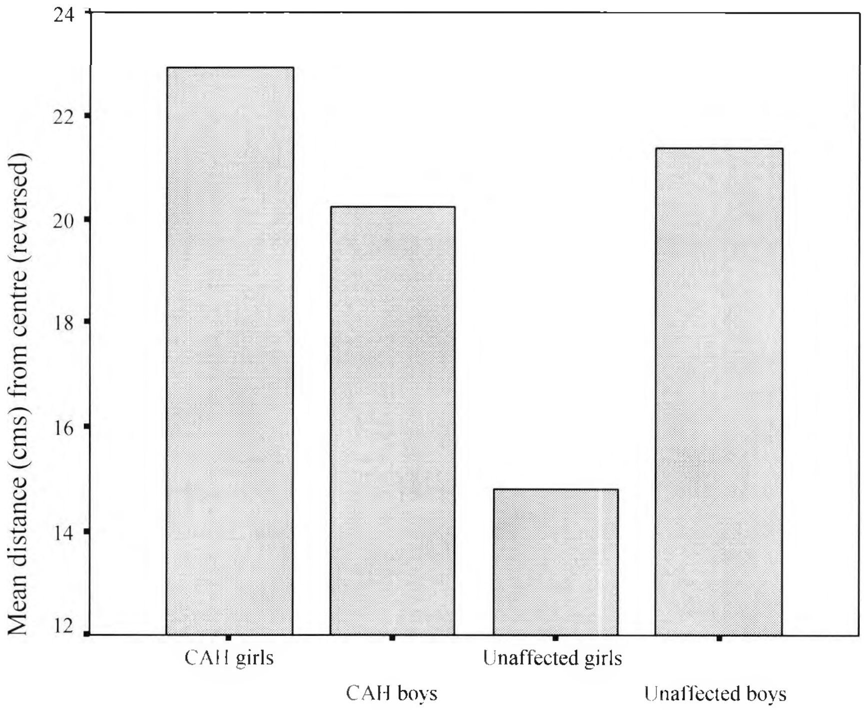
Fig. 6.7 Composite targeting performance (standard scores) by CAH and control comparison groups.



Dart Throwing

For dart throwing, the two-way interaction between sex and diagnosis was significant, F (1, 89) = 4.67, p = .03, but main effects of sex, F (1, 89) = 1.33, p = .25, and diagnosis, F (1, 89) = 3.55, p = .06 were not significant. The planned comparisons revealed that unaffected boys were significantly better than unaffected girls at dart throwing, F (1, 41) = 5.19, p < .03. CAH girls were significantly better than unaffected girls, F (1, 46) = 9.43, p = .004. The dart throwing performance of CAH girls, however, did not differ from unaffected boys, F (1, 46) = 0.26, p = .61, and the performance of CAH boys did not differ from unaffected boys, F (1, 42) = 0.20, p = .89.

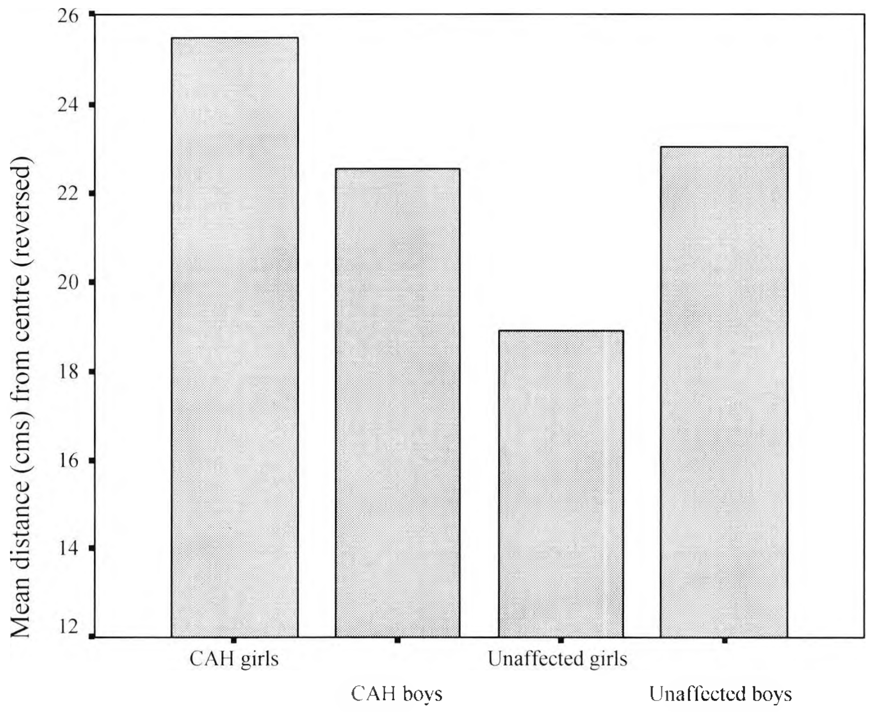
Fig. 6.8. Dart throwing performance. Mean distance (reversed) From centre of target (cms.), by CAH and control comparison groups.



Ball Throwing

For ball throwing, a main effect of diagnosis was significant, F (1, 89) = 4.92, p = .03, and a two-way interaction between sex and diagnosis was also significant, F (1, 89) = 5.07, p < .03. However, there was no significant main effect of sex, F (1, 89) = 0.20, p = .66. The planned comparisons revealed that unaffected boys and girls did not significantly differ in ball throwing performance, F (1, 41) = 3.24, p = .08. CAH girls, however, performed better than unaffected girls, F (1, 46) = 9.57, p = .003, but did not differ from unaffected boys, F (1, 46) = 2.00, p = .17, and CAH boys did not differ significantly from unaffected boys, F (1, 42) = 0.01, p = .99.

Fig. 6.9. Ball throwing performance. Mean distance (reversed) from centre of target (cms), by CAH and control comparison groups.



Effect Sizes for Targeting Performance

Effect sizes for dart throwing and ball throwing were calculated using Cohen's ‘d’ procedure. The size of the differences between unaffected boys and girls was moderate, and between CAH and unaffected girls the size of the differences was large. However, between CAH girls and unaffected boys and CAH and unaffected boys, effect sizes were small to moderate (see Table 6.15).

Table 6.15 Effect Sizes for targeting performance, by CAH and control comparison groups.

	Dart Throw	**Ball Throw**
	d	**d**
Unaffected girls vs. unaffected boys	0.60	0.50
CAH girls vs. unaffected girls	0.80	0.90
CAH girls vs. unaffected boys	0.15	0.35
CAH boys vs. unaffected boys	0.15	0.06

6.4.4 Correlation of Spatial Cognition measures

Partial correlations (controlling for effects of age) between reaction times and response accuracy for the mental rotations task, spatial perception task and performance on the composite targeting task were examined. Mental rotations and spatial perception correlated significantly for reaction time, r = 0.233, p = .03 (one-tailed), but not for response accuracy, r = 0.129, p = .31. Mental rotations did not correlate with targeting: for reaction time, r = 0.009, p = .93 or response accuracy, r = 0.089, p = .400. Spatial perception also did not correlate with targeting: for reaction time r = -0.003, p = .97, or for response accuracy, r = 0.017, p = .88.

Correlation of PSAI(Gender role behaviour) and spatial cognition measures

Correlations (controlling effects of age) were also examined between the spatial cognition measures and gender role behaviour (measured using the PSAI reported on in Chapter 4). PSAI scores did not correlate significantly with reaction time or response accuracy in mental rotations, r = 0.027, p = .79 and r = -0.063, p = .55, respectively. However, PSAI did correlate significantly in a negative direction with reaction times in spatial perception, r = -0.329, p = .007, such that faster reaction times are associated with more masculine gender role behaviour. This was not the case for response accuracy, r = 0.196, p = .11. PSAI scores also correlated significantly and in a positive direction with targeting, r = 0.278, p = .007.

6.5 DISCUSSION

This study investigated spatial cognition in young children with CAH and in unaffected relatives of children with CAH. It was hypothesised that the effects of masculinizing hormones would influence both visual-spatial and targeting ability. Of particular interest was whether the high levels of prenatal androgens experienced by CAH girls would enhance visual-spatial functioning and targeting performance. Prior studies investigating the influence of masculinizing hormones on visual-spatial ability have revealed inconsistent findings (see Collaer & Hines, 1995), and there is only one other study investigating the influence of hormones on targeting performance. Hines et al., (2002, submitted for publication) reported an effect of CAH in an older sample of CAH individuals, and where it was found that females with CAH were better at targeting than unaffected females. Ascertaining whether prenatal androgens influences these sexually differentiated behaviours in children is important in order to clarify the role of hormones in the development of spatial cognition.

Of further interest was whether unaffected boys and girls would differ on these aspects of spatial cognition. It has commonly been found that visual-spatial and targeting ability show large sex differences favouring males in the general population in adolescents and adults. However, prior studies investigating sex differences in visual spatial ability in children have so far revealed inconsistent findings.

First, examining the findings in unaffected boys and girls, the absence of a sex difference on the Vocabulary subtest suggests that the general intellectual function of boys and girls is comparable and thus any differences observed in spatial cognition are unlikely to be due to differences in general intelligence. With regard to visual-spatial ability, several differences were apparent. No sex differences were observed in accuracy of performance on mental rotations or spatial perception, but there was a significant difference in speed of response for spatial perception. Unaffected boys were faster than unaffected girls. However for mental rotations reaction time differences were weaker, and only approached significance in the first block of trials and weakened further in the second block. This suggests practice effects for both mental rotations and spatial perception. One possible explanation for slower reaction times experienced by unaffected girls is the possibility that they are less familiar with spatial concepts having had less experience with them. They are thus more cautious in giving responses and are reluctant to respond quickly without first ensuring successful performance on several trials.

The estimate of the size of the differences in reaction time was found to be considerable for spatial perception, ($d = 1.3$), and moderate for the first 12 trials of the mental rotations task, ($d = 0.5$). In comparison to meta-analytic estimates of effect sizes (Voyer et al., 1995), this correspondence is different from that reported for adolescents and adults on average, where males outperform females by close to 1 standard deviation unit for mental rotations and approximately 0.44 for spatial perception. However, the difference in the magnitude of effects sizes between boys and girls may be attributable to the different task demands in young children compared to adolescents and adults.

With regard to targeting, unaffected boys outperformed unaffected girls on both ball and dart throwing and on a composite of the two measures, and the size of the difference was moderate. This sex difference is unlikely to be attributable to physique as young children do not differ markedly in this respect. If the male advantage in targeting is not attributable to physical differences between the sexes, then it would seem likely that it is related to some aspect of spatial functioning. However, in the present data, targeting did not correlate with either mental rotations or spatial perception performance. Further, given that a sex difference was not evident in performance in the visual-spatial tasks, making inferences in regard to a spatial contribution to targeting are difficult.

Findings in relation to the effects of prenatal androgens revealed no difference in vocabulary between CAH and unaffected girls. In the case of visual-spatial ability, girls with CAH were no better than unaffected girls on either mental rotations or spatial perception, although on spatial perception they were faster than unaffected girls. This was not the case for mental rotations. Although CAH girls were slightly faster on the first half of the mental rotations task, the difference was weak and did not reach statistical significance. It was further found that their performance did not differ from unaffected boys on either visual-spatial task. CAH girls were, however, better at targeting than unaffected girls and their performance was similar to that of unaffected boys. The performance of CAH boys did not differ from unaffected boys on either visual-spatial task or in targeting performance.

The hypothesis that prenatal androgens influence visual-spatial functioning has not been fully supported. The failure to find an effect of CAH in visual-spatial ability does not clarify the inconsistencies found in the research literature to date. The fact that girls with CAH are more masculine-typical in their childhood play and activities (chapter 4) but not in ability to perform visual-spatial tasks, suggests that prenatal androgen levels influence one but not the other. This is consistent with earlier studies whereby CAH girls have been found to engage in more male-typical play behaviours (Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Hines & Kaufman, 1994; Berenbaum & Snyder, 1995) but have not been found to perform better than unaffected relatives in their visual-spatial functioning (Ehrhardt & Baker, 1974; McGuire et al., 1975; Hines et al., 2002, submitted for publication).

There is the possibility that CAH does not affect childhood performance in visual-spatial tasks because it requires the influence of later hormones, such as those seen in adolescence. Children in this study were tested prior to puberty; thus, it has been possible to examine the influence of the early hormone environment on visual-spatial performance; however, no differences were observed. Earlier investigations suggested that sex differences do not emerge fully until adolescence when later hormones are activated (Kail, Pellegrino, & Carter, 1980; Waber, Carlson, & Mann, 1982; Snow & Strope, 1990, see also Maccoby & Jacklin, 1974). Furthermore, in Resnick et al.'s (1986) study, which reports the strongest evidence to date for an effect of androgens on visual-spatial performance, some of the CAH females would have been experiencing or had already experienced puberty, thus drawing conclusions with regard to prenatal effects of androgens is difficult. However, this does not explain the enhanced visual-spatial performance of preadolescent girls with CAH compared to unaffected girls aged 8 to 12 years, observed by Hampson et al., (1998).

Voyer et al., (1995) in their meta analysis, argue that sex differences in early childhood are not convincingly established, but this may be because most measures of visual-spatial performance have been developed for use with adults and makes tasks very difficult for use with children, often producing floor effects. However, it is also the case that sex differences are smaller in children (Voyer et al., 1995), and this study is constrained by a small sample size, which may explain the lack of effects. Furthermore, the task did not reveal the expected sex differences in performance that have been reported in a previous study (Fane, Collins & Hines, in preparation) (Appendix 3). Moreover, at the time of the design of the study, this task was considered the most appropriate, because it has shown a sex difference and is suitable for very young children. However, since this time, another visual-spatial measure with a mental rotations component, showing a larger sex difference has been reported on (Levine et al., 1999). Thus, given all this, it is not possible to draw any definitive conclusions.

In healthy boys and girls, a significant association between hormones and spatial ability has not been consistently found in boys or girls (Jacklin et al., 1988; Finegan et al., 1992). Although it is possible that measures of spatial skill and measures of hormones have not been sensitive enough to detect a relationship, it is also possible that visual-spatial performance is not influenced by early androgens. However, the positive relationship between levels of 2^{nd} trimester testosterone and speed of mental rotations in normal girls observed by Grimshaw et al (1995) corresponds with the CAH girls' faster performance compared to unaffected girls on spatial perception. Thus it would seem that normal variations of prenatal androgens may influence speed of processing in visual-spatial ability. This further corresponds with the enhanced speed of performance on both mental rotations and spatial perception in unaffected boys in the current study. What might have been revealed is that androgens influence visual-spatial functioning differently, with early hormones affecting speed of performance on spatial perception but not on mental rotations, and having no effect on accuracy of performance for either task.

For targeting ability, the hypothesis was supported. An effect of CAH was observed. Girls with CAH were better than unaffected girls and their performance was similar to that of unaffected boys. There is only one other study investigating the effects of prenatal androgens in targeting ability. Hines et al (2002, submitted for publication) also found an effect of CAH on the targeting performance of adolescent and adult females. Females with CAH performed better than unaffected female relatives. The performance of males with CAH, however, did not differ from unaffected male relatives. The predicted sex differences were also observed, with unaffected males performing better than unaffected females. Since the relationship between hormones has not been directly tested before, findings observed in this study and those of Hines et al (2002, submitted for publication) are strongly suggestive of a direct influence of prenatal androgens on this aspect of spatial cognition.

Given that an effect of hormones has been found for targeting but not for performance in visual-spatial ability, it appears that these two aspects of spatial cognition are differentially influenced. Further, since targeting correlated with gender role behaviour but visual-spatial performance did not (apart from speed of spatial perception), there is the proposition that masculine-typical play and activities may also act to foster enhanced targeting skills, although no causal inferences can be made due to the correlational nature of this observation and the fact that the two behaviours may be influenced independently by prenatal androgens.

If prenatal androgens are not related to performance on visual-spatial tasks, and there is no association with childhood gender role behaviour, it might seem plausible to suggest that the sex differences observed in speed of performance might arise from the differential experiences of boys and girls. Existing studies indicate that boys are subject to more spatially relevant input early in life than girls (e.g., Newcombe & Sanderson, 1993), and some correlational studies have shown that participating in spatial activities such as ball playing and playing with spatially manipulative toys are positively related to children's visual-spatial skills (e.g., Fagot & Littman, 1976; Newcombe & Dubas, 1992).

Block (1983) suggests that the differential exposure boys and girls have to male versus female stereotypical toys, predisposes them toward different problem solving experiences which in turn may influence cognitive development. Moreover, Voyer, Nolan, and Voyer (2000) found that adults who reported a preference for play with spatial toys as children, showed improved performance on mental rotations. This is not to say that androgens do not act indirectly to foster skills and provide the necessary spatial experience associated with increased speed of performance on visual spatial tasks. However, a study by Caldera, Culp, O'Brien, Truglio, Alvarez, and Huston (1999) failed to find an association between spatial play and visual-spatial ability in either pre-school boys or girls. These authors, however, used a test of spatial visualisation, the Children's Embedded Figures Test, which does not typically show a large sex difference.

The finding that the performance of CAH and unaffected boys did not differ across all tasks is not unexpected as several studies have found no differences between CAH and unaffected males (e.g., Baker & Ehrhardt, 1974; McGuire et al., 1975; Resnick et al., 1986). Furthermore, research has found that boys with CAH may not experience levels of prenatal androgens that are elevated beyond those expected normally, because feedback mechanisms reduce the production of testicular androgens to compensate for the increased adrenal output of androgens that they experience (Pang et al., 1979). However, neonatally, the down-regulation of testicular hormones is thought to persist. While testicular hormones are likely to remain down-regulated neonatally, medication with corticosteroids also regulates the adrenal production, and thus androgen levels are lower than normal at this time when there is a further surge of androgens (Pang et al., 1979; Hines et al., 2002, submitted for publication). This might explain the impaired performance observed in visual spatial performance in CAH boys compared to unaffected boys in other studies (e.g., Hampson et al., 1998; Hines et al., 2002, submitted for publication).

Given that no effect of prenatal androgens on mental rotations or spatial perception performance has been observed, and that sex differences were only seen in speed of performance for spatial perception, it is important to consider possible methodological limitations in the study.

Firstly, with regard to the type of task used, there is a complication in studying these abilities effectively in young children because the kind of task that shows the largest and most robust sex difference is a measure of three-dimensional mental rotations, which is typically too hard for young children. Thus two-dimensional mental rotations tasks have often been used because they are easier (Linn & Petersen, 1985), but the size of the sex difference is smaller, as it is for tests of spatial perception (Voyer et al., 1995). Coupled with the fact that the size of the sex difference in visual-spatial ability may be smaller in children than it is for adults, this makes it more difficult to detect differences in children even if they exist. There are no standard mental rotations tests or spatial perceptions tests to measure visual-spatial ability in young children, and different studies have used different tasks to investigate this functioning. Thus, given this, it is not possible to draw conclusions regarding early manifestations and causes of sex differences in visual-spatial skill.

Secondly, although the predicted sex difference in unaffected boys and girls was found for speed of performance only on the spatial perception task, there were no differences observed in performance on either task. Boys and girls performed equally well. However, for both boys and girls in the study, faster performance did correlate with accuracy in performance on mental rotations but not for spatial perception, indicating that children who were faster at mental rotations were also better. This suggests the possibility that boys and girls who are faster may implement different strategies to successfully carry out mental rotations tasks. Using a modified (computerised) version of the Marmor task, Estes (1998) evaluated reaction time performance and verbal reports of strategy used in 4 and 5 year old children. The author found that 4 and 5 year olds who gave mental explanations had reaction times consistent with mental rotations. Thus, isolating children's awareness of their mental activity while performing mental rotations, might be one way of demonstrating whether an underlying awareness of the specific form of mental activity is required to successfully perform mental rotations.

Further, although reaction times in the mental rotations task revealed no sex difference or effect of androgens, both CAH and unaffected girls' performance improved in the second half of trials (see Table 6.5). This suggests that practice effects merit consideration when examining the development of mental rotations skill in children, particularly girls. The empirical evidence for practice effects is mixed. Brinkmann (1966) found that following 3 weeks of instruction and practice, high school girls did not differ from boys on a test of spatial relations. Other studies investigating adults have found that females perform two-dimensional mental rotations more slowly, but not necessarily less accurately than males (e.g., Kail, Carter & Pellegrino, 1979; Blough & Slavin, 1987). Further, McGee (1978) found no evidence for a differential response to training or practice on a test of mental rotations in females compared to males.

Finally, with regard to spatial perception, investigations of the Judgment of Line Orientation task, have not reported sex differences before the age of 7 years, and because there is no study which has examined outcomes in children younger than this, the data from this study are somewhat exploratory in nature. Children who did not get more than 60% of the practice trials correct (27% of the total) were not included in the analysis. Of the total not included (28 children in total) all were in the 3-6 yr old range. Of the total 3-6 yr olds in the study, 55% were not included. Thus, given the inconsistent outcomes for each spatial task in this study with regard to speed of response, and given that the spatial perception task is difficult for children younger than 7 years, definitive conclusions about possible causes of differences on this task are difficult to draw.

Given that no correlation was observed between accuracy of performance and speed of performance in spatial perception, this might also reflect the difficulty of the Judgement of Line Orientation (JLO) task to measure spatial perception in young children. The task required matching the direction of a pair of lines with a comparison array, and it is possible that error rates increased because of the speed in making decisions for both lines. Lunn & Kimura (1989) used a simplified version of the JLO task, using only one stimulus line and a matching array containing fewer lines than the standard task. The authors observed sex differences in the opposite direction to what would be hypothesised. 3-5 year old girls performed better than boys. However, they did not measure speed of performance and argued that the child and adult versions of the task might not be equivalent.

To conclude, the data from this study provide evidence for an effect of prenatal androgens on targeting skill, and thus extend the research in spatial cognition to include targeting abilities. The data from this study do not help to resolve the issue of whether androgens influence visual-spatial ability. The findings cast doubt on the hypothesis that the early hormone environment influences all sex-related differences in performance on visual spatial tasks. However, methodological limitations, particularly small sample size, and limited availability of suitable tests, do not allow firm conclusions to be drawn. Furthermore, the expected sex differences were not revealed in healthy children. Based on this, the development of more sensitive techniques for assessing visual-spatial skill is required which may reveal more robust sex differences in young children, thereby allowing for a more meaningful assessment of sex differences and androgenic influences on this aspect of spatial cognition.

CHAPTER SEVEN

GENDER ROLE DEVELOPMENT: A REVIEW

7.1 CHAPTER SUMMARY

Children learn at a very early age what it means to be a boy or a girl, and in most cases behave in ways that accord with their biological sex. Through the numerous activities, encouragements, overt behaviours, covert suggestions, and various forms of guidance, children experience the process of gender role socialization (see Golombok & Fivush, 1994). As boys and girls progress through childhood, they are exposed to many different socialization practices and experiences which influence gender role development (Witt, 1997).

It is very difficult for children to grow up without experiencing some form of gender stereotyping (Huston, 1983; Carter & Levy, 1988), i.e., clusters of characteristics and traits that define masculine and feminine behaviour. They begin to acquire these gender-stereotypes whilst they are also becoming aware of their identities as boys or girls (Kuhn, Nash, & Brucken, 1978). As children develop, these stereotypes become more pervasive and are reinforced in the home, in school, in the playground, and within sex-segregated groups (e.g., Thorne, 1993; Leaper, 1994; Martin, Fabes, Evans, & Wyman, 1999). The consequence for children is that boys and girls will each have a self-concept about what it is to be a boy or a girl.

It is also the case that children's acquisition of knowledge about gender affects gender role behaviour (Weinraub, Clemens, Sockloff, Ethridge, Gracely, & Myers, 1984). It is argued that when children reach an understanding of their own gender identity and that of others (i.e., the knowledge that one is either a boy or a girl), they are motivated to adopt behaviour patterns that are in line with their own sex (Martin & Little, 1990). Children acquire gender stereotypes, which in turn contribute to the same-sex preferences that regulate their own behaviour (Martin & Little, 1990).

Differences in gender role behaviour are also influenced by biological factors. Biological influences on gender role development are evident in studies of children who have developed in unusual hormone environments during the prenatal period (e.g., Money & Ehrhardt, 1972, Ehrhardt & Baker, 1974: Berenbaum & Hines, 1992). Biological theorists would argue that both biological and social factors interact because the physical appearance of children can determine the way they are raised, which in turn influences their gender role development. However, biological factors do not specify the social processes through which children acquire gender-typed patterns of behaviour.

This chapter outlines and reviews some of the evidence for social, cognitive developmental, and biological theories of children's' gender role development. The study carried out in the following chapter investigates the influence of hormones on two social influences (modelling and gender-labelling) that are thought to be part of the process of gender role development.

7.2 THEORIES OF GENDER DEVELOPMENT

Gender role development generally refers to the process by which children learn behaviour that is appropriate for their sex. Behaviours and traits that are typically studied include childhood activities (e.g., toy play, toy preferences, play partner preferences), interests (e.g., sports and vocational interests, maternal interests), and personality characteristics (e.g., aggressiveness, nurturance).

Theories evaluating gender role development have historically fallen within three major theoretical approaches; social learning theory, cognitive developmental theories and biological theories. These 3 approaches represent the dominant perspectives that have been applied to gender role development. Mechanisms derived within each of these 3 frameworks have been used to describe and explain how children adopt gender typed behaviours that are associated with their biological sex. Each of the theories emphasises distinct aspects and dimensions of gender role development. However, none of the three explains all aspects of gender role development.

7.2.1 Social Learning Theory

Social learning theorists (Bandura, 1977; Mischel, 1966, 1970) have argued that children acquire their gender identity, sex-role preferences, and gender-typed behaviour in two ways. Through differential reinforcement and observational learning. Differential reinforcement refers to the tendency of parents, peers, teachers, and other social agents to encourage and reinforce sex appropriate behaviours and punish behaviours considered to be more appropriate for the other sex. Observational learning refers to the idea that children acquire gender-typed behaviour by observing the activities of same-sex models, including parents, peers, teachers, and siblings.

The process of differential reinforcement is based on the principle that behaviour that has favourable consequences is more likely to be repeated (positive reinforcement), whereas behaviour that is not rewarded, or punished, is less likely to be performed again (negative reinforcement) (Fagot, 1978; Langlois & Downs, 1980; Fagot & Leinbach, 1989). It was initially hypothesized that parents' differential treatment of their sons and daughters accounted for the sex differences in the activities of boys and girls. However, reviews of the literature (Maccoby & Jacklin, 1974; Lytton & Romney, 1991) found few variations between the treatment of boys and girls, and those that were found predominantly involved pre-school children.

Block (1983), also challenged the idea that parental treatment of boys and girls accounted for differences in gender role behaviour, arguing that little attention had been paid to the socialization of activities and interests by parents. The focus had been mainly on personal attributes such as aggression and dependency. Further, Lytton and Romney, (1991) reported that gender-typed activities were differentially reinforced by parents. Parents promoted specific gender-typed activities and interests thereby encouraging their children to adopt them.

For example, Fagot (1978) observed 24 children between 20 and 24 months of age in their homes and found that parents responded differently to the activities of their sons and daughters, such that girls were given approval for playing with dolls and dressing up, and boys were encouraged to play with masculine-typical toys. The author also found that fathers were more likely to discourage doll play in boys. In a later study, Fagot and Hagan (1991) found that boys aged 18 months received fewer positive reactions to play with feminine toys from fathers but not from mothers, and that mothers were more likely to give instructions to girls when they communicated to them than fathers did. Similarly, Langlois and Downs, (1980) observed 3 and 5 year old children and their parents, and found that girls were rewarded for play with feminine toys and punished for play with masculine toys, while boys were rewarded for play with masculine toys, and punished for play with feminine toys by fathers. Mothers, however, did not appear to discourage feminine play in boys. This process of differential treatment that boys and girls receive begins very early in life, in the newborn period soon after birth (Fagot, 1978; Lewis & Weinraub, 1979). Thus it appears that in the early years, young children's preferences for sex-typed toys and activities may result from the tendency of parents, particularly fathers, to actively encourage sex-appropriate behaviour and to discourage behaviour that they consider to be sex inappropriate.

These studies relating to the differential encouragement of girls' and boys' play behaviour, while not exhaustive, do, however, emphasise the role of the parent in shaping gender-typed behaviour. They also highlight the idea that children's play has long-term consequences for their gender role development. That is, parents choose to play with gender-typed toys with their toddlers and react more positively to children engaged in gender-typical activities and more negatively to children engaged in gender-atypical activities. This helps to foster the different types of behaviours in children which are later associated with the roles of males and females in our culture (Caldera, Huston & O'Brien, 1989; Leaper, Leve, Strasser, & Schwartz, 1995).

It is not just the differential reinforcement of parents that influences children's gender role development. Peers are also important in this process. There is evidence to suggest that peers provide strong reinforcement for gender-typical behaviour while showing their disapproval for gender-atypical behaviour. For example, Fagot (1977) observed that preschoolers responded negatively to peers who violated gender stereotypes. She also argued that boys may be more likely to avoid other-sex activities because they are more harshly reprimanded than girls from both peers and adults, for engaging in other-sex activities. Moreover, reinforcement of gender typical behaviour has been reported to be effective, with gender typical behaviour persisting longer if it is rewarded. On the other hand, children who are punished for gender atypical behaviour are more likely to stop performing the behaviour (Lamb & Roopnarine, 1980; Lamb, Easterbrooks, & Holden, 1980). This is particularly true of the positive and negative reinforcements established by same-sex peers (Fagot, 1985). Peer influences on gender typical play have been investigated by Serbin, Connor, Burchardt, and Citron (1979), who found that children played less with other-gender typical toys when they were in the presence of peers than when they were alone. Further, Fagot (1984) found that peers behaved more negatively towards boys engaging in feminine-typical behaviours. Similarly, Lamb and Roopnarine (1984) found that same-sex peers rewarded gender appropriate behaviors more than they rewarded gender inappropriate behaviors.

Observational learning is another social learning mechanism through which children are thought to acquire gender role behaviour. According to social learning theory, children acquire a large percentage of their gender-typed behaviour by observing and imitating same-sex models (Bandura, 1977). Children are thought to engage in more same-sex than other-sex behaviour because they pay more attention to same-sex models and perceive them as more similar to themselves. Furthermore, they imitate the behaviour of same-sex models more than models of the other sex (Perry & Perry, 1975; Perry & Bussey, 1979; Liss, 1979; Bussey & Bandura, 1984).

The same-sex hypothesis has not been fully supported. In extensive reviews of the research (Maccoby & Jacklin, 1974; Barklay, Ullman, Otto & Brecht, 1977) it has been concluded that modelling offers a 'weak' explanation for the adoption of gender typed behaviour. However, later studies argued that this conclusion was premature. Perry and Bussey (1979) suggested that the previous research on same-sex imitation was inappropriate. They contended that in a typical study children are only exposed to a single male or female model and this is not a sufficient guide for their own behavior. They posited that it was necessary to reformulate how modelling contributes to gender role development, suggesting that children determine what behaviors are appropriate by observing multiple male and female models. Their research confirmed this, demonstrating that children discern what behaviors are appropriate for females and males by observing the behaviors of multiple models. Children then imitate the behaviors of same-sex models. They also found that the more frequently a same-sex model was observed making an item choice, the greater the imitation of that behavior. Thus, the mere knowledge that same-sex adult models make certain choices, different from those of the other sex, exerts an influence on children's own choices and is instrumental in shaping gender-appropriate behavior (Maccoby, 1999).

Children also learn about gender appropriate behaviour by observing their peers. It is argued that children determine gender typed activities by observing the proportion of boys and girls engaging in particular activities (Perry & Bussey, 1979). There is research that supports this. Bussey and Perry (1982) for example, found that whilst both boys and girls accepted peers same-sex behaviour, boys were more likely to reject other-sex behaviour in their peers than girls were. Furthermore, Shell and Eisenberg (1990) found that children's attention to toys appeared to be affected by peers' interest in the toys. Children appeared to be aware of the relative distribution of same-sex peers in relation to other-sex peers' interest in toys, and confined their toy play to times when a greater proportion or number of the same-sex peers were already engaged with the toy.

Social learning theory, although contributing greatly to our knowledge of how children develop gender role behaviour, on its own is seen as too simple an explanation for the complex processes involved in the differentiation of children's gender behaviour (see Golombok & Fivush, 1994). Cognitive developmental theories have extended the understanding of gender role development by also examining the cognitive mechanisms involved in the process of development. This approach assumes that children's underlying knowledge and understanding about gender influences gender role development.

7.2.3 Cognitive Developmental Theory

Cognitive developmental theory (Kohlberg, 1966) posits that children's gender typed cognitions and understanding of the invariance of being a male or a female, play a major role in gender role development. Cognitive approaches include the investigation of specific cognitive developmental processes that children proceed through at different stages of development, in order to acquire an understanding of what it means to be a boy or a girl. Theorists in this domain are concerned with the cognitive processes that are involved in children's progression to different levels of competency with regard to knowledge about gender (Slaby & Frey, 1975; Emmerich, Goldman, Kirsh, & Sharabany, 1977; Martin & Halverson, 1981). At a very early age children learn to categorise themselves and others according to their sex. Once a basic gender identity is established, they tend to perceive others' activities in sex differentiated ways, and begin to understand that other children either match the self in respect of gender, or do not. This understanding has an impact on behaviours such as playmate preferences and activities that are considered same-sex appropriate (Leinbach & Fagot, 1986; Martin & Little, 1990).

Kohlberg (1966) believed that children's understanding of the invariance of gender, known as gender consistency, was essential for the acquisition of gender role behaviour. He posited that children progress through three stages in the development of their understanding of gender. At about the age of 2 years, children enter the first stage known as gender identity, in which they learn to label themselves and others as male or female. At about 3-4 years of age children move into the second stage, known as gender stability, in which they have come to understand that gender is stable over time. It is only at stage three, the last stage, known as gender consistency, that the gender concept is complete. Children understand that gender is stable across time and situations. Gender at this last stage becomes an unchanging aspect of identity. As a consequence of Kohlberg's (1966) findings, it was concluded that children's understanding that gender remained invariant across situational changes, was a prerequisite for the adoption of, and adherence to, gender roles.

Both Slaby and Frey's (1975) and Emmerich et al's., (1977) assessment measures for gender constancy have been used to measure children's understanding of gender invariance. However, since the introduction of these two measures, there has been much debate regarding the most effective way to measure gender constancy, and the use of several additional methods has made it difficult to interpret outcomes (Zucker 1999).

The results of several studies are consistent with aspects of Kohlberg's (1966) theory (see Ruble & Martin, 1998 for review). For example, Marcus & Overton (1978) found that children's understanding of gender develops gradually and is related to other aspects of their cognitive development in 3-7 year olds. Slaby & Frey (1975) also noted that gender understanding develops sequentially, progressing through the three stages. These authors also found that children who were at the highest stage of gender constancy were more likely to attend to same-sex models than children whose understanding was less well developed.

However, other studies have revealed limitations in Kohlberg's (1966) theory (e.g., Carter & Levy, 1988; Levy & Carter, 1989; Bussey & Bandura, 1984; Martin & Little, 1990). It has been found that children who have not reached the final stage of gender competency, engage in more gender-typed toy play or less gender inconsistent behaviour than other children. Martin and Little (1990) observed that children who understood the stability of gender (stage 2), liked gender typed toys and same-sex peers more than children who understood gender consistency (stage 3). Moreover, Marcus and Overton (1978) found gender constancy (attainment of all 3 stages) was not related to same-sex preferences in children. They suggested that the highest degree of same-sex preference occurs before children achieve gender constancy, when children are at the stage of gender stability, and lacking an understanding that gender will remain constant if they engage in other-sex activities. They also posited that children who have achieved gender consistency are free to be more flexible because they are secure in the knowledge that their gender will not change.

More recently, Zucker, Bradley, Kuksis, Pecore, Birkenfeld-Adams, Doering, Mitchell and Wild (1995) provide a detailed review of the literature contributing to gender constancy and same-sex preferences. The authors highlight methodological issues such as controlling for age and intelligence, variations in cut off points for defining high versus low gender constant children, and variations in measures of assessment, which contribute to the disparate findings in this domain.

Although it is not disputed that children do progress through the three stages of gender understanding, there is some controversy about the importance of these stages in terms of children's pursuit of gender related behaviour. It would appear that Kohlberg's theory (1966) somewhat overstated the idea that a mature understanding of gender is a necessary requirement for gender-typed behaviour to develop.

7.2.3 Gender Schema Theory

Gender schema theory (Martin & Halverson, 1981, 1987) is another aspect of the cognitive developmental approach to gender typing, describing how children learn about gender and behave accordingly, by organizing gender related information. According to this theory, the establishment of a basic gender identity motivates children to learn about the category of sex and to incorporate information related to this into gender schemas. Schemas are organized sets of beliefs and expectations about gender that will influence the kind of information children will attend to and remember.

According to gender schema theory (Martin & Halverson, 1981), children first acquire a simple 'in-group-outgroup schema' that allows them to classify behaviours, traits, toys, etc, on the basis of gender (i.e., for males or for females). They then acquire 'own sex schemas' which consist of a detailed body of knowledge related to their sex, that children need to perform gender consistent behaviours. There is some evidence in support of this idea, that children process information according to the dimension of gender and subsequently behave in ways that act on this. Martin, Wood, & Little (1990) found that when preschool children are told that someone is male or female, they will predict that the individual will engage in a gender consistent way. Further, if told that someone likes to play with toolboxes they will assume that the person is male. As children mature in age these predictions become more complex (e.g., Martin, et al., 1990).

Martin (1989) argues that young children's tendency to make gender consistent inferences about behaviour may be the result of their reliance on the categorical distinction between boys and girls, and posited that young children are unlikely to take on board counter stereotypical information when predicting how a person may behave. The author studied 4-10 year old children providing them with four different descriptions of a target child: involvement in two sex-stereotyped or two sex-counter-stereotyped behaviours, a counter-stereotyped label ('sissy' boy, 'tomboy' girl), and a neutral behaviour. In ratings of liking, Martin (1989) observed that children preferred same-sex peers to other-sex peers, but that peers' involvement in stereotyped versus counter-stereotyped interests, or being labeled negatively, had much weaker effects on children's judgements of behaviour.

7.2.4 Biological Influences

Biological accounts of gender role development have mainly focused on the effects of sex hormones on gender-typed behaviour. Indeed, there is extensive evidence that the early hormone environment influences childhood gender role behaviours such as toy play, activities, peer preferences and toy choice (see Collaer & Hines, 1995, for review).

Research findings are relatively consistent in reporting a link between sex hormones and gender role behaviour, with androgens masculinizing some gender-typed behaviour (e.g., Ehrhardt, Epstein, & Money, 1968; Money & Ehrhardt, 1972; Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Hines & Kaufman, 1994; Berenbaum & Snyder, 1995).

Early work by Money & Ehrhardt (1972) suggested that gender role development is under the influence of both biological and social influences interacting to determine children's gender role behaviour. It is argued that once a boy or a girl is born, social factors come into play, such as others reactions, and they way they are treated based on their appearance. These factors will also influence gender role development.

Children who have been exposed to abnormal hormone environments as a result of genetic disorders during the prenatal period, and in particular females with CAH, have provided evidence that aspects of gender role development are influenced by the early hormone environment (see Chapter 3).

Studies investigating the effects of hormones on childhood behaviour have found that the presence of prenatal androgens causes masculinisation of behaviours such as playmate preferences, toy play and toy and activity preferences (Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Hines & Kaufman, 1994: Berenbaum & Snyder, 1995).

There is also evidence that the early hormone environment contributes to the development of core gender identity. Early studies on gender identity, carried out by Money and colleagues (Money, Hampson & Hampson, 1957) found that only 5 out of a total of 105 hermaphrodites had a "gender role and orientation that was ambiguous and deviant from the sex of assignment and rearing" (Money et al., p. 333). These authors concluded that sex of assignment and rearing was a better predictor of gender role and orientation than factors such as chromosomal sex, hormonal sex, gonadal sex, or reproductive sex. Further, the same authors recommended that if sex reassignment of intersex cases occurred in the neonatal period, adjustment can take place without complications. This recommendation was based on the observations that 11 out of 14 intersex children adjusted to the change without problems. Zucker,

(1999) provides a comprehensive review on the gender identity formation in children with physical intersex cases such as CAH. More recent data has revealed that generally CAH females identify with their gender of rearing, however, there is some variability in the extent to which they are satisfied with their female gender identity (Zucker, 1999).

For example, based on interview data in respect of gender identity, Ehrhardt, Epstein, and Money (1968) reported that 7 (46.6%) out of 15 girls with CAH were content to be a girl, 5 (33.3%) were ambivalent, and 3 (20%) expressed a desire to be a boy. Control girls were more likely to be content to be a girl (93.3%), none were ambivalent, and 6.7% expressed a desire to be a boy. In a similar study, Ehrhardt and Baker (1974) noted that none of the 17 CAH girls was unhappy with her female gender identity, and only 6 indicated that they were undecided. Other studies using different method of assessment (the Draw a Person test) (e.g., Perlman, 1973; McGuire, Ryan, and Omenn, 1975) found that CAH girls were found more often to draw a girl first in the Draw a Person test. However, two other studies using the same method of assessment (Hurtig & Rosenthal, 1987; Slijper, 1984) suggest a slightly less firm female gender identity. Meyer-Bahlburg et al., (1996) reported on 4 CAH patients who had been raised as females but whom later chose to live as males. Similarly, Slijper (1998) found that 2 out of a sample of 18 CAH girls met the criteria for gender identity disorder, with the remaining 16 being content with their female gender identity. Moreover, Berenbaum and Bailey (1998) found little evidence that girls with CAH were uncomfortable being female and concluded that consistent with earlier reports, girls with CAH have a female-typical gender identity. Finally, Zucker et al., (1996) found that 1 of a sample of 31 CAH females was now living as a male, having been raised as female.

Thus, there appears to be some variability in the extent of female gender identification in CAH females. However, as Collaer and Hines (1995) point out it is likely that it may not be as firmly established in females with CAH as it is in unaffected girls, although generally they are satisfied with their sex of rearing. Males with CAH, however, develop a normal male gender identity.

With regard to gender role behaviour, studies have predominantly investigated gender-typical play activities in children with CAH and controls. Early studies used interview methods to assess behaviour. Ehrhardt, Epstein and Money, (1968) found that CAH girls preferred boys toys to dolls, preferred trousers to dresses and considered themselves as tomboys. Baker and Ehrhardt (1974) replicated these results in another study, reporting that CAH girls showed more interest in boys' toys than girls' toys. A later study by Berenbaum and Hines (1992), applying more objective measures (direct observation), confirmed these findings. They found that CAH girls spent more time playing with masculine toys than unaffected same-sex siblings and less time playing with feminine toys. CAH boys however, did not differ from control boys in masculine or feminine play. Further, Hines & Kaufman (1994) examined playmate preferences in CAH children and relative controls, and found that CAH girls preferred boys as playmates to a greater degree than control girls.

7.3 CONCLUSIONS

It is very likely that the distinctive gender-typed activities, play styles and preferences that children adopt are multiply determined and reflect a degree of influence from each of the theories outlined. The early hormone environment alone does not determine gender development, but does seem to facilitate the development of gender-typed behaviour in a male or female direction when postnatal experiences are compatible (Golombok & Fivush, 1994). It is likely that hormonal factors, cognitive factors and socialization factors all are influences interacting together to contribute to the sexually differentiated gender role behaviours manifested in boys and girls.

The study carried out in the next chapter draws on the theories of gender role development to investigate the role of prenatal androgens on social mechanisms influencing gender role development. It involves examining whether social processes, such as modelling and gender-labelling, are altered in a masculine direction because of high levels of prenatal androgens, or whether social processes operate independently of androgens. To date, no studies have directly examined the impact of masculinizing hormones on this dimension of behavioural development, and therefore may shed light on processes involved in the development of gender role behaviour in children.

CHAPTER EIGHT

PRENATAL ANDROGEN EXPOSURE AND SOCIAL MECHANISMS INFLUENCING GENDER-TYPED BEHAVIOUR: EMPIRICAL EVIDENCE

8.1 ABSTRACT

Responses to social mechanisms through which gender role behaviour is influenced, were investigated in this study. 27 CAH girls and 22 female unaffected relatives, and 23 CAH boys and 22 male unaffected relatives, aged from 3-11 years took part. Two sources of social information were manipulated by gender, social modelling and gender-labelling. Responses to this information were measured under two separate protocols. With respect to social modelling (protocol 1), unaffected boys and girls imitated the behaviour of same-sex models more than other-sex models. However, there was no effect of CAH. Girls with CAH responded to modelling in a female-typical fashion, and their behaviour did not differ from unaffected girls in this respect. With respect to gender labelling (protocol 2), the same pattern of results was observed. All boys and girls, irrespective of diagnosis of CAH, spent more time interacting with toys assigned a same-gender label in free play. They also expressed preferences for same-gender labelled toys, and were more likely to approach a same-gender labelled toy first in free play. CAH girls did not differ from unaffected girls

on these dimensions. The behaviour of CAH boys did not differ from unaffected boys following both social modelling and gender-labelling.

It would appear that exposure to social information in respect of gender is a viable mechanism inducing gender-typical behaviour. However, these mechanisms do not appear to be altered in girls with CAH. Even though their gender role behaviour is more masculine than unaffected girls, CAH girls respond to modelling and gender labels in a female-typical fashion. The data from this study would argue against social mechanisms being a route through which CAH girls' play behaviour is masculinised, and suggest that social mechanisms may act independently of prenatal androgens. The findings are discussed in relation to evidence supporting a role for prenatal androgens influencing gender-typed behaviour. Findings are also discussed in relation to methodological factors which may have precluded any detection of an effect of prenatal androgens.

8.2 INTRODUCTION

Gender role development is the process by which children acquire behaviours, attitudes, and interests, defined as being appropriate for their own sex (Perry & Bussey, 1983; Bussey & Bandura, 1984). Sex differences in this domain are apparent at a very early age. From as early as 18 months, girls choose to play with feminine toys and boys choose to play with masculine toys. For example, infant boys prefer robots (Jacklin, Maccoby, & Dick, 1973) and infant girls prefer stuffed animals (Bronson, 1971), and the sex differences extend throughout childhood development. By the end of the pre-school years, boys prefer to play with motor vehicles, balls, blocks, and construction toys, whilst girls prefer play with dolls, kitchen activities, make-up and hair accessory sets, and sewing (Serbin & Connor, 1979; Caldera, Huston & O'Brien, 1989).

It is suggested that sex differences in gender–role behaviour arise from a variety of sex differentiated socialisation practices, in particular, imitation and modelling of the behaviour of same-sex others, reinforcement of sex-appropriate behaviours, discouragement of sex-inappropriate behaviours, and gender labelling of previously neutral stimuli (Bandura, 1977; Perry & Bussey, 1979; Masters, Ford, Arend, Grotevant & Clark, 1979; Block, 1983; Carter, 1987). These are all processes that play an active role in shaping the development of gender-typed behaviours, attitudes, and interests in children. The evidence regarding these practices reveal that girls and boys grow up in psychological learning contexts that are gender differentiated (see Carter, 1987; Ruble & Martin, 1998).

Sex differences in gender role behaviour may also result from the influence of the early hormone environment. Prenatal androgens have been suggested to play an important role in the development of gender-typical behaviour (see Collaer & Hines, 1995). In particular, high levels of androgens present during critical periods of prenatal and neonatal development are thought to produce more masculine-typical behaviour in various domains. These include childhood activities, toy choice and playmate choice, (Ehrhardt, et al, 1968; Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992, Hines & Kaufmann, 1994; Berenbaum & Snyder, 1995; but see also Collaer & Hines, 1995 for review). Studies of girls with congenital adrenal hyperplasia (CAH), who have been exposed to high levels of prenatal androgens, support this (Berenbaum & Hines, 1992; Hines & Kaufman, 1994, Berenbaum & Snyder, 1995). CAH girls are more masculinised than unaffected girls in certain childhood behaviours, and the differences observed are generally considered to be a consequence of the high levels of circulating androgens experienced during critical periods of prenatal development, before detection of CAH.

The masculinizing effects of CAH on gender role behaviour have been demonstrated using different modes of assessment. Early studies used interview methods to assess play behaviour in children with CAH. For example, Ehrhardt, et al (1968) interviewed CAH girls and their mothers and found that CAH girls preferred boys toys to dolls, preferred boys clothes to girls clothes and considered themselves to be tomboys. Baker and Ehrhardt (1974) replicated these results in another study using interview techniques, where it was found that CAH girls showed more interest in boys' toys than girls' toys. A later study by Berenbaum and Hines (1992), using more objective measures (observation of overt behaviour), corroborated these findings. They found that CAH girls spent more time playing with masculine toys than unaffected same-sex relatives and spent less time playing with feminine toys. CAH boys, however, did not differ from unaffected boys in masculine or feminine play. Further, Berenbaum and Snyder (1995) examined playmate preferences and gender-typed activities in CAH children and their relative controls using direct observation, and found that CAH girls preferred masculine-typical boys toys and activities over feminine-typical toys and activities compared to same-sex relatives. They also preferred boys as playmates more than relative control girls did. Hines and Kaufmann (1994) observed rough and tumble play in girls and boys with CAH and their relatives. As expected, they found that unaffected boys and girls differed on this dimension. However, contrary to expectation, CAH girls did not differ from unaffected girls. One explanation given for their findings was that the testing situation may not have allowed the detection of an effect in CAH girls even if one existed. Girls ordinarily do not engage in rough and tumble play and boys only engage in this kind of play with other boys. Hence, if CAH girls did not have a willing partner, then even if they did want to play in a rough and tumble manner, lack of a partner would prevent this. Moreover, their study also found that boys with CAH showed reduced rough and tumble play compared to unaffected boys.

Even though girls with CAH are surgically feminised to correct the masculinisation of their genitalia, have normalised adrenal output and are raised as girls, in some studies they have been found to have a female gender identity (Hurtig & Rosenthal, 1987; Dittmann, Kappes, Kappes, Borger, Stegner, 1990; Berenbaum & Snyder, 1995). However, others have reported that they are less likely than normal females to have a secure female gender identity (Zucker, Bradley, Oliver, Hood, Blake, & Fleming, 1992; Meyer-Bahlburg et al., 1996), and they show masculinisation in their toy play and toy choice (Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992), childhood activities, and peer preferences. The empirical evidence for masculinised behaviour in girls with CAH, argues for a role for the prenatal androgen environment as a plausible mechanism through which these sexually differentiated behaviours are influenced.

With regard to the influence of social mechanisms on gender role development, it is reasonable to speculate that these too may be altered in girls with CAH. This study is the first to directly examine the possibility that prenatal androgens influence social mechanisms thought to guide children's gender-role development.

Both modelling and gender labelling are sources of social information considered to be important determinants and guides of children's gender-role development. It has been demonstrated that similarity between a model and an observer increases the likelihood that the model's behaviour will be imitated (e.g., Bandura, 1969; Mischel, 1970; Perry & Bussey, 1979; Bussey & Bandura, 1984; Fane, Blair & Hines, 2002, submitted for publication). It has also been demonstrated that the gender labels "for boys" and "for girls", assigned to previously neutral stimuli, have positive and negative effects, as a function of a child's sex. That is, when an activity or object is perceived as sex appropriate or sex inappropriate it has a direct influence on children's subsequent behaviour, having been associated with social approval or disapproval in the past (Masters et al., 1979). Thus both modelling and gender labelling can confirm whether an activity or preference is perceived as being sex-appropriate or sex-inappropriate and influence children's subsequent gender-typical responses as a consequence.

Early gender labeling studies have found evidence for an effect of gender label on subsequent behaviour. For example, Montemayor (1974) found that the performance of 6-8 year old children on a game was higher when the gender label attached to the game was sex-appropriate and lower when the gender label attached was gender-inappropriate. Moreover, Stein, Pohly and Mueller (1971) reported that the gender label assigned to paper and pencil tests determined which test was chosen. Furthermore, for boys in the study, time spent on the task was influenced by the perceived gender appropriateness of the task.

Masters et al (1979) investigated both modelling and gender labelling of gender-neutral toys in 4 and 5 year old children. They found that the gender label verbally assigned to neutral toys was a more powerful determinant of children's subsequent play behaviour and toy choice than modelling was. The authors argued that the differential impact of the two information sources is explicable. That is in the modelling situation, children were aware that a single model is not necessarily representative of the behaviour of a particular sex, but that in the gender-labelling situation, assigning a gender label to a neutral stimulus is unequivocal, being clearly categorised by gender.

Much of the research in this domain, however, has been carried out on the influence social modelling in gender role development. Social learning theorists (Bandura, 1977, Mischel, 1970) emphasised the role of observational learning and modelling processes, with the acquisition of gender-typical behaviour being a product of observing and imitating behaviours of adults, particularly the same-sex parent. However, modelling as a process by which children acquire gender-typed behaviour came under attack in the 1970s. Reviews by Maccoby & Jacklin (1974) and Barklay, Ullman, Otto & Brecht (1977) concluded that boys and girls were not more likely to imitate models of the same sex. Thus same-sex imitation came to be viewed as unimportant for gender role development.

Perry & Bussey (1979) argued that this conclusion was premature and that the modelling of gender-typical behaviour was a viable mechanism by which children acquire a behavioural repertoire that is appropriate to their own sex. These authors suggested that the previous research on same-sex imitation was inappropriate, contending that in a typical study children are only exposed to a single male or female model which was not a sufficient guide for their own behavior. They posited that it was necessary to reformulate how modelling contributes to gender role development, suggesting that children determine what behaviors are appropriate by observing multiple male and female models. Their research confirmed this, demonstrating that children discern what behaviors are appropriate for females and males by observing the behaviors of multiple models. Children then imitate the behaviors of same-sex models (Perry & Bussey, 1979; Bussey & Bandura, 1984, Fane et al, 2002, submitted for publication). They also found that the more frequently a same-sex model was observed making an item choice, the greater the imitation of that behavior. Thus, the mere knowledge that same-sex adult models make certain choices, different from those of the other sex, exerts an influence on children's own choices and is instrumental in shaping gender-appropriate behavior (Maccoby, 1999).

Social Learning theorists would support this view that multiple models maximize the probability of same-sex imitation, arguing that collectively they are less likely to be seen as atypical or out of character, and are more likely to be thought of as behaving in a desirable fashion (e.g., Liss, 1979).

Early studies investigating modelling and subsequent imitative behaviour, examined the role of same-sex adults as constituting the primary models for influencing gender role development (Maccoby, 1990). However, children also imitate many other people, including non-family adults and other children (Hinde, Easton, Meller & Tamplin 1983, Liss, 1979, Perry & Bussey, 1979). For example, peers play an important role in the process of learning gender roles (Carter & McClosky 1983-84; Shell & Eisenberg, 1990; Harris, 1995). Studies have reported that children serve as significant socialization agents for one another with same-sex peers rewarding gender- appropriate behaviors more than gender-inappropriate behaviors (e.g., Lamb & Roopnarine, 1979). Further, according to Hinde et al (1983) children differ in the extent to which they direct their social behavior to adults versus peers. They found that 3-4 year old boys were oriented more towards their peers than girls, while girls tended to interact more with adults than did boys. Thus, gender role development, as Katz & Boswell (1985) argue, may not follow a parallel course for boys and girls. That is, there may be differences in relation to interactions with adults and peers, with boys attending more to peers.

More recently, Harris (1995) has also stressed the importance of children's peer groups, arguing that the major influence in children's gender role development is the peer group. She challenged the notions of 'parent-centered influence', arguing that children greatly influence the behavior of other children, because peers have a much greater effect on behavior than parents. Katz and Boswell, (1985) also argue that parents are not necessarily the most significant source of influence throughout childhood. Thus, it might be argued that children would be more likely to model the behaviour of same-sex peers than same-sex adults.

This chapter describes two protocols, carried out to assess mechanisms influencing gender-typed behaviour following the manipulation of social information. The first protocol, replicates, in part, the modelling paradigm used by Perry & Bussey (1983), modified by Fane et al, (2002, submitted for publication) (see Appendix 12), to include peer as well as adult models. Children observe multiple male and female adult and peer models stating preferences for gender-neutral items. Children are subsequently asked which items they prefer. The second protocol replicates the gender labelling aspect of Masters et als (1979) study. Children are shown four neutral toys and learn which two are masculine and which two are feminine. Following this, the first toy approached in a free play session is noted, time spent interacting with the toys, and toy preferences are recorded. Since children traditionally have gender-typed toy preferences and activities, the use of gender-neutral stimuli allowed for the assessment of the role of the model and gender-label in relation to gender-typical behaviour without the influence of past gender-typing associations.

The primary goal of the present study is to investigate the role of prenatal androgens on social mechanisms thought to influence gender-role behaviour in girls with CAH. The behaviour of CAH girls is of particular relevance because prior studies have revealed masculine-typical patterns of childhood play behaviour (Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Hines & Kaufman, 1994, Berenbaum & Snyder, 1995). Thus it might be expected that the early masculine hormone environment to which they have been exposed, predisposes them to follow patterns of responding more similar to that of healthy boys than to that of healthy girls. A further goal is to attempt to replicate past findings reporting sex differences in both imitative behaviour, following exposure to multiple modelling sequences, and interactions with previously neutral toys assigned a gender label.

8.3 METHOD

8.3.1 Participants

Ninety-four children, 50 CAH children (27 girls and 23 boys) and 44 unaffected relatives (22 girls and 22 boys), aged 3-11 years, took part. CAH and unaffected children were the same as those reported on in Chapter 4. Children with CAH were recruited through Paediatric Endocrine Consultants at Great Ormond Street Hospital in London and via a CAH Support Group in the UK. Forty nine patients were 21-hydroxylase (21-0H) and salt-losing and one was 21-0H and non salt losing (simple virilising). Unaffected siblings and cousins (40 siblings and 4 cousins) served as control participants. Cousins were asked to participate when siblings were not available. Table 8.1 sets out the frequency of patients with sibling or cousin control participants.

Table 8.1. Frequency of CAH patients with one or more sibling and/or cousin control.

	One unaffected sister	Two unaffected sisters	One unaffected brother	Two unaffected brothers	One Unaffected female cousin	Two Unaffected female cousins	No relative controls
CAH girls	6	0	6	1	3	1	13
CAH Boys	7	0	9	0	1	0	8

Relatives represent a good comparison group when random assignment to groups is not possible, because they are similar to patients on factors such as genetic make-up, socioeconomic status, and family background (Reinsich & Gandelman, 1978). Although they cannot be matched individually on age they generally do match on this. Unaffected relative controls were also recruited from a similar study examining some of the same behaviours and traits in adolescents and adults with CAH (see Table 8.2).

Table 8.2. Frequency of unaffected boys and girls with a CAH brother or sister participating in adolescent and adult study.

	CAH sister	CAH brother
Unaffected girls with CAH brother and/or sister in adult study	1	3
Unaffected boys with CAH brother and/or sister in adult study	2	1

All children were white Caucasian. Parents provided written consent for children's participation. In this sample, patient and control groups were comparable in age at the time of testing (see Table 8.3).

It was not possible to calculate participation rate in the study. Because of ethical considerations, no information from Great Ormond Street was given when families did not consent to participate. With respect to recruitment from the CAH Support Group, all families were contacted but not all of the families had CAH children in the 3-11 year old age range. Further, because of confidentiality, it was not possible to find out how many families replied following the invitation to participate.

Table 8.3. Age of CAH and unaffected boys and girls at time of testing

	CAH girls		**Unaffected Girls**		**CAH Boys**		**Unaffected Boys**	
	M	SD	M	SD	M	SD	M	SD
Mean age	7.6	2.48	7.0	2.40	7.2	2.68	7.5	2.13

8.3.2 Protocol 1 - Modelling

8.3.2.1 Predictions

Two specific hypotheses were tested. The first hypothesis is based on the social learning theory of gender role development (Bandura & Walters, 1963; Mischel, 1966) stating that unaffected boys and girls will be more inclined to imitate the modelling behaviour displayed by same-sex models than other-sex models. The second hypothesis is based on a hormonal explanation for sex differences in imitative behaviour, stating that responses to modelling in girls with CAH will be more masculine compared to the responses of unaffected girls, and more similar to those predicted for unaffected boys. Specific predictions regarding boys with CAH were not made however, their performance was compared to unaffected boys in order to assess whether changes in imitative behaviour would be observed.

8.3.2.2 Stimuli

Videotapes of males and females selecting 16 pairs of gender-neutral items served as the primary stimuli. Items for the 16 pairs were selected based on independent ratings (made by 50 undergraduate students) of 66 potential items (some expected to be gender-typed and some expected to be gender-neutral). Items were rated on a Likert scale of 1 to 7, where (1= extremely feminine and 7 = extremely masculine). All gender-neutral items used in the modelling sequences received average ratings, between 3 and 5 (the gender-neutral range).

8 females (4 women and 4 girls) and 8 males (4 men and 4 boys) acted as models. The adult models were all in their early twenties, and the child models were all 10 years old. All models were Caucasian, in order to control for any potential effects of ethnicity on children's imitative behaviour. The16 pairs of gender-neutral items were gender stereotyped by having all the female models choose the same item from the pair, and all the males choose the other item from the pair. Item pairs were always of the same category (e.g., a plastic apple and a plastic banana, a plastic horse and a plastic cow). (See Appendix 9 for a list of item pairs).

Models (adults and children) were filmed individually approaching each of the item pairs and were asked which item they liked best. They responded both verbally ("I like the .... best") and by pointing to their preferred item. Order of models making choices was counterbalanced by sex. Different counterbalanced sequences were shown in a fixed random order. Four different sequences were shown, with each of the 8 models performing each sequence. In the first sequence, four females and then four males were seen choosing the items. In the second sequence, two males, followed by two females, then two males and then two females were seen choosing the items. In the third sequence, three males and one female, followed by one male and three females, were seen choosing the items. The final sequence showed one female and then one male (repeated four times) each choosing one of the item pairs. Two videos were made, each video showed half the males and half the females choosing first, in a fixed random sequence. However, the first 4 sequences showed four females and four males each chose items. The rationale for this was that children would be given a chance to learn that all the females had a preference for the same item and all the males had a preference for the opposite item. For each of the videos half of the sequences showed child models and half showed adult models. Females endorsing items in video 1 were shown endorsing the other items in video 2. Children were randomly assigned to view either video 1 or video 2. Each video was 11 minutes long.

8.3.2.3 Procedure

Children were shown one of the videos individually in the testing room. Immediately following viewing, imitative performance was measured by presenting coloured photographs of the 16 item pairs (in the same order as they had been viewed on the screen) to the children who were asked to indicate which one from each pair they preferred. Scores for imitation of male adult and peer models combined could range from 0 (no male adult and peer imitation) to 16 (100% male adult and peer imitation), and from 0 to 8 for imitation of male adults and peers considered separately.

In order to assess memory for items chosen by models in the video, a test of recall was administered following the test of imitative performance. Children were presented with the same photographs of the item pairs and asked who they remembered seeing choose each item ("who did you see choose the........?" "Was it the man, the lady, the boy or the girl?").

8.4.4 Results

Social Modelling – Analysis of recall

Because age of the models (adults, peers) choosing items was treated as a within subjects factor, correct recall of item choices made by both male and female adult and peer models was initially examined in order to see if differences would be evident in children's recall. This would enable determination of i) a relation between recall of item choices and imitation, and, ii) differences in recall of same- or other-sex models.

Age correlated with correct recall of item choices made by both male peer and adult models , r = 0.454. p < .001 and r = .344, p = .001 respectively, and female peer and adult models, r = .509, P < .001 and r = .410, p < .001, respectively. Because of the significant correlations age was entered as a covariate in this analysis.

A four-way analysis of variance (ANCOVA), sex (boys, girls) and diagnosis (CAH, unaffected relatives) as between factors and age of model (adult, peer) and sex of model (male, female) as within factors and age as a covariate was carried out on the recall data to determine differences in memory for item choices made by female and male adult and peer models.

Main effects of age of models making item choices, F (1, 89) = 12.18, p = .001, and sex of models making item choices, F (1, 89) = 9.45, p = .003, were significant. Item choices made by male peers were better recalled than adult male models and more item choices made by male models were correctly recalled than item choices made by female models. Main effects of sex, F (1, 89) = 0.25, p = .62, and diagnosis, F (1, 89)

= 3.34, p = .07 were not significant, and none of the two-, three-, or four-way interactions were significant either.

Social Modelling – Male adult and male peer imitative performance

Imitative performance was measured by examining the modelling of male adult and peer models. The reasoning for this stems from the same-sex imitation hypothesis, that children's imitation of male responses should be highest for boys and lowest for girls. This follows the prediction that endorsement of an item choice is a function of sex of model choosing the item, and as girls are predicted to imitate the behaviour of female models, low responses to male modelling should reflect greater same-sex imitation. Further, because of the hypotheses regarding exposure to prenatal androgens and childhood behaviour, it was anticipated that the imitative behaviour of girls with CAH would be more male-typical compared to unaffected female relatives. Analysis of male adult and peer models allowed assessment of this.

Social Modelling – Correlations of age and imitation

Correlations of age and imitation of male adult and peer models were examined. Age did not correlate with either imitation of male adult models, r = -0.09, p = .38, or with imitation of male peer models, r = 0.130, r = .21.

Correlations of imitation and recall

Correlations for male imitation and recall of item choices made by male and female models were also calculated. Imitation of choices made by male models did not correlate significantly with recall of item choices made by male models. r = 0.084, p = .42 or female models, r = -0.012, p = .91.

Social Modelling - Analysis

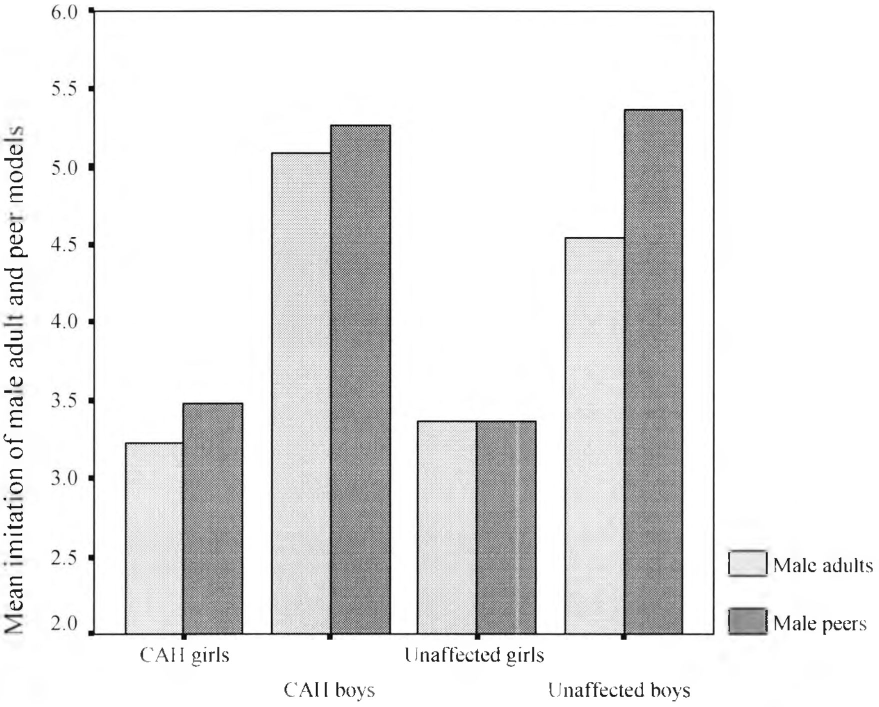
A three-way ANOVA, with sex (boys, girls) and diagnosis (CAH, unaffected relatives) as between factors and age of male model (adult, peer) as the within factor was carried out on the data to determine group differences. In addition to the ANOVA, four planned comparisons were carried out (unaffected girls versus unaffected boys, CAH girls versus unaffected girls, CAH girls versus unaffected boys and CAH males versus unaffected males). These comparisons allowed testing of the specific hypotheses relating to CAH, and an assessment of sex differences in social modelling.

Table 8.4 Social Modelling. Imitation of male adults and peers as a function of CAH and control comparison groups.

	CAH girls (N=27)		**Unaffected girls (N=22)**		**CAH boys (N=23)**		**Unaffected boys (N=22)**	
	M	SD	M	SD	M	SD	M	SD
Male adult imitation	3.22	2.03	3.36	1.80	5.10	2.13	4.55	2.00
Male peer imitation	3.48	2.20	3.36	1.50	5.26	1.91	5.36	1.80

There was a significant main effect of sex, F (1, 90) = 23.32, p < .001. Main effects of diagnosis, F (1, 90) = 0.90, p = .77, and age of male model, F (1, 90) = 2.71, p = .10 were not significant, and no two- or three way interactions reached significance either (sex by diagnosis, F (1, 90) = 0.11, p = .74; imitation by sex, F (1, 90) = 0.93; p = .34, imitation by diagnosis; F (1, 90) = 0.30, p = .61; imitation by sex and diagnosis, F (1, 90) = 0.90, p = .1.41, p = .24). The planned comparisons revealed that unaffected boys imitated male adult and peer models significantly more than unaffected girls', F (1, 42) = 12.24, p = .001, but boys and girls together did not differ in their imitation of adult versus peer models, F (1, 40) = 2.10, p = .15. CAH girls and unaffected girls did not differ in their imitation of male adult and peer models, F (1, 47) = 0.01, p = .98 and together did not imitate adult or peer models differently, F (1, 47) = 0.28, p = .60. CAH girls, however, imitated male adult and peer models significantly less than unaffected boys, F (1, 47) = 9.80, p = .003, However, both CAH girls and unaffected boys together imitated male peer models significantly more than male adult models, F (1, 47) = 4.02, p = .05. CAH and unaffected boys did not differ in their imitation of male adult versus peer models, F (1, 43) = 0.20, p = .67, and together did not imitate male adult or peer models differentially, F (1, 43) = 2.86, p = .10.

Fig.8.1. Male adult and peer imitation, by CAH and control comparison groups.



Correlations of social modelling and childhood gender role behaviour (PSAI)

Correlations between imitative behaviour of male adult and male peer models and PSAI scores were examined in boys and girls separately. For girls, no correlation was observed for imitation of male adult or male peer models with PSAI scores, r = 0.1484, p = .31, and r = 0.1751, p = .23, respectively. Similarly, for boys, imitation of male adult and male peer models did not correlate with PSAI scores, r = 0.1709, p = .267, and r = 0.2860, p = .06, respectively. However, it was noted that the correlation of male peer models and PSAI scores approached significance.

8.3.3 Protocol 2 – Gender Labelling

8.3.3.1 Predictions

Two specific hypotheses were tested. 1) The first hypothesis is based on social learning, stating that sex appropriateness of the gender label will elicit gender typical behaviour. 2) The second hypothesis relates to a hormonal explanation for differences in gender typical behaviour and toy preferences. Specifically it states that CAH girls' gender-labelling behaviour will be more male-typical than unaffected girls' and more similar to the behaviour of unaffected boys. No predictions were made for boys with CAH; however their behaviour was compared to unaffected boys.

8.3.3.2 Stimuli and Procedure

Four gender-neutral toys were used for the gender labelling task, two round balloons: one gold, one metallic purple, and two xylophones: one with a green base and coloured keys, one with a yellow base and coloured keys.

The toys were laid out side by side in the middle of the testing room. The order of layout was counterbalanced so that for half the testing sessions, the balloons were laid out on the right and the xylophones were on the left and vice versa.

Children were shown the four toys and were told that some of the toys were for boys to play with and some were for girls to play with. The investigator further explained to each child that she did not know which toys were for boys and which were for girls, but that there were some cards with pictures of the toys to tell them which were for boys and which were for girls.

20 coloured cards, measuring 13centimetres by 21 centimetres were used for assigning a gender-label to each of the toys (the learning trials). Each card had a picture of a boy or a girl playing with either a purple balloon, a gold balloon, a green xylophone, or a yellow xylophone. Half of the children saw a girl with a purple balloon and a boy with a gold balloon, a girl with a green xylophone and a boy with a yellow xylophone. The remaining children saw a boy with a purple balloon and a girl with a gold balloon, a girl with a yellow xylophone and a boy with a green xylophone. The pictures of the boy and girl models in the cards were black and white, and the balloons and xylophones were coloured in the same colours as the actual items (see example in Appendix 10).

The investigator demonstrated the learning trials by sorting four of the gender-labelling cards (2 masculine and 2 feminine) into 2 respective gender piles. Following this, 16 sorting cards were placed in front of the children who were asked to sort each card into the 'boy pile' and the 'girl pile' so that they learned which toys were for boys to play with and which toys were for girls to play with. This was to ensure that they remembered the gender label assigned to each toy. The sorting cards were presented in a fixed random sequence, meeting the following criteria: (i) that no more than three consecutive cards were of the same-sex gender label; and, (ii) that the same toy did not appear more than three times in a row. Stand up drawings of a boy and a girl (30 x 9.5 centimetres) were used as markers for the boy and girl piles (see Appendix 10).

Following the learning trials, children were shown a picture of the yellow xylophone and green xylophone and asked which one was for boys to play with and which one was for girls to play with. They were then shown a picture of the gold and the purple balloon and asked the same question (See Appendix 11). All children successfully identified the gender label assigned to each of the toys.

The investigator then told the children that she was going to leave the room for about 3 minutes, and that while she was gone they could play with the toys. Children were observed from behind a one-way mirror and the first toy they approached and interacted with was recorded and the time they spent interacting with each of the toys was also recorded. The order of layout was counterbalanced so that for half of the time masculine-labelled toys were on the right and for half the time they were on the left of the pairs of toys.

At the end of the 3-minute free play session, the experimenter returned to the testing room and asked children the following questions, 1) which balloon they preferred to play with, 2) which xylophone they preferred to play with, 3) which balloon was for boys, 4) which balloon was for girls, 5) which xylophone was for boys, and, 6) which xylophone was for girls.

The dependent measures were, 1) toy preference, 2) first toy approached during free play and, 3) duration of time interacting with masculine- and feminine-labelled toys in free play. For duration of interaction with toys, percent data were used because of individual differences in total time in contact with the toys.

8.3.3.3 Results

Gender Labelling - Analysis

Correlations

Correlations for age and time spent with masculine gender-labelled toys age and feminine gender labelled toys, age and toy preferences and age and first toy approached were examined in boys and girls separately. For boys none of the outcome measures correlated with age: time spent with masculine labelled toys, r = 0.002, p = .99, time spent interacting with feminine labelled toys, r = 0.196, p = .19, first toy approached, r = -0.185, p = .22, toy preference, r = -0.107, p = .48. For girls, however, age correlated significantly and in a negative direction with time spent interacting with feminine-labelled toys, r = -0.266, p = .032 (one-tailed). None of the other outcome measures correlated with age: time spent with masculine labelled toys, r = 0.212, p = .14, first toy approached, r = -0.220, p = .13, toy preference, r = -0.060, p = .68.

A three-way ANOVA, with sex (boys, girls) and diagnosis (CAH, unaffected relatives) as between factors and time spent in free play with toys assigned a gender label (masculine, feminine) as the within factor, was carried out on the data to determine group differences. In addition to the ANOVA, four planned comparisons were carried out (unaffected girls versus unaffected boys, CAH girls versus unaffected girls, CAH girls versus unaffected boys and CAH males versus unaffected males). Time spent in free play with masculine and feminine labelled toys was a within subjects factor. These comparisons allowed the testing of specific hypotheses relating to CAH, and an assessment of sex differences in behaviour following the gender labelling of neutral toys.

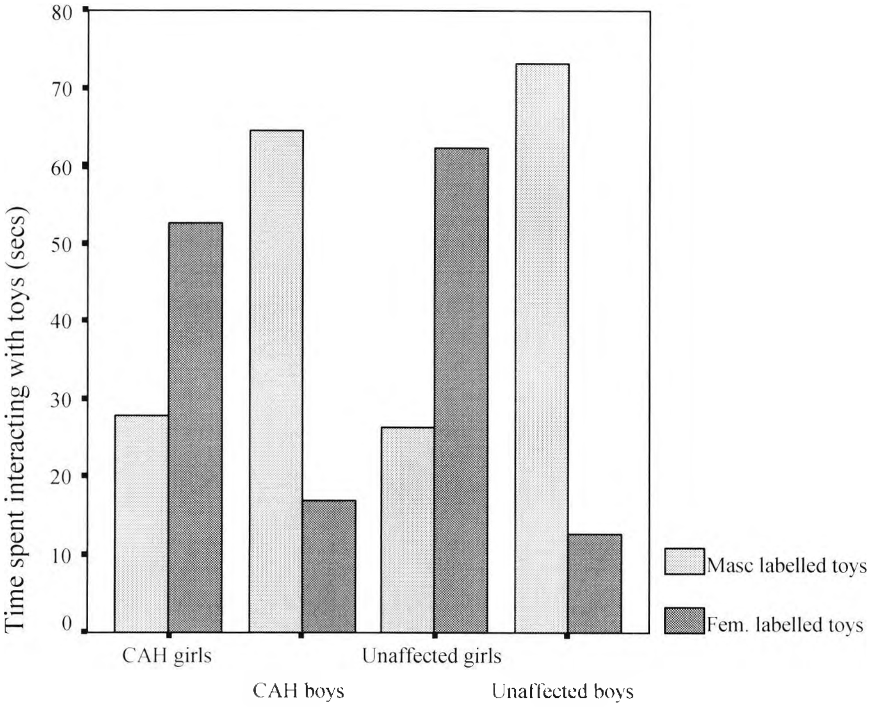
Masculine- and Feminine-labelled toys

Table 8.5 Gender Labelling. Percentage time (secs) spent interacting with masculine-and feminine- labelled toys in free play, by CAH and control comparison groups.

Group	**CAH girls (N=27)**		**Unaffected girls (N=22)**		**CAH boys (N=23)**		**Unaffected boys (N=22)**	
	M	SD	M	SD	M	SD	M	SD
Time (secs) spent interacting with masculine-labelled toys	28.10	30.05	26.00	28.42	64.34	46.52	73.30	43.11
Time (secs) spent interacting with feminine-labelled toys	52.45	35.45	62.70	32.22	17.13	26.42	12.57	20.30

Main effects of sex, F (1, 90) = 0.21, p = .89, diagnosis, F (1, 90) = 0.98, p = .77, and free play with masculine and feminine labelled toys, F (1, 90) = 3.51, p = .06 were not significant. However a two-way interaction between sex and time spent in free play with masculine and feminine toys was significant, F (1, 90) = 45.86, p <.001. No other two- or three-way interactions reached significance, (sex and diagnosis, F (1, 90) = 0.90, p = .77; diagnosis and time spent in free play with masculine and feminine toys, $F (1, 90) = 0.01$; $p = .96$; sex, diagnosis and time spent in free play with masculine and feminine toys, $F (1, 90) = 1.07$, $p = .30$). Planned comparisons revealed that unaffected boys spent significantly more time interacting with masculine-gender labelled toys than unaffected girls, $F (1, 42) = 18.50$, $p < .001$ and unaffected girls spent more time interacting with feminine-gender labelled toys than unaffected boys, $F (1, 42) = 38.13$, $p < .001$. Both CAH girls and unaffected girls spent significantly more time interacting with toys assigned a feminine-gender label than with toys assigned a masculine-gender label, $F (1, 46) = 7.85$, $p = .007$. CAH girls spent significantly more time interacting with feminine-gender labelled toys than unaffected boys, $F (1, 47) = 21.94$, $p < .001$ and unaffected boys spent significantly more time interacting with masculine-gender labelled toys than CAH girls, $F (1, 47) = 18.65$, $p < .001$. Both CAH and unaffected boys interacted for significantly longer with toys assigned a masculine-gender label than with toys assigned a feminine-gender label, $F (1, 42) = 5.30$, $p < .03$.

Fig 8.2 Gender Labelling. Percentage time children interacted with masculine- and feminine-labelled toys, by CAH and control comparison groups.



Children's preference for same-sex labelled toys

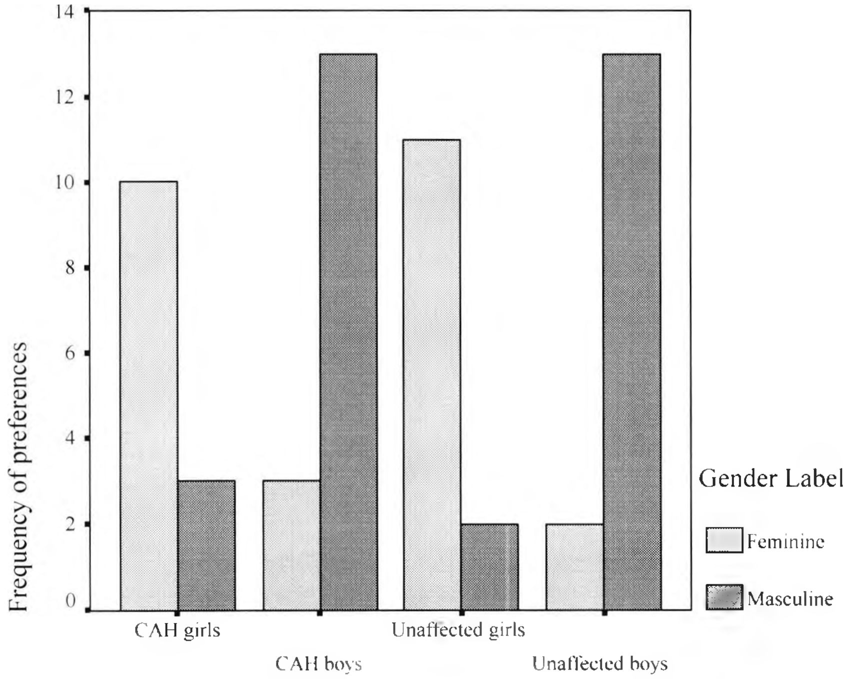
Table 8.6 Gender Labelling. Number of times masculine and feminine labelled toys were approached first, and preference for same- and other-gender labelled toys.

	First toy approached			**Toy Preference**		
Group	Masculine-gender labelled	Feminine-gender labelled	One of each	Masculine-gender labelled	Feminine-gender labelled	One of each
CAH girls	9	17	1	4	10	13
Unaffected girls	5	17	0	2	11	9
CAH boys	15	5	3	13	3	7
Unaffected boys	17	4	1	13	2	7

In order to assess group differences in preferences for either same-gender labelled toys, other-gender labelled toys or preferences for one of each, children were asked which of the two balloons and which of the two xylophones they liked best following the free play session.

Because the data were categorical, a four-way frequency model was performed to develop a hierarchical loglinear model of preference for both same-gender labelled toys, both other-gender labelled toys, and one of each gender labelled toys, by sex and diagnosis. Backwards deletion produced a model that included one first-order (main) effect. A first order effect of same-gender preference was observed, such that 50% of all children preferred same-gender labelled toys to other-gender labelled toys (11.7%) or to one of each (38.3%) $\chi^2(2) = 25.10$, $p < .001$ (see Table 8.4). No other first (main effects) or second order (interaction) effects were significant. The results of this analysis add further support to the possibility that diagnosis of CAH does not appear to be associated with alterations in preferences for same-gender labelled toys. Irrespective of exposure to excessive levels of prenatal androgens, children preferred same-gender labelled toys to other-gender labelled toys or to one of each.

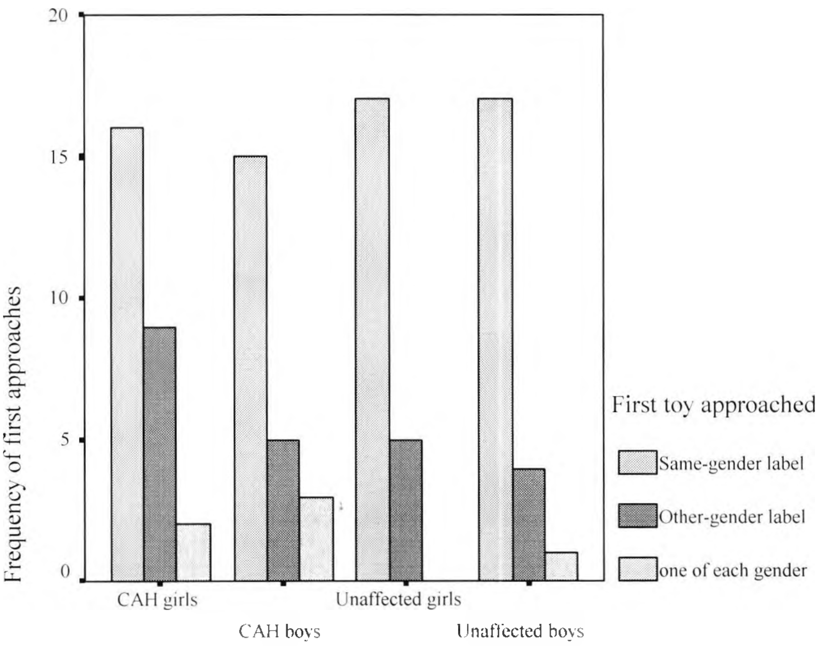
Fig. 8.3 Frequency of preferences for masculine- and feminine-labelled neutral toys by CAH and control comparison groups



Gender Label assigned to first toy approached

A second three-way heirarchical loglinear model was performed on the data to develop a model of gender label of toy first approached by sex and diagnosis. Backwards deletion produced a model that included one first-order (main) effect for gender label of toy approached first. Across all the children, same-gender labelled toys were approached first significantly more often (69%) than other-sex labelled toys (6.4%) or one of each (24.5%), $\chi^2(1) = 60.80$, $p < .001$ (see Table 8.4). The results of the analysis of gender label assigned to the first toy approached do not appear to be linked to diagnosis of CAH. Irrespective of exposure to prenatal androgens, boys and girls approached same-gender labelled toys first, more often than they approached other-gender labelled toys first or one of each.

Fig. 8.4 Gender label of first toy approached by CAH and control comparison control groups



Correlations of PSAI scores and Gender labelling measures

Correlations were examined between gender role behaviour (measured using the PSAI), and time spent with masculine- and feminine-labelled toys, and with toy preference and first toy approached. These were examined separately for boys and girls. For boys, a significant correlation in a positive direction was observed for PSAI and first toy approached in free play, r = -0.366, p = .013. Higher (more masculine) scores on the PSAI were associated with preference for same-gender-labelled toys. No other correlations between PSAI and gender-labelling measures were observed. For time spent with masculine-labelled toys, r = -0.086, p = .57, feminine-labelled toys, r = 0.045, p = .77, or with toy preference, r = -0.089, p = .56. For girls, PSAI scores did not correlate with any of the gender-labelling outcome measures. For time spent with masculine-labelled toys, r = 0.024, p = 87, with feminine-labelled toys, r = -

0.058, p = .69, toy preference, r = 0.156, p = .28, or first toy approached in free play, r = 0.012, p = 93.

Correlations of Modelling and Gender labelling measures

Correlations between gender labelling measures and male adult and imitation were also examined in boys and girls separately. For boys, time spent interacting with masculine-labelled toys did not correlate with male adult imitation, r = 0.024, p = .87, or with male peer imitation, r = 0.237, p = 12. Time spent interacting with feminine-labelled toys also did not correlate with male adult imitation, r = -0.067, p = .661, or with male peer imitation, r = -0.221, p = 15. Toy preference correlated significantly in a negative direction with male adult imitation, r = -0.291, p = .05, and with male peer imitation, r = -0.451, p = .002 (indicating that increased male imitation was associated with decreased preference for feminine-labelled toys). However, first toy approached in free play did not correlate with either male adult or peer imitation, r = -0.220, p = .15, r = -0.216, p = .15. For girls, time spent interacting with masculine-labelled toys did not correlate with male adult imitation, r = 0.137, p = .35, but correlated significantly in a positive direction with male peer imitation, r = 0.255, p < .03. Time spent interacting with feminine- labelled toys did not correlate with male adult imitation, r = -0.133, p = .36, but correlated significantly in a negative direction for male peer imitation, r = -0.314, p < .03 (decreased play with feminine-labelled toys was associated with increased male peer imitation). Toy preference and first toy approached in free play did not correlate with male adult or peer imitation, r = 0.66, p = .65; r = -0.005, p = .97; r = 0.044, p = .76 and r = -0.063, p = .66, respectively.

8.6 DISCUSSION

This study examined the relationship between prenatal androgens and social mechanisms (modelling and gender-labelling) thought to be important determinants of children's gender role development. To date, no other studies have investigated whether girls with CAH might respond differentially to social mechanisms because of exposure to excessive levels of androgens prenatally. However, given that prior studies have revealed that girls with CAH show increased masculine toy play and activities and playmate preferences (Ehrhardt & Baker, 1974; Berenbaum & Hines, 1992; Hines & Kaufman, 1994), it might be expected that they would be influenced in a similar manner to that of unaffected boys.

Like prior studies (e.g., Perry & Bussey, 1979; Masters et al, 1979; Bussey & Bandura, 1984), it was demonstrated that both modelling and gender-labelling are viable mechanisms through which children discern behaviours appropriate for their own sex, and in both situations. Unaffected boys and girls showed a tendency to imitate the behaviour of same-sex models. They also spent more time interacting with, showed preferences for and approached first, same-gender labelled toys compared to other-gender labelled toys.

It was hypothesized that CAH girls would respond to social information in a more masculine-typical fashion. This hypothesis was not confirmed. CAH girls, like unaffected female relatives, imitated the behaviour of same-sex models more than other-sex models. They also spent more time with, and stated preferences for, toys assigned a feminine-gender label compared to toys assigned a masculine-gender label, just like other girls. Further, like other girls, their behaviour differed from unaffected male relatives in these respects.

The outcomes were not consistent with predictions. The results suggest that social learning mechanisms such as modelling and gender-labelling act independently of androgen exposure. The sample of CAH girls participating in the study are masculinised in their gender role behaviour, results from the PSAI (see Chapter 4) clearly reflect this, and their gender atypical behaviour in this respect implicates the prenatal hormone environment. However, it would seem that masculinisation of gender role behaviour in girls with CAH is not caused by alterations in responses to these social mechanisms.

One possible explanation for the findings might be that because through modelling and gender-labelling children discern what behaviours are appropriate for their own sex, then CAH girls are likewise, discerning behaviours appropriate for their own sex, and responding in accord with this, irrespective of their masculine-typical behaviour in other areas.

Another explanation is that CAH girls are conforming to social expectations. This is speculative, but if they know that their behaviour is different to other girls then exposure to a social situation in which other females are all performing in the same manner, could impose pressure to conform in a gender consistent fashion, irrespective of how they really might feel. Thus CAH girls may be adjusting their behaviour to fit this particular setting. Because the study did not address children's evaluative reactions in regard to the actions of the models, it is not possible to explore this further. However, there are differences in the way that children process information on the basis of gender, which suggests that there may be a cognitive component involved (Martin & Halverson, 1981). Thus, it may be worthwhile for future investigations to examine CAH girls' evaluative reactions towards the collective behaviour of same- and other-sex models in order to ascertain whether this affects their subsequent behaviour and whether they feel differently to healthy girls.

Parental attitudes and socialisation practices were also not assessed in this study. Thus it is not known whether CAH girls are socialised in a female-typical fashion and whether this has influenced the pattern of responding observed. However, other studies of CAH report that parents do not treat their CAH daughters in a more masculine fashion (Ehrhardt & Baker, 1974, Resnick, 1982; Berenbaum & Hines, 1992).

Alternatively, some studies have reported that CAH girls have a female gender identity (Perlman, 1973; Ehrhardt & Baker, 1974; McGuire, Ryan & Omenn, 1975; Berenbaum & Snyder, 1995). If this is the case for CAH girls in this sample, then it is possible that the female-typical behaviour observed following the modelling situation arises from identification with other females. Gender identity seems not to be as vulnerable to the influences of masculinizing hormones in the same way that childhood play and activities are, and this is consistent with the findings from this study. Further, Berenbaum & Snyder (1995) found that the majority of CAH girls in their study preferred other girls as playmates, lending further support to the idea that imitative behaviour might be explained by a desire to identify with female models.

The data indicate no changes in gender-typed behaviour in boys with CAH following exposure to social learning mechanisms. Consistent with other findings (Ehrhardt & Baker, 1974; McGuire et al, 1975; Berenbaum & Snyder, 1995), boys with CAH show male-typical patterns of behavioural responding. This is not unexpected given that past research has generally not suggested behavioural demasculinisation. Moreover, boys with CAH are born physically unambiguous, and raised as boys, thus, it is unlikely that they would respond differently from unaffected male relatives to social learning mechanisms.

This study extends the CAH research literature by investigating another aspect of behaviour that might be influenced by androgens. There is some research which argues that the most significant factor accounting for the difference in behaviours that show sex differences between CAH females and female relative controls, is the effect of prenatal androgens (see Meyer-Bahlburg, 2001). However, this study adds another dimension to this proposition. That is, girls with CAH respond to social information in a female-typical fashion, suggesting that social factors are influential even when behaviour is masculinised. Thus it would seem that different behaviours could have different causes, and reflects the multidimensional nature of gender-typed behaviour.

An alternative explanation accounting for the findings is in relation to one particular methodological feature of the present study. Typically, studies have observed play with toys and toy preferences using toys that are unequivocally gender-typed, being clearly defined as either "for boys" or "for girls", and children will have been exposed to the gender features of these toys many times. Further, different toys elicit different behaviours. For example, many feminine-typical toys, such as dolls, engender caregiving behaviours, while many masculine-typical toys, such as trucks, foster more activity and higher mobility. In the gender labelling protocol, gender was imposed on both neutral toys - xylophones and balloons - which were the same in every respect except colour. The kind of behaviour generally elicited from each toy, is not gender-specific, and would not be expected to differ even after the attachment of a gender label. Typically notes are played on xylophones and balloons are batted in the air. On this basis, if the kind of actions performed on the toys does not differ by gender label, then it is possible that CAH girls chose to engage in play with feminine labelled toys because it felt more comfortable to conform in a gender typical way in the testing situation, and knowing that the same actions are elicited from the toys irrespective of gender label.

With regard to developmental trends, the data from this study suggest that the influence of both social mechanisms persists into later childhood. The fact that neither imitation nor gender labelling was associated with age, suggests that motivating forces guiding gender typed behaviour do not differ in their intensity in older children. Further, there were no group differences observed in the imitation of adult versus peer models. Thus it would seem that processes of imitation in this respect do not differ for boys or girls within this age group.

Results from this investigation indicate that social learning mechanisms influencing gender development are independent of the influences of androgens. Although hormones influence gender role behaviour, they do not influence responses to social information manipulating gender. However, in view of the fact that this is the first investigation to explore the contribution of hormones on this aspect of gender role development. it will be important to replicate these findings in other CAH patient populations.

CHAPTER NINE

CONCLUSIONS

This research has investigated the role of prenatal androgens in spatial cognition and social influences on gender role development. Research in non-human species has demonstrated that sexually differentiated behaviours are influenced by levels of hormones present during early development (Phoenix et al., 1959; Goy & McEwen, 1980). Further, studies of females with CAH who experience high levels of androgens during prenatal life were initially conducted to substantiate these findings in humans, and have largely done so. Behavioural studies in children and adults with CAH report that female patients differ from unaffected same-sex relatives on a number of dimensions. They have corroborated conclusions drawn from the earlier studies in non-human species, that androgens do influence human behavioural development. The behavioural differences that have been observed are generally considered to be a result of high levels of prenatal androgens.

Previous studies have also extended our understanding by defining aspects of behaviour that appear not to be altered as a consequence of androgens. For example, Hines & Kaufman (1994) did not find that rough and tumble play was masculinised in girls with CAH. Furthermore, studies of other behaviours are inconclusive. The outcomes with regard to visual-spatial ability have precluded definitive conclusions being drawn in respect of hormonal influences. Some studies have reported enhanced spatial abilities in females with CAH (Resnick et al., 1986, Hampson et al., 1998), while others have not found such an advantage (Ehrhardt & Baker, 1974; McGuire et al., 1975, Hines et al., 2002, in submission). Moreover, gender identity appears to be less firmly female, and several females with CAH have been reported to be at risk for symptoms of gender identity disorder (Zucker, 1996, Meyer-Bahlburg, 1996). In contrast, other studies have found that gender identity in females with CAH is not altered in a masculine direction (Ehrhardt & Baker, 1974; Berenbaum & Snyder, 1995). Thus, although it is likely that androgens influence gender identity it is unlikely that they determine it.

With respect to behavioural functioning in males with CAH, studies have reported few behavioural differences between males with CAH and unaffected males. The absence of differences reported is compatible with data from animal studies which have indicated relatively few differences in behaviour as a result of androgens (Diamond, Llacuna, & Wong, 1973; Baum & Schretlen, 1975).

This research was carried out to address further the relation between hormones and two aspects of behavioural development; spatial cognition and gender role behaviour. It was also conducted in order to extend the research literature by including an examination of social mechanisms influencing gender role development. No research to date has investigated the possibility that masculinising hormones influence social mechanisms in CAH. This may be due to assumptions made about biological effects being permanent and immune to environmental impact (see Ruble & Martin, 1998). Moreover, there is also the possibility that hormones might act by modifying these social mechanisms. That is, girls with CAH may exhibit more masculine-typical behaviour because they are less likely to respond to same-sex models or gender-labels.

Clearly, an evaluation of the social learning mechanisms involved in gender-typed behaviour cannot be derived from the testing of hypotheses in animal models because manipulation of gender-typed information is not possible. However, it has been reported that the social environment can modify the effects of hormones in some non-human species (Goy & Phoenix, 1971). The possibility that prenatal androgens could be linked to social mechanisms influencing gender development is appealing, and to date social-environmental factors are largely unexplored in CAH females. Thus, it is yet unknown whether social influences are altered because of their prenatal hormone history.

Firstly, reviewing sex differences found in the studies, the expected pattern of results were observed for gender role behaviour (chapter 4). Unaffected boys' PSAI scores reflected male-typical gender role behaviour, and unaffected girls' PSAI scores reflected female-typical gender role behaviour. Moreover, the effect size for the sex differences observed was large ($d = 4.0$). Results suggest that unaffected boys and girls in the study, like other children, are typical in their gender role behaviour (e.g., Golombok & Rust, 1993).

With regard to sex differences in spatial cognition (chapter 6), the performance of unaffected boys and girls did not differ on either mental rotations or spatial perception. Boys however, were faster at both mental rotations and spatial perception than girls. Sex differences in speed of responding suggest the possibility that there may be differences in strategies implemented to successfully carry out these tasks for boys and girls. However, given that this was only the case in the first half of the mental rotations task. the data suggest that practice effects also influence visual spatial functioning, at least for girls.

Factors such as speed of responding undoubtedly influence visual-spatial performance, and contribute to the sex differences in adults that have been reported in the literature (Goldstein, Haldane & Mitchell, 1990). Of particular interest is the observation by Maccoby and Jacklin (1974) that males tend to perform visual-spatial tasks quickly, whereas females work more slowly and carefully. Thus, females' slower performance on visual-spatial tasks could be a result of a number of factors, including lower levels of confidence with spatial concepts. However, if females work more slowly because of factors other than lower levels of ability, then speed of response is likely to underestimate their ability and contribute to the male advantage.

Thus, it could be argued that if one removes time limits, female performance would more closely resemble male performance. One study of mental rotations investigating times versus untimed effects in adults observed that sex differences were eliminated in untimed conditions (Goldstein, et al., 1990). However, another study found that differences in speed of mental rotations was not a sufficient explanation of the sex difference, with more males scoring at the high end and more females at the low end of the distribution (Resnick, 1993). This is relevant to results reported in Chapter 6, as speed and accuracy of response were measured concomitantly in order to maximize the possibility of detecting differences. Standard testing conditions devised for adults which include setting time limits and measuring accuracy within these limits, were not imposed. Furthermore, there is the possibility that accuracy of performance is less sensitive to effects of sex in children than speed of performance, and therefore larger samples would be necessary to detect differences.

Sex differences in targeting ability were also observed. Boys outperformed girls on dart throwing, but for ball throwing this was not the case, boys were better but the difference did not reach statistical significance. However, the size of the sex difference observed for dart throwing (d = 0.8) and ball throwing (d = 0.9) were large, but not as large as those reported in prior studies, where effect sizes show even larger differences in both adults (d = 1.3) and children (d = 1.5) (Jardine & Martin, 1983; Thomas & French, 1985; Watson & Kimura, 1991).

In respect of social mechanisms (chapter 8), unaffected boys and girls imitated the behaviour of same-sex models more than other-sex models. They also spent more time interacting with, and showed greater preferences for same-gender labelled toys compared to toys assigned the other-gender label. This is consistent with prior studies investigating responses to social modeling and gender labelling (Masters et al., 1979; Perry & Bussey, 1979; Bussey & Bandura, 1984), and confirm the viability of social learning as a mechanism through which gender role behaviour is influenced (Bandura, 1977; Masters et al., 1979; Perry & Bussey, 1979; Bussey & Bandura, 1984).

With respect to the hypotheses for CAH, the outcome of the research is consistent with the hypothesis that prenatal androgens influence gender role behaviour (chapter 4). CAH girls are clearly more masculine than unaffected girls in childhood play and activities, and the results are compatible with those reporting masculine-typical play activities in females with CAH (Ehrhardt & Baker, 1974; Dittman, et al., 1990; Berenbaum & Hines, 1992; Berenbaum & Snyder, 1995). This suggests that this sample of CAH girls is typical of individuals with CAH on this dimension.

Relationships between CAH and visual-spatial ability were the opposite of predictions (chapter 6). Outcomes were not consistent with the hypothesis that prenatal androgens influence visual-spatial functioning. The pattern of effects for CAH and unaffected girls were similar to those found for unaffected boys and girls. Mental rotations and spatial perception were not enhanced in CAH girls, although like unaffected boys and girls, CAH girls were faster at spatial perception than unaffected girls, but this was not the case for mental rotations. The research however, is consistent with the hypothesis that prenatal androgens influence targeting ability. CAH girls showed enhanced targeting performance compared to unaffected girls, and their performance was similar to that of unaffected boys. This suggests a direct effect of prenatal androgens on this dimension of spatial cognition, and the data add to the growing investigation of the behavioural consequences of CAH.

Several prior studies have reported enhanced spatial performance in females with CAH compared to unaffected females (Resnick et al., 1986; Hampson et al., 1998), while others have not (Ehrhardt & Baker, 1974, McGuire et al., 1975; Helleday et al., 1994). It has been argued that methodological problems, such as small sample size and use of measures that do not reveal large sex differences, may account for the disparate findings. Methodological limitations cause complications in reaching conclusions, not just on the basis of some reporting differences and others reporting an absence of differences, but also on the basis of not adequately tapping dimensions that show the largest sex differences. However, Hines et al (2002 submitted for publication) tested a larger sample of individuals with CAH using both two- and three-dimensional mental rotations tests. These tests show large sex differences in the general population, and found no effect of CAH. Previous studies have included preadolescent as well as post adolescent individuals in the same study (e.g., Ehrhardt & Baker, 1974), and this would limit interpretation of outcomes as the effects of later adult hormones on visual-spatial functioning cannot be ruled out. The research in this thesis attempted to address this by restricting age. The sample comprised of preadolescent children exclusively, in whom later hormones have not yet been activated.

However, sex differences were not evident in either spatial perception or mental rotations and this creates difficulties in concluding that androgens do, or do not enhance visual-spatial functioning. The possibility that the mental rotations task was not sensitive enough to detect sex differences and that the spatial perception task was too difficult for young children was discussed. A previous study (Fane, Collins & Hines, 2002, in preparation) using the same mental rotations task did reveal the expected sex differences in children as young as 3 years. On this basis the task was also considered appropriate to assess the relationship between androgens and visual-spatial ability. For spatial perception, the inclusion of the Judgment of Line Orientation task was exploratory in nature, as it has not been reported on in children younger than 7 years of age. Performance was examined to determine whether sex differences would be observed in a sample of children including those younger than 7 years of age, and to establish whether prenatal androgens are related to spatial perception. However, 51% of 3-6 year olds were not included in the analysis because they did not pass enough practice trials, and on this basis it was concluded that it may not be a suitable measure of spatial perception for detecting sex differences in younger children. This precludes the possibility of drawing conclusions in regard to androgens and spatial perception.

Given that other studies have produced mixed findings with regard to sex differences in visual-spatial ability in young children, and given the inconsistency of findings in CAH, it is also not possible to rule out earlier suggestions that sex differences in visual-spatial functioning are not reliably observed before later hormones have been activated (such as those in adolescence). The size of sex differences in visual-spatial functioning increases markedly during adolescence, and appears to be more consistent from this time (Kail, Pellegrino & Carter, 1980; Waber, Carlson, & Mann, 1982; Snow & Strope, 1990; see also Maccoby & Jacklin, 1974, for an early review).

The age at which sex differences emerge has been the subject of much debate over the past few decades. Several researchers have argued that it is a relatively late developmental phenomenon that does not emerge fully until the onset of adolescence (e.g., Waber, 1977; Hier & Crowley, 1982; Christiansen & Knussman, 1987). Voyer et al (1995) in their meta analysis, argue that sex differences in early childhood are not convincingly established, and suggest that this may be because most measures of visual-spatial performance have been developed for use with adults. If the same tasks are used with children, they can produce floor effects.

The suggestion that spatial cognition is related to childhood play activities was also discussed. Sex differences in visual-spatial and targeting skills are sometimes attributed to differences in the gender role socialization of boys and girls. Studies indicate that boys receive more spatially relevant input than girls (e.g., Newcombe & Sanderson, 1993), and correlational studies have reported that participation in spatial activities is positively related to children's visual-spatial skills (e.g., Fagot & Littman, 1976; Newcombe & Dubas, 1992; Voyer et al., 2000). Moreover, females with CAH do show greater participation in masculine-typical play and activities than unaffected females (e.g., Ehrhardt & Baker, 1974, Hines & Kaufman, 1994, Berenbaum & Snyder, 1995, Hines et al., 2002, submitted for publication). Thus it is more likely that they experience different learning experiences in this respect.

An examination of associations between gender role behaviour and spatial measures revealed relationships among targeting, speed of performance in spatial perception and masculine gender role behaviour. Because both spatial measures are influenced by prenatal androgens (CAH girls were better at targeting and faster at spatial perception than unaffected girls), this might suggest that hormonal influences operate through masculine play and activities to foster the development of these spatial skills.

The present research added a new dimension to the study of effects of prenatal androgens on subsequent behaviour by examining social factors known to induce gender-typed behaviour in children. Behaviour following modeling and gender-labelling shows robust sex differences in children in the general population (Masters et al., 1979; Perry & Bussey, 1979; Bussey & Bandura, 1984). However, it is not known whether hormones influence such behaviour. The study found that girls with CAH consistently behaved in a female-typical fashion, like other girls, despite the fact that they are more masculine-typical in their gender role behaviour.

The possibility that social mechanisms, which play a prominent role in gender role development, operate independently of early hormones was suggested. Because socialization factors play a major role in the development of gender-typed behaviour (for reviews see Golombok & Fivush, 1994; Ruble & Martin, 1998), the proposition that they may influence behaviour independently of hormones is perhaps not unexpected. The fact that gender-typical behaviour was observed following social modeling and gender labeling implies that sex differences result from social learning. However, it is unclear why this might be the case for CAH girls. Parental attitudes were not assessed in this study, although prior studies have reported that with respect to parenting practices, CAH girls are not treated in a more masculine fashion compared to other girls (Ehrhardt & Baker, 1974; Resnick, 1982). Thus identifying the attitudes of parents of girls with CAH towards gender-typical behaviour might be one way of assessing the contribution of socializing influences such as parental encouragement of gender-typical behaviour on this aspect of gender role development. On the basis of prior findings, however, it might be predicted that CAH girls are socialized in the same way as unaffected girls and their responses to social modeling and gender labelling reflects this. The present research also put forward gender identity as a possible explanation for the gender-typical behaviour observed in CAH girls. If CAH girls identify as females, it could be argued that they are more likely to identify with same-sex models and respond to same-sex labels in a gender-typical fashion because of this.

Methodological problems were discussed in relation to the findings for girls with CAH with respect to modelling and gender labelling. Specifically, CAH girls imitated the behaviour of same-sex models, preferred feminine-labelled toys, and played for longer with these toys. It is possible that they did so because they felt more comfortable in the testing situation conforming to social expectations. Further, with regard to gender labelling, the knowledge that despite gender labels, the same actions are elicited from masculine- and feminine-labelled toys, might increase this tendency.

The performance of CAH boys did not differ from unaffected boys in their gender role behaviour. These findings are similar to those reported for childhood play in other studies (Ehrhardt et al., 1968, Baker & Ehrhardt, 1974; Berenbaum & Hines, 1992). Their visual-spatial and targeting performance also did not differ from unaffected boys. Again this is not unexpected, given that behavioural differences have been reported only occasionally in males with CAH, and most studies have reported no differences (Ehrhardt & Baker, 1974; McGuire et al., 1975). However, they were reported to engage in play with girls more often than unaffected boys. This was unexpected and will need to be clarified by further data. This finding may in part explain the observation of reduced rough and tumble play in boys with CAH reported by Hines & Kaufman, (1994). That is, if boys with CAH are more likely to play with girls than other boys, they might be less likely to engage in rough and tumble activities. This warrants further investigation. However, results suggest that for boys with CAH, prenatal androgens may not influence all gender role behaviours in the same manner.

There were also general methodological limitations noted in the research. Due to difficulties in finding appropriate tasks that show sex differences in young children, choice of mental rotations and spatial perception tasks was limited to confirmation in the research literature that young children can successfully carry out such tasks. Further, that sex differences in these tasks have been observed in prior studies. A sex difference was reported in a previous study using the Marmor Mental Rotations Task (Fane, Blair & Hines, submitted for publication). For spatial perception, tasks appropriate for use with very young children were difficult to find. The Judgment of Line Orientation Task has previously shown sex differences in children as young as 7 years. Given its ease of use and lack of demands on young children, it was considered to be the most appropriate. However, it did not show a sex difference for performance, and was difficult for younger children. Thus it is likely that the pattern of results has been influenced by limited availability of suitable measures. Subsequent to the design of the study investigating spatial cognition, a visual-spatial task with a mental rotations component has been tested in young children, and has shown a larger sex difference (Levine et al., 1999). This task thus might prove more effective in future studies investigating effects of androgens on visual-spatial ability.

Potential problems regarding sample size were also discussed. Although a relatively large sample of CAH children and their relatives were studied, the sample size was still far from ideal. Studies of CAH patients are often restricted to small samples because of the low incidence of the disorder, making it difficult to observe differences between groups (Berenbaum, 1990). Thus failures to detect differences may in part be explained by a lack of statistical power.

Taken as a whole, the results of studies carried out in this thesis provide some understanding of the behavioural consequences of CAH, and they also contribute to our awareness of factors that can influence normal behavioural development. The results do not suggest that social factors are irrelevant in shaping behaviour, but rather indicate that they act independently of prenatal androgens. Even when gender role behaviour and targeting performance is clearly masculinised, girls with CAH are influenced in a gender-typical fashion following social modeling and gender labelling.

The research also highlighted methodological limitations in the studies. Some limitations are inherent in the study of clinical samples such as CAH (i.e., small sample size), and others, such as sensitivity of tasks, and outcome measures, which impede the ability to understand whether hormones are influential in the development of visual-spatial ability, hence they need to be addressed in further investigations in this domain.

In conclusion, the results of the studies suggest behavioural demasculinisation on one dimension in boys with CAH compared to unaffected male relatives. In all other areas their behaviour parallels that of other boys. Results are consistent with the hypothesis that behavioural masculinisation in girls with CAH results from high levels of androgens prenatally for gender role behaviour and targeting ability. Furthermore, these effects do not appear to be caused by alterations in response to modeling and gender-labelling. Thus, this data add to the growing body of evidence that masculinisation of behaviour in girls with CAH reflects hormonal influences. There is no evidence, however, to support the hypothesis that prenatal exposure to androgens enhances visual-spatial performance. However, as discussed earlier, methodological limitations have created interpretive difficulties and preclude more definitive conclusions. The development of more sensitive techniques for assessing visual-spatial skill in young children would help to resolve the issue of whether the visual spatial functioning is associated with the effects of exposure to androgens prenatally.

REFERENCES

Allen, L. S., & Gorski, R. A. (1991). Sexual dimorphism of the anterior commissure and massa intermedia of the human brain. *Journal of Comparative Neurology*, **312**, 97-104.

Allen, L. S., Hines, M., Shryne, J. E., & Gorski, R. A. (1989). Two sexually dimorphic cell groups in the human brain. *Journal of Neuroscience*, **9**, 933-942.

Arnold, A. P., & Breedlove, S. M. (1985). Organizational and activational effects of sex steroids on brain and behavior: A reanalysis. *Hormones and Behavior*, **19**, 469-498.

Arnold, A. P., & Gorski, R. A. (1984). Gonadal steroid induction of structural sex differences in the central nervous system. *Annual Review of Neuroscience*, **7**, 413-442.

Bachavelier, J., & Hagger, C. (1991). Sex differences in the development of learning abilities in primates. *Psychoneuroendocrinology*, **16**, 177-188.

Baenninger, M., & Newcombe, N. (1989). The role of experience in spatial test performance: A meta-analysis. *Sex Roles*, **20**, 327-344.

Baker, S. W., & Ehrhardt, A. A. (1974). Prenatal androgen, intelligence and cognitive sex differences. In: Friedman, R.C., Pichart, R.M., & Vande Wiele, R.L. (Eds.), *Sex differences in behaviour* (pp 53-76). New York: Wiley.

Bandura, A. (1977). *Social learning theory.* Englewood Cliffs, NJ: Prentice Hall.

Barklay, R. A., Ullman, D. G., Otto, L., & Brecht, J. M. (1977). The effects of sex typing and sex appropriateness of modeled behavior on children's imitation. *Child Development*, **48**, 721-725.

Baum, M. J., & Schretlen, P. (1975). Neuroendocrine effects of perinatal androgenization in the male ferret. *Progress in Brain Research*, **42**, 343-355.

Beach, F. A., & Kuehn, R. E. (1970). Coital behavior in dogs: X. Effects of androgenic stimulation during development on masculine mating responses in females. *Hormones and Behavior*,

Beatty, W. W. (1979). Gonadal hormones and sex differences in non-reproductive behaviors in rodents: Organizational and activational influences. *Hormones and Behavior*, **12**, 112-163.

Beatty, W. W. (1992). Gonadal hormones and sex differences in non-reproductive behaviors. In A. A. Gerall, H. Moltz, & I. L. Ward (eds.), *Handbook of behavioral neurobiology*: Vol 11. *Sexual differentiation.* New York: Plenum.

Becker, J. B., Breedlove, S. M., & Crews, D. (eds.). (1993). *Behavioral endocrinology.* Cambridge, MA: MIT Press.

Benbow, C. P. (1988). Sex differences in mathematical reasoning ability in intellectually talented preadolescents: Their nature, effects, and possible causes. *Behavioral and Brain Sciences*, **11**, 169-232.

Benton, A. L., Hamsher, K. S., Varney, N. R., & Spreen, O. (1983). *Contributions to neuropsychological assessment. A clinical manual.* New York. Oxford University Press.

Berenbaum, S. A. (1990). Congenital adrenal hyperplasia: Intellectual and psychosexual functioning. In: C. Holmes, (Ed.). *Psychoneuroendocrinology: Brain behavior, and hormonal interactions*. New York: Springer-Verlag, 227-260.

Berenbaum, S. A, & Bailey, J. M. (1998). Variation in female gender identity: Evidence from girls with congenital adrenal hyperplasia, tomboys, and typical girls. *Paper presented at the meeting of the Midwestern Psychological Association, Chicago.*

Berenbaum, S. A., & Hines, M. (1992). Early androgens are related to childhood sex-typed toy preferences. *Psychological Science*, **3**, 203-206.

Berenbaum, S. A., & Resnick, S. M. (1997). Early androgen effects on aggression in children and adults with congenital adrenal hyperplasia. *Psychoneuroendocrinology*, **22**, 505-515.

Berenbaum, S. A., & Snyder, E. (1995). Early hormonal influences on childhood sex-typed activity and playmate preferences: Implications for the development of sexual orientation. *Developmental Psychology*, **31**, 31-42.

Block, J. H. (1983). Differential premises arising from differential socialization of the sexes: Some conjectures. *Child Development*, **54**, 1335-1354.

Blough, P. M. & Slavin, L. K. (1987). Reaction time assessments of gender differences in visual-spatial performance. *Perception and Psychophysics*, **41**, 276-281.

Breedlove, S. M. (1994). Sexual differentiation of the human nervous system. *Annual Review of Psychology*, **45**, 389-418.

Brinkmann, E. H. (1966). Programmed instruction as a technique for improving spatial visualization. *Journal of Applied Psychology*, **50**, 179-184.

Bussey, K. & Bandura, A. (1984). Influence of gender constancy and social power on sex-linked modelling. *Journal of Personality and Social Psychology*, **47**, 1292-1302.

Bussey, K. & Perry, D. G. (1982). Same-sex imitation: The avoidance of cross-sex models or the acceptance of same-sex models? *Sex Roles*, **8**, 773-784.

Butterfield, S. A., & Loovis, E. M. (1993). Influence of age, sex, balance, and sport participation on development of throwing by children in grades K-8. *Perceptual and Motor Skills*, **76**, 459-464.

Byne, W., Lasco, M. S., Kemether, E., Shinwari, A., Edgar, M. A., Morgello, S., Jones, L. B., & Tobet, S. (2000). The interstitial nuclei of the human anterior hypothalamus: An investigation of sexual variation in volume and cell size, number and density. *Brain Research*, **856**, 254-258.

Caldera, Y. M., Huston, A. C., & O'Brien, M. (1989). Social interaction and play patterns of parents and toddlers with feminine, masculine and neutral toys. *Child Development*, **60**, 70-76.

Carpenter, P. A., & Just, M. A. (1981). Spatial ability: An information processing approach to psychometrics. *Unpublished manuscript*, Carnegie-Mellon University.

Carter, D. B. (1987). The roles of peers in sex role socialization. In D.B. Carter (Ed.), *Current conceptions of sex roles and sex typing: Theory and research*. New York: Praeger.

Carter, D. B., & Levy, G. D. (1988). Cognitive aspects of children's early sex-role development: The influence of gender schemas on preschoolers' memories and preferences for sex-typed toys and activities. *Child Development*, **59**, 782-793.

Carter, D. B., & McClosky, L. A. (1984). Peers and the maintenance of sex-typed behavior: The development of children's conceptions of cross-gender behavior in their peers. *Social Cognition*, **2**, 294-314.

Christiansen, K., & Knussman, R. (1987). Sex hormones and cognitive functioning in men. *Neuropsychobiology*, **18**, 27-36.

Clark, A. S., & Goldman-Rakic, P. S. (1989). Gonadal hormones influence the emergence of cortical function in nonhuman primates. *Behavioral Neuroscience*, **103**, 1287-1295.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Collaer, M. L., & Hines, M. (1995). Human behavioral sex differences: A role for gonadal hormones in early development? *Psychological Bulletin*, **118**, 55-107.

Conway, G. C. (2000). Congenital adrenal hyperplasia: Information for adults. *Unpublished paper*. Middlesex Hospital, London.

Courbois, Y. (1999). The role of stimulus axis salience in children's ability to mentally rotate unfamiliar figures. *European Journal of Cognitive Psychology*, **12**, 261-269.

Dawson, J. L., Cheung, Y. M., & Lau, R. T. S. (1975). Developmental effects of neonatal sex hormones on spatial and activity skills in the white rat. *Biological Psychology*, **3**, 213-229.

Diamond, M., Llacuna, A., & Wong,, C.L. (1973). Sex behavior after neonatal progesterone, testosterone, estrogen, or antiandrogens. *Hormones and Behavior*, **4**, 73-88.

Dittmannn, R. W., Kappes, M. H., Kappes, M. E., Börger, D., Stegner, H., Willig, R. H., Wallis, H. (1990). Congenital adrenal hyperplasia I: Gender-related behavior and attitudes in female patients and sisters. *Psychoneuroendocrinology*, **15**, 412-434.

Dittmannn, R. W., Kappes, M. M., Borger, D., Meyer-Bahlburg, H. F. L., Stegner, H., Willig, R. H., & Wallis, H. (1990). Congenital adrenal hyperplasia II: Gender related behavior and attitudes in female salt-wasting and simple-virilising patients. *Psychoneuroendocrinology*, **15**, 401-420.

Dittmannn, R.W., Kappes, M. M., & Kappes, M. H. (1992). Sexual behaviour in adolescent and adult females with congenital adrenal hyperplasia. *Psychoneuroendocrinology*, **17**, 153-170.

Ehrhardt, A. A., & Baker, S. W. (1974). Fetal androgens, human central nervous system differentiation, and behavior sex differences. In R. C. Friedman, R. M. Richart, & R. L. Vande Wiele (Eds.), *Sex differences in behavior* (pp 33-51). New York: Wiley.

Ehrhardt, A. A., Epstein, R., & Money, J. (1968). Fetal androgens and female gender identity in the early-treated adrenogenital syndrome. *Johns Hopkins Medical Journal*, **126**, 237-248.

Ehrhardt, A. A., & Meyer-Bahlburg, H. F. L. (1981). Effect of prenatal sex hormones on gender-related behavior. *Science*, **211**, 1312-1318.

Ehrhardt, A. A., & Money, J. (1967) Progestin-induced hermaphroditism: IQ and psychosexual identity in a study of 10 girls. *Journal of Sex Research*, **3**, 83-100.

Emmerich, W., Goldman, K. S., Kirsh, B., & Sharabany, R. (1977). Evidence for a transitional phase in the development of gender constancy. *Child Development*, **48**, 930-936.

Estes, D. (1998). Young children's awareness of their mental activity: The case of mental rotation. *Child Development*, **69**, 1345-1360.

Fagot, B. I. (1978). The influences of sex of child on parental reaction to toddler children. *Child Development*, **49**, 459-465.

Fagot, B. I. (1985). Beyond the reinforcement principle: Another step toward understanding sex-role development. *Developmental Psychology*, **21**, 1097-1104.

Fagot, B. I. & Hagan, R. (1991). Observations of parent reactions to sex-stereotyped behaviors. *Child Development*, **62**, 617-628.

Fagot, B. I., & Leinbach, M. D. (1989). The young child's gender schema: Environmental input, internal organization. *Child Development*. **60**, 663-672.

Fagot, B., & Littman, I. (1976). Relation of preschool sex-typing to intellectual performance in elementary school. *Psychological Reports*, **39**, 699-704.

Fane, B., Blair, S., & Hines, M. (2002). The role of peers and adults in same-sex imitation by girls and boys. *Accepted for publication.*

Fane, B., Collins, Z., & Hines, M. (2002). Sex differences in mental rotations in young children: Their magnitude and relationship to culture and experience. *Submitted for publication.*

Finegan, J., K., Niccols, G. A., & Sitarenios, G. (1992). Relations between prenatal testosterone levels and cognitive abilities at 4 years. *Developmental Psychology*, **28**, 1075-1089.

Fouts, G., & Liikanen, P. (1975). The effects of age and developmental level on imitation in children. *Child Development*, 46, 555-558.

Gaulin, S. J. C., & Fitzgerald, R.W. (1986). Sex differences in spatial ability: An evolutionary hypothesis and test. *American Naturalist*, **127**, 74-88.

Goldstein, D., Haldane, D., & Mitchell C. (1990). Sex differences in visual-spatial ability: The role of performance factors. *Memory & Cognition*, **18**, 546-550.

Golombok, S., & Fivush, R. (1994). *Gender Development.* Cambridge, UK: Cambridge University Press.

Golombok, S., & Rust, J. (1993). The measurement of gender role behavior in pre-school children: A research note. *Journal of Child Psychology and Psychiatry*, **34**, 805-811.

Golombok, S,. & Rust, J. (1993). The pre-school activities inventory: A standardized assessment of gender role in children. *Psychological Assessment*, **5** 131-136.

Gorski, R. A., Gordon, J. H., Shryne, J. E., & Southam, A.M. (1978). Evidence for a morphological sex difference within the medial preoptic area of the rat brain. *Brain Research*, **143**, 333-346.

Gorski, R. A., Harlan, R. E., Jacobsen, C. D., Shryne, J. E., & Southam, A. M. (1980). Evidence for the existence of a sexually dimorphic nucleus in the preoptic area of the rate. *Journal of Comparative Neurology*. **193**, 529-539.

Govier, E., & Feldman, J. (1999). Occupational choice and patterns of cognitive ability. *British Journal of Psychology*, **90**, 99-108.

Goy, R. W. (1968). Organizing effects of androgen on the behavior of rhesus monkeys. In R. P. Michael (Ed.), *Endocrinology and human behavior.* London: Oxford University Press.

Goy, R. W., & Phoenix, C. H. (1971). The effects of testosterone propionate administered before birth on the development of behaviour in genetic female rhesus monkeys. In C. H. Sawyer & R. A. Gorski (Eds.*), steroid hormones and brain function* (pp 193-205). Berkeley: University of California Press.

Goy, R. W., & McEwen, B.S. (1980). *Sexual differentiation of the brain.* Cambridge, MA: MIT Press.

Goy, R. W., & Resko, J. A. (1972). Gonadal hormones and behavior of normal and pseudohermaphroditic nonhuman female primates. *Recent Progress in Hormone Research*, **28**, 707-733.

Grady, K. L., Phoenix, C. H., & Young, W. C. (1965). Role of the developing rat testis in differentiation of neural tissue mediating behavior. *Journal of Comparative and Physiological Psychology*, **59**, 176-182.

Greenspan, F. S., & Forsham, P. H. (1986). *Basic and clinical endocrinology* (2nd ed.), Los Altos. CA: Lange Medical.

Grimshaw, G. M., Sitarenios, G., & Finegan, J-A. K. (1995). Mental rotation at 7 years: Relations with prenatal testosterone levels and play experiences. *Brain and Cognition*, **29**, 85-100.

Halpern, D. (1992). *Sex differences in cognitive abilities.* Lawrence Erlbaum Associates, Hillsdale, New Jersey.2nd Edition.

Halverson, L. E., Roberton, M. A., Safrit, M. J., & Roberts, T. W. (1977). Effect of guided practice on overhand-throw ball velocities of kindergarten children. *Research Quarterly*, **48**, 311-318.

Halverson, L. E., Roberton, M. A., & Langdorfer, S. (1982). Development of the overarm throw: Movement and ball velocity changes by seventh grade. *Research Quarterly*, **53**, 198-205.

Hampson, E. A., & Kimura, D. (1992). Sex differences and hormonal influences on cognitive function in humans. In J.B. Becker, S.M. Breedlove, & D. Crews (Eds.), *Behavioral endocrinology* (pp. 357-397). Cambridge, MA: MIT Press.

Hampson, E. A., Rovet, J. F., & Altman, D. (1998). Spatial reasoning in children with congenital adrenal hyperplasia due to 21-hydroxylase deficiency. *Developmental Neuropsychology*, **14**, 299-320.

Harris, J. R. (1995). Where is the child's environment: A group socialization theory of development. *Psychological Review*, **102**, 458-489.

Hier, D. B., & Crowley, W. F. (1982). Spatial ability in androgen deficient men. *New England Journal of Medicine*, **306**, 1202-1205.

Hinde, R. A., Easton D. F., Meller, R. E., & Tamplin A. (1983). Nature and determinants of preschoolers' differential behavior to adults and peers. *British Journal of Developmental Psychology,* **1**, 3-19.

Hines, M., Chiu, L. McAdams, L. A., Bentler, P. M., Lipcamon, J. (1992). Cognition and the corpus callosum: Verbal fluency, visuospatial ability and language lateralization related to midsagittal surface areas of caollosal subregions. *Behavioral Neuroscience*, **106**, 3-14.

Hines, M. (1990). Gonadal hormones and human cognitive development. In J. Balthazart (Ed), *Brain & Behavior in Vertebrates 1: Sexual differentiation, neuroanatomical aspects, neurotransmitters, and neuropeptides* (pp. 51-63). Basle, Switzerland: Karger.

Hines, M. (2001). Gonadal hormones and sexual differentiation of human behavior: Effects on psychosexual and cognitive development. In *Sexual Differentiation of the Brain,* (pp 257-277). (A. Matsumoto, ed.) CRC Press, New York.

Hines, M., & Collaer, M. L. (1993). Gonadal hormones and sexual differentiation of human behavior: Developments from research on endocrine syndromes and studies of brain structure. *Annual Review of Sex Research*. **4**, 1-48.

Hines, M. & Kaufman, F. R. (1994). Androgen and the development of human sex-typical behaviour: Rough and tumble play and sex of preferred playmates in children with congenital adrenal hyperplasia (CAH). *Child Development*, **65**, 1042-1053.

Hines, M., Fane, B., Pasterski, V., Mathews, G., Conway, G., & Brook, C. (2002). Spatial abilities following prenatal androgen abnormality: Targeting and mental rotations performance in individuals with congenital adrenal hyperplasia. *Submitted for publication.*

Hurtig, A. L., & Rosenthal, I. M. (1987). Psychological findings in early treated cases of female pseudohermaphroditism caused by virilising congenital adrenal hyperplasia. *Archives of Sexual Behavior*, **16**, 209-223.

Huston, A. C. (1983). Sex-typing. In E. M. Hetherington (Ed.), P. H. Mussen (Series Ed.), *Handbook of child psychology*: Vol 4. Socialization, personality, and social development (pp 387-476). New York: Wiley.

Jacklin, C. N., Maccoby, E. E., & Dick, A. E. (1973). Barrier behaviours and toy preferences (and their absence) in the year-old child. *Child Development*, **38**, 713-722.

Jacklin, C. N., Wilcox, K. T., & Maccoby, E. E. (1988). Neonatal sex-steroid hormones and cognitive abilities at six years. *Developmental Psychobiology*, **21**, 567-574.

Jardine, R., & Martin, N. G. (1983). Spatial ability and throwing accuracy. *Behavior Genetics,* **13,** 331-340.

Johnson, E. S., & Meade, A. C. (1987). Developmental patterns of spatial ability: An early sex difference. *Developmental Psychology*, **58**, 725-740.

Juraska, J. M. (1991). Sex differences in "cognitive regions" of the rat brain. *Psychoneuroendocrinology*, **16**, 105-119.

Kail, R., Carter, P., & Pellegrino, J. (1979). The locus of sex differences in spatial ability. *Perception and Psychophysics*, **26**, 182-186.

Kail, R., Pellegrino, J., & Carter, P. (1980). Developmental change in mental rotation. *Journal of Experimental Child Psychology*, **29**, 102-116.

Karadi, K., Szabo, I., & Szepesi, T. (1999). Sex differences on the hand mental rotation task for 9-yr old children and young adults. *Perceptual and Motor Skills*, **89**, 969-972.

Katz, P. A., & Boswell, S. (1985). Flexibility and Traditionality in Children's Gender Roles. *Genetic, Social, and General Psychology Monographs*. **112**, 105-147.

Kenyon, J. (1984). Paper-and-pencil test of Piaget's water level test: sex differences and test modality. *Perceptual and Motor Skills*, **59**, 739-742.

Kerns, K. A., & Berenbaum, S. A. (1991). Sex differences in spatial ability in children. *Behavior Genetics*, **21**, 383-391.

Kimura, D. (1999). *Sex and cognition*. The MIT Press. Cambridge, Massachusetts

Kohlberg, L. A. (1966). A cognitive-developmental analysis of children's sex-role concepts and attitudes. In E. E. Maccoby (Ed.), *The development of sex differences* (pp. 82-173). Stanford, CA: Stanford University Press.

Kohlberg, L. (1969). Stage and sequence: The cognitive-developmental approach to socialization. In D. A. Goslin (Ed.), *Handbook of socialization theory and research. Chicago: Rand McNally.*

Kosslyn, S. M., & Koenig, O. (1992). *Wet Mind: The new cognitive sci*ence. Chapter 3, pp 52- 127. Free Press.

Kosslyn, S. M., Digirolamo, G. J., Thompson, W. L., & Alpert, N. M. (1998). Mental rotations of objects versus hands: Neural mechanisms revealed by positron emission tomography. *Psychophysiology*, **35**, 151-161.

Kuhn, D., Nash, S. C., & Brucken, L. (1978). Sex-role concepts of two- and three-year olds. *Child Development*, **49**, 445-451.

Langlois, J. H., & Downs, A. C. (1980). Mothers, fathers and peers as socialization agents of sex-typed play behaviours in young children. *Child Development*, **51**, 1237-1247.

Lamb, M. E., Easterbrooke, M. A., & Holden, G. W. (1980). Reinforcement and punishment among preschoolers: Characteristics, effects, and correlates. *Child Development*, **51**, 1230-1236.

Lamb, M. E. & Roopnarine, J. L. (1979) Peer influences on sex-role development in preschoolers. *Child Development*, **50**, 1219-1222.

Leaper, C. (1994). Exploring the correlates and consequences of gender segregation: Social relationships in childhood, adolescence, and adulthood. In B. Damon (Series Ed.) & C. Leaper, (Vol. Ed.), *New Directions for child development. The development of gender relationships.* San Francisco: Josey-Bass.

Leaper, C., Leve, L., Strasser, T., & Shwartz, R. (1995). Mother-child communication sequences: Play activity, child gender, and marital status effects. *Merrill Palmer Quarterly*, **41**, 307-327.

Leinbach, M. D., & Fagot, B. (1986). Acquisition of gender labeling: A test for toddlers. *Sex Roles*, **15**, 655-666.

LeVay, S. (1991). A difference in hypothalamic structure between heterosexual and homosexual men. *Science*, **253**, 1034-1037.

Leveroni, C. L., & Berenbaum, S. A. (1998). Early androgen effects on interest in infants: Evidence from children with congenital adrenal hyperplasia. *Developmental Neuropsychology*, **14**, 321-340.

Levine, S. C., Huttenlocher, J., Taylor, A., & Langrock, A. (1999). Early sex differences in spatial skill. *Child Development*, **35**, 940-949.

Levy, G. D., & Carter, D. B. (1989). Gender schema, gender constancy, and gender-role knowledge: The roles of cognitive factors in preschoolers' gender role stereotype attributions. *Developmental Psychology*, **25**, 444-449.

Lewis, V. G., Money, J., & Epstein, R. (1968). Concordance of verbal and nonverbal ability in the adrenogenital syndrome. *Johns Hopkins Medical Journal*, **122**, 192-195.

Lewis, M., & Weinraub, M. (1979). Origins of early sex-role development. *Sex Roles*, **5**, 135-153.

Lindgren, S. D., & Benton, A. L. (1980). Developmental patterns of visuospatial ability. *Journal of Pediatric Psychology*, **5**, 217-225.

Linn, M. C., & Peterson. A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child Development*, **56**, 1479-1498.

Liss, M. B. (1979). Variables influencing modeling and sex-typed play. *Psychological Reports*, **44**, 1107-1115.

Lohman, D. (1988). Spatial abilities as traits, as processes and knowledge. In R. J. Sternberg (Ed.), *Advances in the psychology of human intelligence* (Vol 4, pp. 181-248). Hillsdale, NJ: Lawrence Erlbaum Associates.

Lunn, D., & Kimura, D. (1989). Spatial abilities in preschool-aged children. *Research Bulletin #681*. Department of Psychology, The University of Western Ontario. London, Canada.

Lytton, H., & Romney, D. M. (1991). Parents' differential socialization of boys and girls: A meta-analysis. *Psychological Bulletin*, **109**, 267-296.

Maccoby, E. E. (1998). *The Two Sexes: Growing up Apart, Coming Together.* The Belknap Press of Harvard University Press, Cambridge, Massachusetts.

Maccoby, E. E., & Jacklin, C. N. (1974). *The psychology of sex differences.* Stanford, CAH: Stanford University Press.

MacLusky, N. J., & Naftolin, F. (1981). Sexual differentiation of the central nervous system. *Science*, **211**, 1294-1303.

MacLusky, N. J., Clark, A. S., Naftolin, F., & Goldman-Rakic, P. S. (1987). Estrogen formation in the mammalian brain: Possible role of aromatase in sexual differentiation of the hippocampus and neocortex. *Steroids*, **50**, 459-474.

MacLusky, N. J., Lieberburg, I., McEwen, B. S. (1979). The development of estrogen receptor systems in the rat brain: perinatal development. *Brain Research*, **178**, 129-142.

Marcus, D. E., & Overton, E. F. (1978). The development of cognitive gender constancy and sex-role preferences. *Child Development*, **49**, 434-444.

Marmor, G. S. (1975). Development of kinetic images: When does child first represent movement in mental images? *Cognitive Psychology*, **7**, 548-559.

Marmor, G. S. (1977). Mental rotation and number conservation: Are they related? *Developmental Psychology*, **13**, 320-325.

Martin, C. C, (1989). Children's use of gender-related information in making social judgments. *Developmental Psychology*, **25**, 80-88.

Martin, C. C., & Halverson, C. F. (1981). A schematic processing model of sex typing and stereotyping in children. *Child Development*, **52**, 1119-1134.

Martin C. C., & Little, J. K. (1990). The relation of gender understanding to children's sex-typed preferences and gender stereotypes. *Child Development*, **61**, 1427-1439.

Martin C. C., Wood, C. H., & Little, J. K. (1990). The development of gender stereotype components. *Child Development*, **61**, 1891-1904.

Martin, C. L., Fabes, R. A., Evans, S. M., & Wyman, H. (1999) Social cognition on the playground: Children's beliefs about playing with girls versus boys and their relations to sex segregated play. *Journal of Social and Personal Relationships*, **16,** 751-771.

Masters, J. C., Ford, M. E., Arend, R., Grotevant, H. D., & Clark, L. V. (1979). Modelling and labeling as integrated determinants of children's sex-typed imitative behavior. *Child Development*, **50**, 364-371.

Maxwell, J. W., Croake, J. W., & Biddle, A. P. (1975). Sex differences in the comprehension of spatial orientation. *Journal of Psychology*, **91**, 127-131.

McGee, M. G. (1979). *Human spatial abilities*. Praeger Publishers. New York.

McGillicuddy-DeLisi, A.V., DeLisi, R., & Youniss, J. (1978). *Representation of the horizontal coordinate with and without liquid.* Merrill-Palmer Quarterly, **24**, 199-208.

McGuire, L. S., Ryan, K. O., & Omenn, G. S. (1975). Congenital adrenal hyperplasia II: Cognitive and behavioral studies. Behavior Genetics, **5**, 175-188.

Meaney, M. J. (1988). The sexual differentiation of social play. *Trends in Neuroscience*, **11**, 54-58.

Meyer-Bahlburg, H. F. L., Gruen, R. S., New, M. I., Bell, J. J., Morishima, A., Shimshi, M., Bueno, Y., Vargas, I., & Baker, S.W. (1996). Gender change from female to male in classical congenital adrenal hyperplasia. *Hormones and Behavior*, **30**, 319-332.

Miller, W. L., & Levine, L. S. (1987). Molecular and clinical advances in congenital adrenal hyperplasia. *Journal of Pediatrics*, **111**, 1-17.

Mischel, W. (1970). Sex-typing and socialization. In P. H. Mussen (Ed.), *Carmichael's manual of child psychology*. New York: Wiley, 1970.

Money, J. & Ehrhardt, A. A. (1972). *Man and Woman, boy and* girl. The differentiation and dimorphism of gender identity from conception to maturity. Baltimore: Johns Hopkins University Press.

Money, J., & Lewis, V. (1966). IQ, genetics and accelerated growth: Adrenogenital syndrome. *Bulletin of the Johns Hopkins Hospital*, **118**, 365-373.

Money, J., Schwartz, M., & Lewis, V. (1984). Adult heterosexual status and hormonal masculinization and demasculinization: 46XX congenital virilising adrenal hyperplasia and 46 XY androgen-insensitivity syndrome compared. *Psychoneuroendocrinology*, **9**, 405-414.

Montemayor, R. (1974). Children's performance in a game and their attraction to it as a function of sex-typed labels. *Child Development*, **45**, 152-156.

Nash, S. C. (1975). The relationship among sex-role stereotyping, sex-role preferences and the sex differences in spatial visualization. *Sex Roles*, **1**, 15-32.

New, M. I., & Levine, L .S. (1984). Steroid 21-hydroxyase deficiency. In M. I. New & L. S. Levine (Eds.), *Adrenal diseases in childhood.* (pp. 1-46). Basel, Switzerland: Karger.

New, M. I., & Levine, L. S. (1984). Recent advances in 21-hydroxylase deficiency. *Annual Review of Medicine*, **35**, 649-663.

New, M. I., & Speiser, P. W. (1986). Genetics of adrenal steroid 21-hydroxylase deficiency. *Endocrine Reviews*, **7**, 331-349.

Newcombe, N. (1982). Sex related differences in spatial ability: Problems and gaps in current approaches. In M. Potegal (Ed.), *Spatial abilities.* New York: Academic Press.

Newcombe, N., & Sanderson, H. L. (1993). The relation between preschoolers' everyday activities and spatial development. Paper presented at the meeting of the Society for Research in Child Development, New Orleans, LA.

Niall, K. N. (1997). 'Mental rotation', pictured rotation, and tandem rotation in depth. *Acta Psychologica*, **95**, 31-83.

Pang, S., Levine, L. S., Chow, D. M., Faiman, C., & New, M. I. (1979). Serum androgen concentrations in neonates and young infants with congenital adrenal hyperplasia due to 21-hydroxylase deficiency. *Clinical Endocrinology*, **11**, 373-384.

Pennings, A. H. (1991). Altering the strategies in embedded figures and water level tasks via instructions: a neo-Piagetian learning study. *Perceptual and Motor Skills*, **72**, 639-660.

Perlman, S. M. (1973). Cognitive abilities of children with hormone abnormalities: Screening by psychoeducational tests. *Journal of Learning Disabilities*, **6**, 21-29.

Perry D.G., & Bussey, K. (1979) The social learning theory of sex differences: Imitation is alive and well. *Journal of Personality and Social Psychology*, 37, 1699-1712.

Phoenix, C. H., Goy, R.W., Gerall, A. A., & Young, W. C. (1959). Organizing action of prenatally administered testosterone propionate on the tissues mediating mating behavior in the female guinea pig. *Endocrinology*, **65**, 163-196.

Poole, C., & Stanley, G. (1972). A factorial and predictive study of spatial abilities. *Australian Journal of Psychology*, **24**, 317-320.

Quadagno, D. M., Briscoe, R., & Quadagno, J. S. (1977). Effects of perinatal gonadal hormones on selected nonsexual behavior patterns: A critical assessment of the nonhuman and human literature. *Psychological Bulletin*, **84**, 62-80.

Raisman, G., & Field, P. M. (1973). Sexual dimorphism in the neuropil of the preoptic area of the rat and its dependence on neonatal androgen. *Brain Research*, **54**, 1-20.

Reinisch, J. M. (1981). Prenatal exposure to synthetic progestins increases potential for aggression in humans. *Science*, **211**, 1171-1173.

Reinisch J. M., & Sanders, S. A. (1984). Prenatal gonadal steroidal influences on gender related behavior In J. G. De Vries, J. P. C. De Bruin, H. B. M. Uylings, & M. A. Corner (Eds.), *Progress in Brain Research*, Vol 61: Sex differences in the brain (pp 407-416). Amsterdam: Elsevier.

Resnick, S. M. (1992). Psychological functioning in individuals with congenital adrenal hyperplasia: Early hormonal influences on cognition and personality. *Doctoral Dissertation, University of Minnesota.*

Resnick, S. M., Berenbaum, S. A., & Gottesman, I. I., & Bouchard, T. J. (1986). Early hormonal influences on cognitive functioning in congenital adrenal hyperplasia. *Developmental Psychology*, **22**, 191-198.

Roof, R. L., & Havens, M. D. (1992). Testosterone improves maze performance and induces development of a male hippocampus in females. *Brain Research*, **572**, 310-313.

Resnick, S. M. (1993). Sex differences in mental rotations: An effect of time limits? *Brain and Cognition*, **21**, 71-79.

Rosser, R. A., Ensing, S. S., Glider, P. J., & Lane S. (1984) Information-processing analysis of children's accuracy in predicting the appearance of rotated stimuli. *Child Development*, **55**, 2204-2211.

Ruble, D. N., & Martin, C. L. (1998) Gender development. In W. Damon, (Series. ed.) and N. Eisenberg. (Vol. ed.), *Handbook of Child Psychology* (5th ed.). Vol. 3: Social, Emotional and Personality Development, Wiley, New York, pp 933-1016.

Serbin, L. A., & Connor, J. M. (1979). Sex typing of children's play preferences and patterns of cognitive performance. *Journal of Genetic Psychology*, **134**, 315-316.

Serbin, L. A., Connor, J. M., Burchardt, C. J., & Citron, C. C. (1979). Effects of peer pressure on sex-typing of children's play behaviour. *Journal of Experimental Child Psychology*, **27**, 303-309.

Shell, R., & Eisenberg, N. (1990). The role of peers' in children's naturally occurring interest in toys. *International Journal of Behavioral Development*, **13**, 373-388.

Shepard, R. N., & Cooper, L. A. (1982). Mental images and their transformations. *Cambridge Massachusetts Institute of Technology.*

Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science*, **171**, 701-703.

Short, R. V. (1974). Sexual differentiation in the brain of the sheep. *Endocrinoligie Sexuelle de la Periode Perinatale*,**32**, 121-124.

Sinforiani, E., Livieri, C., Maufi, M., Bisio, P., Sibilla, L., Chiesa, L., & Martelli, A. (1994). Cognitive and neuroradiological findings in congenital adrenal hyperplasia (CAH). *Progress in Brain Research*, **19**, 55-64.

Slaby, R. G., & Frey, K. S. (1974). Development of gender constancy and selective attention to same sex models. *Child Development*, **46**, 849-856.

Slijper, F. M. E. (1984). Androgens and gender role behavior in girls with congenital adrenal hyperplasia (CAH). In G. J. DeVries, J. P. C. DeBruin, H. B. M. Uylings, & M. A. Corner (Eds.), *Progress in brain research*, Vol 61, pp 417-422.

Slijper, F. M. E., Drop, S. L. S., Moelnaar, J. C., & de Muinck Keizer-Schrama, S. M. P. F. (1998). Long-term psychological evaluation of intersex children. *Archives of Sexual Behavior* **27**, 125-144.

Snow, J. H., & Strope, E. E. (1990). Development of mental rotation matching abilities with children. *Developmental Neuropsychology*, **6**, 207-214.

Stein, A. H., Pohly, S., & Meuller, E. (1971). The influence of masculine and feminine, and neutral tasks on children's achievement behavior, expectancies of success, and attainment values. *Child Development*, **42**, 195-207.

Swaab, D. F., & Fliers, E. (1985). A sexually dimorphic nucleus in the human brain. *Science*, **228**, 1112-1115.

Thomas, J. R., & French, K. E. (1985). Gender differences across age and motor performance: A meta analysis. *Psychological Bulletin*, **98**, 260-282.

Thomas, J. R., & Thomas, K. T. (1988). Development of gender differences in physical activity. *Quest*, **40**, 219-229.

Thorne, B. (1993). *Gender play: Girls and boys in school.* New Brunswick, NH: Rutgers University Press.

Thurstone, T. G. (1962). Primary mental abilities for grades 6-9. Chicago: Science Research Associates.

Turner, J. W. (1975). Influence of neonatal androgen on the display of territorial marking in the gerbil. *Physiology and Behavior*, **15**, 265-270.

Vandenberg, S. G., & Kuse, A. R. (1978). Mental rotations: A group test of three-dimensional spatial visualization. *Perceptual & Motor Skills*, **47**, 599-604.

Vederhus, L., & Krekling, S. (1996) Sex differences in visual spatial ability in 9-year old children. *Intelligence*, **23**, 33-43.

Voyer, D., Nolan, C., & Voyer, S. (2000). The relation between experience and spatial performance in men and women. *Sex Roles*, **43**, 891-915.

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin*, **117**, 250-270.

Waber, D. P. (1977). Sex differences in mental abilities, hemispheric lateralization and rate of physical growth at adolescence. *Developmental Psychology*, **13**, 29-38.

Waber, D. P., Carlson, D., & Mann, M. (1982). Developmental and differential aspects of mental rotation in early adolescence. *Child Development*, **53**, 1614-1621.

Wada, J. A., Clarke, R., & Hamm, A. (1975). Cerebral hemispheric asymmetry in humans. *Archives of Neurology*, **32**, 239-246.

Warne, G. L., Faiman, C., Reyes, F. I., & Winter, J. S. D. (1977). Studies on human sexual development. V. Concentrations of testosterone, 17-hydroxyprogesterone and progesterone in human amniotic fluid through gestation. *Journal of Clinical Endocrinology and Metabolism*, **44**, 934-938.

Watson, N. V., & Kimura, D. (1991). Nontrivial sex differences in throwing and intercepting: relation to psychometrically-defined spatial functions. *Personality and Individual Differences*, **12**, 375-385.

Wechsler, D. (1949). *Manual for the Wechsler Intelligence Scale for Children*. New York: Psychological Corporation.

Wechsler, D. (1989). *Manual for the Wechsler Preschool and Primary Scale of Intelligence – Revised*. San Antonio, TX: Psychological Corporation.

Weinraub, M., Clemens, L. P., Sockloff, A., Ethridge, R., Gracely, E. & Myers, B. (1984). The development of sex role stereotypes in the third year: Relationships to gender labeling, gender identity, sex-typed toy preferences and family characteristics. *Child Development*, **55**, 1493-1503.

Whiting, B. B. & Edwards, C. P. (1988) *Children of Different Worlds: The Formation of Social Behavior*. Cambridge, MA: Harvard University Press.

Willemsen, E. W. (1974). Judgment of the vertical as a function of stimulus characteristics, age and sex. *Perceptual and Motor Skills*, **38**, 1344.

Williams, C. L., Cohen, R. A., & Meck, W. H. (1990). Development of sexually dimorphic spatial ability: neural sites of estradiol action. *Society Neuroscience Abstracts*. **20**, 472.

Williams, C. L., & Meck, W. H. (1991). The organizational effects of gonadal steroids on sexually dimorphic spatial ability. *Psychoneuroendocrinology*. **16**, 155-176.

Witkin, H. A., Goodenough, D. R., & Karp, S. A. (1967). Stability of cognitive-style from childhood to young adulthood. *Journal of Personality and Social Psychology*, **7**, 291-300.

Witt, S. D. (1997). Parental influence on children's socialization to gender roles. *Adolescence*, **32**, 253-259.

Woodward, J. L., Benedict, R. H. B., Roberts, V. J., Goldstein, F. C., Kinnner, K. M., Capruso, D. X., & Clark, A. N. (1996). Short-form alternative to the judgment of line orientation test. *Journal of Clinical and Experimental Neuropsychology*, **18**, 898-904.

Zucker, K. J., Bradley, S. J., Oliver, G., Blake, J., & Hood, J. (1996). Psychosexual development of women with congenital adrenal hyperplasia. *Hormones and Behavior*, **30**, 300-318.

Zucker, K. J. (2001). Biological influences on sexual differentiation. In: R.K. Unger (Ed.), *Handbook of the Psychology of Women and Gender*. (pp. 101-115). New York: Wiley.

APPENDICES

APPENDIX 1

PRE-SCHOOL ACTIVITIES INVENTORY

PRE-SCHOOL ACTIVITIES INVENTORY

Name: ....

Age: ....years........................months

Sex: M / F (delete as appropriate)

INSTRUCTIONS

THIS INVENTORY IS ABOUT THE EVERYDAY ACTIVITIES OF PRE-SCHOOL CHILDREN. IT IS IN THREE SECTIONS: TOY PREFERENCES, ACTIVITIES, AND CHARACTERISTICS. EACH QUESTION ASKS HOW FREQUENTLY THE CHILD PLAYS WITH PARTICULAR TOYS, ENGAGES IN PARTICULAR ACTIVITIES OR SHOWS PARTICULAR CHARACTERISTICS. THERE ARE FIVEPOSSIBLE ANSWERS: (N) NEVER, (HE) HARDLY EVER, (S) SOMETIMES, (O) OFTEN, (VO) VERY OFTEN. ANSWER EACH QUESTION BY CIRCLING THE RESPONSE WHICH BEST DESCRIBES THE CHILD.

E.G. N HE S O VO

PLEASE ANSWER ALL OF THE QUESTIONS. IF YOU ARE UNSURE ABOUT WHICH RESPONSE BEST DESCRIBLES THE CHILD FOR ANY OF THE QUESTIONS THEN PLEASE ANSWER ACCORDING TO THE RESPONSE WHICH SEEMS MOST APPROPRIATE.

Key : N = Never, He = Hardly Ever, S = Sometimes, O = Often, Vo = Very Often

PART 1 : TOYS: **Please answer these questions according to how often the child played with the following toys during the past month.**

1. Guns (or used objects as guns)……N HE S O VO
2. Jewellery……N HE S O VO
3. Tool Set……N HE S O VO
4. Dolls, doll's clothes or doll's carriage……N HE S O VO
5. Trains, cars or airplanes……N HE S O VO
6. Swords (or used objects as swords)……N HE S O VO
7. Tea set……N HE S O VO

PART 2: ACTIVITIES: **Please answer these questions according to how often the child engaged in the following activities during the past month.**

1. Playing house (e.g. cleaning, cooking)……N HE S O VO
2. Playing with girls……N HE S O VO
3. Pretending to be a female character (e.g. a princess)……N HE S O VO
4. Playing at having a male occupation (e.g. soldier)……N HE S O VO
5. Fighting……N HE S O VO
6. Pretending to be a family character (e.g. parent)……N HE S O VO
7. Sports and ball games……N HE S O VO
8. Climbing (e.g. fences)……N HE S O VO
9. Playing at taking care of babies……N HE S O VO
10. Showing an interest in real cars, trains and airplanes……N HE S O VO
11. Dressing up in girlish clothes……N HE S O VO

PART 3: CHARACTERISTICS: **Please answer these questions according to how often the child shows the following characteristics.**

1. Likes to explore new surroundings……N HE S O VO
2. Enjoys rough and tumble play……N HE S O VO
3. Shows interest in snakes, spiders or insects……N HE S O VO
4. Avoids getting dirty……N HE S O VO
5. Likes pretty things……N HE S O VO
6. Avoids taking risks……N HE S O VO

NOW PLEASE CHECK YOU HAVE ANSWERED ALL THE QUESTIONS

APPENDIX 2

TEST BATTERY

FORM A

1. SOCIAL MODELLING TASK
2. MENTAL ROTATIONS TASK
3. BALL THROW TASK
4. GENDER LABELLING TASK
5. JUDGMENT OF LINE ORIENTATION TASK
6. DART THROW TASK
7. VOCABULARY SUB-TEST
8. SELF AND SOCIAL REACTIONS TASK

- PARENTS TO COMPLETE PSAI AND NURTURING INTERESTS QUESTIONNAIRE

FORM B

1. SELF AND SOCIAL REACTIONS TASK
2. VOCABULARY SUB-TEST
3. DART THROW TASK
4. JUDGMENT OF LINE ORIENTATION TASK
5. GENDER LABELLING TASK
6. BALL THROW TASK
7. MENTAL ROTATIONS TASK
8. SOCIAL MODELLING TASK

- PARENTS TO COMPLETE PSAI AND NURTURING INTERESTS QUESTIONNAIRE

APPENDIX 3

SEX DIFFERENCES IN MENTAL ROTATIONS AND TARGETING ABILITY IN VERY YOUNG CHILDREN (STUDY SUBMITTED FOR PUBLICATION)

SEX DIFFERENCES IN MENTAL ROTATIONS ABILITY IN YOUNG CHILDREN: THEIR MAGNITUDE AND RELATIONSHIP TO CULTURE AND EXPERIENCE

Briony Fane[a], Zoe Collins[a] & Melissa Hines[a,b]

[a]City University, London

University of California, Los Angeles

Corresponding Author:

Briony Fane
Department of Psychology
City University
Northampton Square
London, EC1V 0HB

e-mail: B.A. Fane@city.ac.uk
Phone: 020 7040 8948

Briony A. Fane, Zoe Collins, and Melissa Hines, Department of Psychology, Cityu University, Northampton Square, London, EC1V 0HB. Corresponding Author: Briony A. Fane, e-mail: B.A.Fane@city.ac.uk

Melissa Hines, Department of Psychiatry & Biobehavioral Sciences, University of California, Los Angeles.

This research was supported in part by a USPHS grant # HD24542.

We are especially grateful to the children of Penwortham Primary School in south London, S.W.16, and to the children of The International School, Bergen, Netherlands who took part in the studies. We are also grateful to their teachers who kindly allowed us to use school facilities.

ABSTRACT

Two studies investigated the magnitude and causes of sex differences in children's mental rotations ability. Study 1 related performance on Marmor's (1975) mental rotations task to targeting performance. Study 2 related performance on a modification of the same task to masculine-typical play activities, and investigated cultural variability. Seventy, 3- 8 years olds participated in study 1 and forty-five 4-5 year olds participated in study 2. In both studies, boys performed better than girls on mental rotations. In study 1, boys were better at targeting than girls. However, for girls, better targeting performance was associated with better mental rotations performance. This was not the case for boys, where the correlation between targeting and mental rotations performance was not significant. In study 2, cultural differences were seen in mental rotations performance. Dutch children scored higher than British children. Cultural differences exceeded sex differences for mental rotations, but for masculine-typical play activities, the opposite was the case. Further, for girls, masculine-typical play activities related positively to mental rotations performance. Results suggest that sex differences in mental rotations can be seen in young children, that cultural differences are larger than sex differences for mental rotations but not for masculine-typical play activities, and that for girls, mental rotations competency relates to other play activities with a spatial component.

INTRODUCTION

Mental rotations is a component of visual spatial ability in which males' performance generally surpasses that of females' (Maccoby & Jacklin, 1974; Linn & Petersen, 1985; Halpern, 1992). At one time, researchers concluded that sex differences appeared only after puberty (Maccoby & Jacklin, 1974), but subsequent meta-analyses indicate that sex differences in mental rotations are present in pre-adolescence (Linn & Petersen, 1985, Voyer, Voyer & Bryden, 1995). In fact sex differences have been seen in children as young as 4-6 years, (Rosser, Rosser, Ensing, Glider & Lane, 1984; Levine, Huttenlocher, Taylor & Langrock, 1999), and near adult effect sizes have been reported in 9 year olds (e.g., Vederhus & Krekling,1996).

The work of Piaget and Inhelder (1971) might have prompted the conclusion that sex differences in mental rotations are unlikely to be seen in young children. They argued that the ability to imagine a rotation movement (kinetic imagery) coincides with the development of concrete operations, and found that children who could not perform concrete-operations were unable to invoke mental imagery. Children under the age of 9 years did not appear to understand that the shape of a rotating object remained the same throughout its movement around an axis, and therefore should not be able to perform mental rotations at above chance levels. Since young children were assumed to be unable to perform mental rotations tasks, it followed that sex differences would not be seen.

Marmor (1975), however, found conflicting results, and suggested that the apparent failure of pre-operational children to invoke mental imagery was due, at least in part, to Piaget and Inhelder's (1971) methodology. Using the Shepard and Metzler (1971) mental rotations paradigm, she observed that 5 year old children performed at levels better than chance. She also found significant linear trends for both 5 year olds and 8 year olds, (i.e., reaction times increasing with angular discrepancy), indicating a rotational strategy. Subsequently, Marmor (1977) found that 4 and 5 year olds used a rotational strategy, and that pre-training did not influence performance. Further, Marmor's (1977) investigation found no association between mental rotations performance and number conservation (thought to reflect concrete operations), providing additional evidence that concrete operations is not a pre-requisite for successful mental rotation.

Several variables may contribute to sex differences in mental rotations. For example, they may relate to sex differences in target-directed motor tasks, such as ball throwing and dart throwing, where a male advantage is apparent as early as 3 years of age (e.g., Jardine & Martin, 1983; Watson & Kimura, 1991; Thomas & French, 1985; Lee, Fant, Life, Lipe & Carter, 1978; Kolakowski, 1974). According to Pellizer and Georgopoulos (1993) the mental rotations phenomenon extends to motor processes, particularly to representations of the intended direction of movement. Moreover, Anastasi (1981) proposes that males excel at target-directed motor tasks because they employ a type of spatial functioning using speed and co-ordination of gross bodily movements.

Differential exposure to spatial play activities may also contribute to the male advantage in spatial tasks. Baenninger and Newcombe (1989) found a positive correlation between play with boys' toys, which are more spatial in nature, and mental rotations. Further, Voyer, Nolan and Voyer (2000) found that adults who reported a preference for play with spatial toys as children showed improved performance on a mental rotations task. According to Block (1983), boys' toys are more likely than girls' toys, to encourage manipulation and enhance spatial ability. Block (1983) also suggests that the differential exposure boys and girls have to male versus female stereotyped toys predisposes them toward different problem solving experiences which in turn may influence cognitive development.

Cultural differences may also relate to sex differences in mental rotations abilities. Boys' and girls' experience with sex stereotyped toys is said by some to be "pan-cultural" (e.g., Whiting & Edwards, 1988). However, Turner, Gervai and Hinde (1993) found that Hungarian children of both sexes engaged more frequently in male-typical activities than British children. Further, Emmanuelsson and Svensson (1986) found that 13-year old Swedish girls score similarly to boys on a test of mental rotations. Greater sex differences in spatial tasks have also been found in cultures that are more authoritarian and adhere to more rigid sex roles (e.g., Sherman, 1967; Witkin, 1967).

We conducted two studies examining sex differences in mental rotations performance in very young children. Study 1 examined mental rotations in children as young as 3 years, for whom sex differences in mental rotations have not yet been documented. In addition, performance on a target directed motor task (ball throwing) was assessed to ascertain its relation to mental rotations ability. Study 2 tested children as young as 4 years, again exploring sex differences in mental rotations. This study also examined the relationship of mental rotations to masculine-typical play activities and to cultural background.

STUDY 1

The specific aims of Study 1 were, 1) to examine the existence and magnitude of sex differences in mental rotations and targeting in children as young as 3 years; and, 2) to examine the relationship between targeting performance and mental rotations performance in young children.

METHOD

Participants

70 children (35 boys and 35 girls) attending a primary school in south London participated in the study. The children were thirty-one, 3-5 year olds (16 boys and 15 girls), with a mean age of 4.6, (range 3 years, 4 months to 5 years, 8 months) and thirty-nine, 6-8 year olds (19 boys and 20 girls) with a mean age of 7.4, (range 6 years, 2 months to 8 years, 9 months). Participating children were selected at random by class teachers who drew names out of a hat. The sample was representative of a south-west London community, being predominantly middle and lower middle class and ethnically diverse.

Materials and Procedure

Marmor's (1975) mental rotations task was used. It requires the child to view a pair of simultaneously presented figures and decide whether they are the 'same' or 'different', regardless of the orientation of one of the pair of figures around a horizontal axis. This task is well suited for investigating mental rotations ability in very young children because it requires no motor output and the stimuli (Panda bears) are appealing enough to hold a child's attention. A ball-throw task was used to test target-direct motor ability (targeting). Vocabulary sub-tests from the age-appropriate

Wechsler Intelligence scales were used to measure general intellectual ability for control purposes.

Marmor Mental Rotations Task (Marmor, 1975, 1977) – Experimental procedures for this task followed those of Marmor (1975)[1], with three alterations: 1) the test stimuli were presented as Panda Bears pasted into 8.27" by 11.69" folders, instead of Panda Bears standing upright in front of a plywood backdrop; 2) the experimental procedures and test trials were carried out in one session, instead of extending over 4 days; and, 3) responses were verbal throughout the training procedures and test trials, instead of manual (i.e., pressing levers that indicated 'same' and 'different'). Procedures included four parts: 1) pre-training for same-different judgments, 2) criterion test for same-different judgments, 3) mental rotations training, and, 4) the experimental mental rotations task.

3 sets of stimuli were used. The first set consisted of 2 yellow cards, 8.27" by 11.69", with Bears in the upright position (one with a right arm raised and one with a left arm raised), and one blank card. A separate cut-out Panda Bear could be placed on the blank card. This allowed demonstration of the concepts of matched ('same') versus reflected ('different') stimuli. (These stimuli were used for the first two parts of the procedure, i.e., pre-training and criterion test for same-different judgments). In addition, the cut-out Panda Bear could be rotated on the blank 8.27" by 11.69" card and was also used for the third part of the procedure, the mental rotations training ("tipping over"). The second set of stimuli was also used in the mental rotations training and consisted of four folders 8.27" by 11.69" with two Panda Bears in each,

---

[1] Descriptions of procedures are found in Marmor (1975, pp. 551-552).

set in the upright position. In two of the folders, the Panda Bears are waving with the same arms, and in the other two folders the Panda Bears are waving with different arms (see Fig.1a where the Panda Bears are in the upright position and waving with different arms).

Fig. 1 here

The third set of stimuli consisted of twenty 8.27" by 11.69" folders, each containing two 8" x 4" Panda Bear figures, which were used for the experimental mental rotations task. Panda Bears on the inside left of each folder were fixed in an upright position. 10 folders had upright Panda Bears with their left arms raised and 10 had upright Panda Bears with their right arms raised. On the inside right of each folder the Panda Bears were fixed at one of 5 angles (0^0, 30^0, 60^0, 120^0, and 150^0). Ten of the rotated Panda Bears had the opposite arm raised to that of the Panda Bear on the inside left of each folder (different trials), and 10 had the same arm raised (same trials). For each angle of orientation, four sets of two Panda Bears were presented: left-left, left-right, right-right and right-left. (See Fig. 1b where the 2 Panda Bears are the 'same'. The Panda Bear on the left is upright with its left arm raised and the Panda Bear on the right has the same arm raised but is rotated to 150^0). These stimuli were used for the fourth part of the procedure – the experimental mental rotations task.

The experimental mental rotations task began approximately 30 seconds following the mental rotations training and practice session. The first folder was placed unopened in front of the child. The experimenter explained that inside each folder were two Panda Bears, and that sometimes they would be waving with the same arms and sometimes with different arms, and that some would be 'tipping over', but that it did not matter if they were 'tipping over'. What was important was for the children to tell the researcher as quickly and as accurately as possible, whether the Panda Bears were waving with the 'same' or 'different' arms. Children were told that the time they took to do this would be recorded so that the difference between boys and girls could be measured. The dependent measure was the number of correct judgments at each angle for 'same' and 'different' stimuli. The task required approximately 20-25 minutes to complete.

Targeting Task - A ball throwing task was used as a measure of children's target-directed motor ability (targeting). The target consisted of a 26"x 26" square of backed black Velcro. A pink and green Velcro flower (12" in diameter) was positioned in the middle of the square and it had a black center dot (1½" in diameter). Tennis balls, designed to stick to Velcro, were thrown at the target, which was viewed from a distance of 2.25 meter's, subtending an angle of 16.35°. Each child was asked to aim at the center dot on the target using the hand with which they were most comfortable. 3 practice trials and 20 test trials were given. All throws were overarm. The dependent measure was the mean distance of the thrown ball from the center of the target on the 20 test trials.

Vocabulary Task - Vocabulary sub-tests from the Wechsler Pre-school and Primary Scale of Intelligence (WPPSI) (for 3-5 year olds), and the Wechsler Intelligence Scale for Children (WISC) (for 6-8 year olds), provided a measure of general intelligence. They were administered as specified in the Wechsler Manuals. These measures were included to ensure that any observed group differences in mental rotations performance did not reflect underlying differences in general intelligence.

RESULTS

Means (standard deviations in parentheses) for total scores on all the tests are presented as a function of age and sex in Table 1.

Scaled Vocabulary Score - Vocabulary scores were analyzed using a two-way (2 x 2) between-subjects analysis of variance (ANOVA). The factors were, sex (boys and girls) and age (3-5 year olds and 6-8 year olds). No main effect of sex was found, $\underline{F}$ (1, 70) = 1.382, $\underline{p}$ = .244, indicating comparability in general intelligence for male and female groups. However, there was a significant main effect of age $\underline{F}$ (1, 70) = 4.947, p < .03. 3-5 year olds performed better than 6-8 year olds. This may be explained by the use of different Wechsler sub-tests for the two groups.

Table 1 here

Marmor Mental Rotations Task - A 4-way (angle of orientation x stimulus type x sex x age) mixed design Analysis of Covariance (ANCOVA) was used on the data, with vocabulary score entered as the covariate. The within-subject factors were angle of orientation (0^0, 30^0, 60^0, 120^0, & 150^0) and stimulus type (whether Bears were waving with the 'same' or 'different' arms). The between-subjects factors were sex (boys and girls) and age (3-5 year olds and 6-8 year olds). Significant main effects were seen for all factors, except stimulus type, $\underline{F}$ (1, 66) = 0.89, $\underline{p}$ = .76). Boys' performance was better than girls', $\underline{F}$ (1, 66) = 4.94, $\underline{p}$ < .03. The performance of 6-8 year olds' was better than 3-5 year olds', $\underline{F}$ (1, 66) = 14.34, $\underline{p}$ < .001, and some angles of rotation were more difficult than others $\underline{F}$ (4, 260) = 2.834, $\underline{p}$ = .025. There was no sex by age interaction indicating that sex differences were stable across 3-5 and 6-8 year olds. There were no other significant interactions.

Targeting Task - A 2-way, sex (boys and girls) and age (3-5 year olds and 6-8 year olds) between subjects ANOVA revealed main effects of sex $\underline{F}$ (1, 66) = 36.57, $\underline{p}$ <. 001 and age $\underline{F}$ (1. 66) = 36.28, $\underline{p}$ <. 001 on targeting performance. Boys' performance was significantly better than girls', and 6-8 year olds performed significantly better than 3-5 year olds (see Table 1). There was no age by sex interaction, $\underline{F}$ (1, 66) = 0.45, $\underline{p}$ = .502, again indicating that the sex difference in targeting was stable across the two age-groups.

Effect size indexes for vocabulary, mental rotations and targeting by age-group and by sex can be seen in Table1.

Correlations - Pearson's correlation coefficients were carried out between mental rotations and targeting for each sex. Targeting did not correlate significantly with performance on the mental rotations task for boys, $\underline{r}$ = -.114, $\underline{p}$ = .515, but did correlate significantly with performance on mental rotations in girls, $\underline{r}$ = -.411, $\underline{p}$ = .014. Girls who were better at targeting were also better at mental rotations.

STUDY 2

Both Dutch and British children were tested in study 2. Studying two cultures allowed us to compare the magnitude of sex differences and cultural differences in gender-linked traits.

The specific aims of Study 2 were: 1) to examine further the existence and size of sex differences in mental rotations performance in very young children; 2) to determine if masculine play activities predict mental rotations' performance; and, 3) to assess whether sex differences are of similar magnitude in different cultures.

METHOD

Participants

45 children (age range: 4 years and 1 month to 5 years and 4 months) attending a European school in Holland participated. The subjects were 23 Dutch children (11 girls and 12 boys) and 22 British children (12 girls and 10 boys). The teacher randomly selected children from the class register to participate in the study.

Materials and Apparatus

In study 2, like study 1, the Marmor (1975) task was used. However its application was modified (see below). Study 2 also included a naturalistic observation of children's engagement in masculine-typical play activities on the school playground, in order to examine the relationship between these activities and mental rotations performance.

Mental Rotations Task – The main stimulus was a clock face, without hands, with the numbers 1-12 set at the correct time positions. It measured 23.6 cms in diameter and was constructed from cardboard. A black arrow underneath the clock pointed towards the centre. The arrow was fixed on a spindle so that it could be rotated to the numbers around the clock. A cut-out Bear was used for rotation and could be placed on top of the clock, again fixed with a spindle, to allow rotation. 10 response cards were constructed measuring 8.2 x 25.7 cms. Each showed 3 different orientations of the Bear to include 2 incorrect orientations and 1 correct orientation.

Children were tested individually in a quiet area outside the classroom. They were was asked to play a game with the Investigator. They were first shown the clock face with the rotating arrow and a demonstration was provided of the arrow moving around the outside of the clock to point to any of the numbers. Children were then introduced to the Bear, and was shown how it could be placed on the spindle in the middle and rotated around the clock face. They then had an opportunity to rotate the Bear and the arrow and to observe it pointing to the numbers on the clock face.

Following this, children were given 5 learning trials. The Bear was placed on the spindle and remained in the upright position pointing to the 12 on the clock. The arrow was then rotated to each of the 5 angles of orientation (90^0. 120^0, 180^0, 270^0 and 300^0) in turn. At each angle children were asked to indicate the position of the Bear if its head was pointing to the arrow. No response boards were used for the learning trials. the Investigator indicated verbally whether responses were correct or not. If a child did not indicate the correct position. the bear on the clock was rotated to the correct position for them to see.

The test trials began immediately after the learning trials. The Bear was rotated twice to each of the 5 angles of orientation. Trials were given in a fixed random order.

The arrow was rotated by the experimenter to the first number while the Bear remained in the upright position on the front of the clock face. Children were asked to imagine rotating the Bear to the position of the arrow. 6 seconds were given to do this and then the appropriate response card was presented and children were asked to indicate (by pointing) which Bear they perceived to be the correct one. There was no time limit for responding. The same procedure was used for each trial. The dependent measure was the number of correct responses children gave for the 10 trials.

Masculine Play Activities – Six masculine play activities were assessed on the playground. These were, playing with building blocks, racing on bikes, using a climbing frame, playing football, playing with toy cars and playing chase. The activities were chosen based on ratings of 25 activities. The 6 chosen for the playground assessment were those rated as most male gender stereotyped by 50 undergraduate students. Four of the six activities (blocks, climbing, football and playing cars) are consistent with spatial items in Bates and Bentler's (1973) Child Games Inventory, and five of the six (blocks, climbing, riding toys, football, playing with cars) were the same as those identified as spatial toys by Voyer, Nolan and Voyer (2000) in their spatial activities inventory. Dutch and British children were observed during recess 4 times each over a two day period, for 15 minutes each time. The dependent measure was the number of times that each child engaged in any of the 6 masculine play activities.

RESULTS

Table 2 here

Mental Rotations Task - A 3-way (sex x culture x angle of rotation) mixed design ANOVA was carried out on the data. The between-subjects factors were sex (boys and girls) and culture (Dutch and British). The within-subjects factor was angle of rotation (90^0, 120^0, 180^0, 270^0 and 300^0). ANOVA indicated significant main effects for all factors. Boys achieved significantly more correct responses than girls, F (1, 41) = 4.267, p = .045. Dutch children achieved significantly more correct responses than British children, F (1, 41) = 11.063, p = .002 and there were significant differences in number of correct responses across the angles of rotation, F (4. 164) = 9.233, p <.001. No interactions were significant (see Table 2).

Masculine Play Activities - A 2-way, sex (boys and girls) by culture (British and Dutch children) ANOVA indicated a significant main effect of sex, F (1, 41) = 24.94, p < .001 such that boys engaged in significantly more masculine play activities than girls did. The main effect of culture was not significant, F (1, 41) =1.02, p = .319), nor was the interaction between sex and culture, F (1, 41) = .559, p = .459) (see Table 2).

Effect size indexes using Cohen's d statistic (see Cohen, 1977) were calculated for scores on both mental rotations and masculine-play activities, by sex and culture. The effect size for sex differences in mental rotations was moderate (0.6), and for the sex difference in masculine play activities, the effect size was large (1.52). The effect size for cultural differences in mental rotations was large (1.07), but for cultural differences in masculine-play activities, the effect size was small (0.34).

To determine the relationship between masculine-play activities and mental rotations, correlation coefficients (using Pearson's r) were calculated for each sex. A significant positive correlation was observed among girls between masculine play activities and total number of correct responses on mental rotations, r = .391, p = .04 (one-tailed). For boys, however, no significant correlation was found, r = .211, p = .347.

DISCUSSION

A major purpose of our study was to examine the nature and magnitude of sex differences in mental rotations ability in very young children. Our results provide information confirming sex differences in mental rotations in young children, and indeed the ability of young children of both sexes, to perform mental rotations, and lends further support to the idea that concrete operations are not necessarily required for this. These findings are similar to those from other studies investigating mental rotations ability in pre-adolescent children (Levine et al 1999; Vederhus & Krekling, 1996, Rosser et al, 1984).

In study 1, we found sex differences of approximately 1.0 standard deviation in children aged 3-5 years, and of approximately 0.8 standard deviation in children aged 6-8 years. The magnitude of the sex differences in these young children is very similar to that seen on mental rotations in adults ($d = 0.9$) (e.g., Masters & Sanders, 1998; Linn & Petersen, 1985, Voyer et al, 1995). The sex difference seen for mental rotations in study 2, although significant, was smaller ($d = 0.6$). This difference in the magnitude of the sex difference may reflect differing levels of complexity for each task. The modification of the Marmor task in study 2 made it somewhat easier to perform. Further, in study 1, children had to respond as quickly and accurately as possible, whereas in study 2 no time pressure was imposed. Goldstein, Haldane and Mitchell (1990), argue that the performance of females more closely resembles that of males under unspeeded conditions. Moreover, Resnick (1993), found that the magnitude of the sex difference was reduced in unspeeded mental rotations tests in adult subjects.

We also examined other traits that differ for girls and boys and have been hypothesized to relate to mental rotations. When the pattern of correlations was investigated separately for boys and girls, we found systematic differences in the relationships between mental rotations and targeting and mental rotations and masculine play, such that they were significantly positive for girls only. In examining the relationship between mental rotations and targeting, the association we found for girls may in part be explained by the fact that targeting and mental rotations have some overlapping requirements, even though they appear to measure somewhat different spatial abilities. In contrast, for boys the absence of any relation suggests that there is no common mechanism, rather, that both skills may be within the spatial domain, but are discrete.

These findings differ from those of Watson and Kimura (1991) who observed no association between throwing accuracy and performance on a mental rotations task, in either young adult males ($r = .12$) or females ($r = -.08$). The mental rotations task they used, however, was a modification of a measure originally developed by Stefanatos, Bucholz and Miller (1998), which did not report on sex differences. Thus it is possible that the lack of any interrelation may reflect task differences.

The relationship between spatial toy play and mental rotations performance has been investigated in prior studies (e.g., Newcombe, Bandura & Taylor, 1983; Voyer, Nolan & Voyer, 2000) on the basis that such play may account (at least in part) for the sex difference in ability. As for mental rotations and targeting, we found a significant positive correlation between mental rotations and masculine play activities (which are considered to be spatial in nature) only in girls. This suggests that for girls, increased exposure to masculine play leads to increased mental rotations performance. This relationship was not evident in boys. Other studies have linked experience with spatial play activities to the development of spatial skills in both boys and girls (e.g., Baenninger & Newcombe, 1989). In our study, the correlations of mental rotations, targeting performance and masculine-typical play, although not significant for boys were in the same direction as for girls. Thus the difference may be one of degree, with girls more influenced than boys by the activities they engage in. One potential explanation for the difference between boys and girls may be that girls do not participate in masculine play activities as much as boys and so benefit more than boys when they do participate in them. Alternatively, it has been suggested that testosterone contributes to the development of mental rotations performance (e.g, Hines, 1990; Grimshaw, Sitarenios & Finegan, 1995; Gouchie & Kimura, 1991; but see also Hines, 2001). If so, girls, may be less affected by biological contributions to spatial performance than boys, and so may be more likely to show improvements from spatial training via exposure to masculine play activities.

Finally, ours is the first study we know of that compares the magnitude of cultural differences to that of sex differences. Silverman and Phillips (1996) found that effect sizes for sex differences in mental rotations performance were large for both Japanese (1.36) and Canadian (1.19) young adults, but did not comment on the size of the cultural difference. We estimated this effect size from their data, using Cohen's d statistic (taking the difference between the two mean scores for Japanese and Canadian students, and dividing by the pooled standard deviation). The magnitude of this difference (Japanese students outperforming Canadian students), was large (d = 1.15). Like Silverman and Phillips (1996), we also found that the magnitude of the cultural difference in mental rotations was large (d = 1.09) with Dutch children outperforming British children. However, we found that the magnitude of the sex difference in mental rotations on the task used, was moderate (d = 0.6). The opposite was the case for masculine-typical play activities, where the magnitude of the sex difference was large (1.52) and the magnitude of the cultural difference was small (0.34). Given that the effect sizes for sex differences and cultural differences in masculine-play and mental rotations differ, it seems likely that sex differences in these behaviors have somewhat different causes.

In summary, the results of our studies demonstrate several important points regarding sex differences in mental rotations. First, a sex difference favoring males is evident in children as young as three years of age. Second, sex differences in mental rotations performance are similar in size both before and after puberty. Third, the absence of a sex difference on the Wechsler vocabulary sub-test indicates that the male advantage in mental rotations is not caused by a difference in general intellectual ability. Fourth, environmental influences, including experience with masculine-typical activities, appear to benefit mental rotations performance in females more than in males. And fifth, large cultural differences in mental rotations abilities suggests that cultural factors affect children's mental rotations performance.

REFERENCES

Anastasi, A. (1981). Sex differences: Historical perspectives and methodological implications. Developmental Review, **1**, 187-206.

Baenninger, M., & Newcombe, N. (1989). The role of experience in spatial test performance: A meta-analysis. Sex Roles, **20**, 327-344.

Bates, J., & Bentler, P. (1973). Play activities of normal and effeminate boys. Developmental Psychology, **9**, 20-27.

Cohen, J (1977). Statistical Power for the Behavioral Sciences (2nd ed.). Hillsdale, NJ:Erlbaum.

Collaer, M., and Hines, M. (1995) Human behavioral sex differences: A role for gonadal hormones? Psychological Bulletin, **118**, 55-107.

Emmanuelsson, I., & Svensson, A. (1986) Does the level of intelligence decrease: A comparison between thirteen-year olds tested in 1960, 1966 and 1980. Scandinavian Journal of Educational Research, **30**, 25-27.

Goldstein, D., Haldane, D., & Mitchell C. (1990). Sex differences in visual-spatial ability: The role of performance factors. Memory & Cognition, **18**, 546-550.

Gouchie, C. and Kimura, D. (1991). The relationship between testosterone levels and cognitive ability patterns. Psychoneuroendocrinology, **16**, 323-334.

Grimshaw, G. M., Sitarenios, G., & Finegan, J-A. K. (1995). Mental rotation at 7 years: relations with prenatal levels play experiences. Brain and Cognition, **29**, 85-100.

Halpern, D. (1992). Sex differences in cognitive abilities. Lawrence Erlbaum Associates, Hillsdale, New Jersey. (2nd ed).

Hines, M. (1990). Gonadal hormones and human cognitive development. In J.Balthazart (Ed), Brain & Behavior in Vertebrates 1: Sexual differentiation, neuroanatomical aspects, neurotransmitters, and neuropeptides (p.p. 51-63). Basle, Switzerland: Karger

Hines, M. (2001). Gonadal Hormones and sexual differentiation of human behavior: Effects on psychosexual and cognitive development. In Sexual Differentiation of the Brain (A. Matsumoto ed.) CRC Press New York.

Jardine, R. & Martin, N. G. (1983). Spatial ability and throwing accuracy. Behavior Genetics, **13**, 331-340.

Kail, R., Carter, P., & Pellegrino, J. (1979). The locus of sex differences in spatial ability. Perception and Psychophysics, **26**, 182-186.

Kimura, D. (1992). Sex differences in the brain. Scientific American, **267**, 80-87.

Kowalski, D., & Malina, R. M. (1974). Spatial ability, throwing accuracy and man's hunting heritage. Nature, **251**, 410-412.

Lee, A., Fant, H., Life, M.L., Lipe, L., & Carter, J.A. (1978). Field independence and performance on ball-handling tasks. Perceptual and Motor Skills,**46**, 439-442.

Levine, S. C., Huttenlocher, J., Taylor, A., & Langrock, A. (1999). Early sex differences in spatial skill. Child Development, **35**, 940-949.

Linn, M. C., & Peterson, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. Child Development, **56**, 1479-1498.

Maccoby E. E., & Jacklin, C. N. (1974). The Psychology of Sex Differences. Stanford: Standford University Press.

Marmor, G. S. (1975). Development of kinetic images: When does child first represent movement in mental images? Cognitive Psychology, **7**, 548-559.

Marmor, G. S. (1977). Mental rotation and number conservation: are they related? Developmental Psychology, **13**, 320-325.

Masters, M. S. & Sanders,, B. (1993) Is the gender difference in mental rotation disappearing? Behavior Genetics, **23**, 337-341.

Newcombe, N., Bandura, M., & Taylor, D. (1983). Sex differences in spatial ability and spatial activities. Sex Roles, **9**, 377-386.

Pellizer, G., & Georgopolous, A. P. (1993). Mental rotation of the intended direction of movement. Current Directions in Psychological Science, **2**, 12-17.

Piaget, J., & Inhelder, B. (1971). Mental Imagery in the child. New York: Basic Books.

Resnick, S. M. (1993). Sex differences in mental rotations: An effect of time limits? Brain and Cognition, **21**, 71-79.

Rosser, R.A., Ensing, S.S., Glider, P.J., & Lane S. (1984) Information-processing analysis of children's accuracy in predicting the appearance of rotated stimuli. Child Development, **55**, 22-4-2211.

Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. Science, **171**, 701-703.

Sherman, J.A. (1967) Problem of sex differences in space perception and aspects of intellectual functioning. Psychological Review, **74**, 290-299.

Silverman, I., & Phillips, K. (1996). Homogeneity of effect sizes for sex across spatial tests and cultures: Implications for hormonal theories. Brain and Cognition, **31**, 90-94.

Stefanatos, G.A., Bucholz, E.S., & Miller N.F. (1998) Mental Rotation: A task for the assessment of visuospatial skills in children. Perceptual and Motor Skills, **86**, 527-536.

Thomas, J.R., & French, K.E. (1985). Gender differences across age and motor performance: A meta analysis. Psychological Bulletin, 98, 260-282.

Turner, P. J., Gervai, J., & Hinde, R.A (1993). Gender-typing in young children – preferences, behavior and cultural differences. British Journal of Developmental Psychology, **11**, 323-342.

Vederhus, L., & Krekling, S. (1996) Sex Differences in visual spatial ability in 9-year old children. Intelligence, **23**, 33-43.

Voyer, D., Nolan, C., & Voyer, S. (2000). The Relation Between Experience and Spatial Performance in Men and Women. Sex Roles, **43**, 891-915.

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. Psychological Bulletin, **117**, 250-270.

Watson, N.V., & Kimura, D. (1991). Nontrivial sex differences in throwing and intercepting: relations to psychometrically-defined spatial functions. Personality and Individual Differences, **12**, 375-385

Whiting , B.B. & Edwards, C.P. (1988) Children of Different Worlds: The Formation of Social Behavior. Cambridge, MA: Harvard University Press.

Witkin, H. A. (1967) A cognitive style approach to cross-cultural research. International Journal of Psychology, **2**, 233-250.

Table 1 – Means (SDs) and effect sizes (Cohen's d) for total scores on vocabulary, mental rotations, and targeting, by age and sex, for children in study 1.

Wechsler Vocabulary[a]			Mental Rotations[a]			Targeting[b]		
3-5 year olds (16 boys and 15 girls)								
Boys	Girls	d	Boys	Girls	d	Boys	Girls	d
13.29	12.00	0.3	12.63	10.64	0.80	4.06	5.34	1.66
(3.26)	(3.67)		(2.63)	(2.34)		(0.83)	(0.71)	
6-8 year olds (19 boys and 20 girls)								
Boys	Girls	d	Boys	Girls	d	Boys	Girls	d
11.20	10.70	0.16	14.89	13.10	1.0	3.04	4.06	1.23
(3.49)	(2.64)		(1.49)	(2.26)		(0.96)	(0.70)	

Legend: [a] = higher scores indicate better performance: [b] = lower scores indicate better performance.

Fig. 1 Mental Rotations performance by age and sex

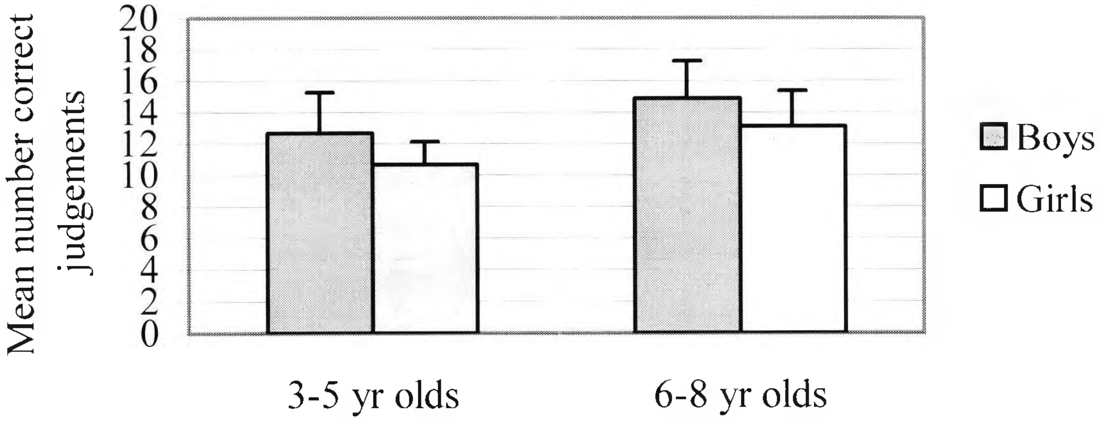


Fig. 2 Targeting Performance by age and sex

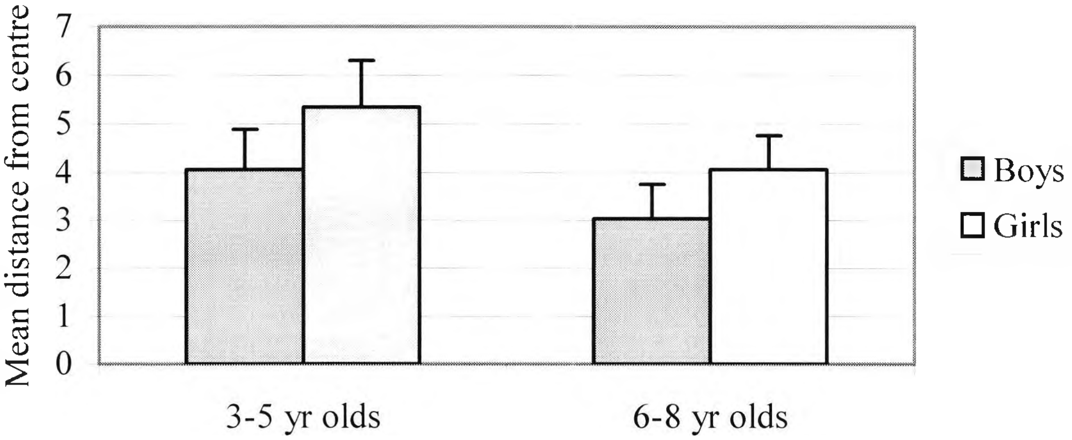


Table 2. Mean response accuracy for degree of rotation by nationality and sex for children in Study 2.

		Masculine Play Activities	Mental Rotations[a]
Dutch	Boys (N= 12)	3.08 (1.08)	7.25 (1.14)
	Girls (N= 11)	1.73 (1.01)	6.64 (1.21)
English	Boys (N=10)	3.00 (1.25)	6.00 (1.56)
	Girls (N=12)	1.17 (0.94)	4.92 (1.78)

Data are means (standard deviations in parentheses) for total scores on mental rotations

a = higher scores denote better performance

Fig. 3 Mental Rotations Performance by nationality and sex

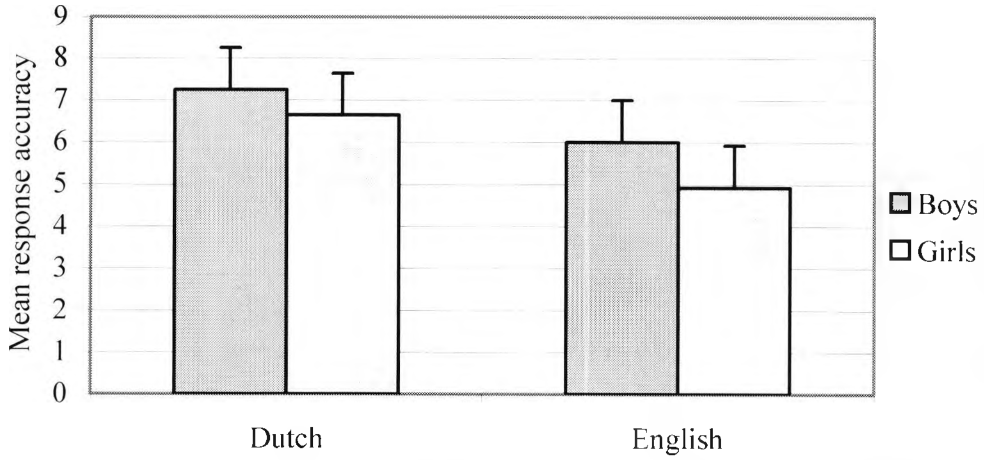
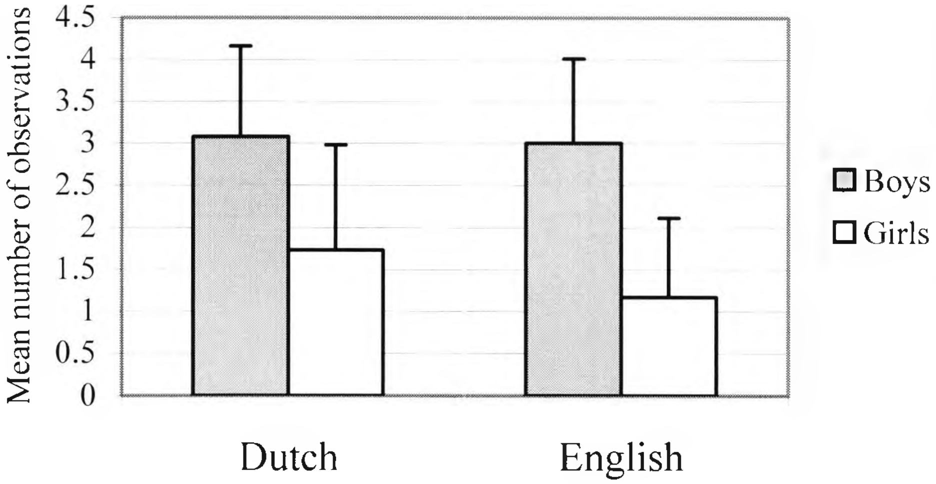
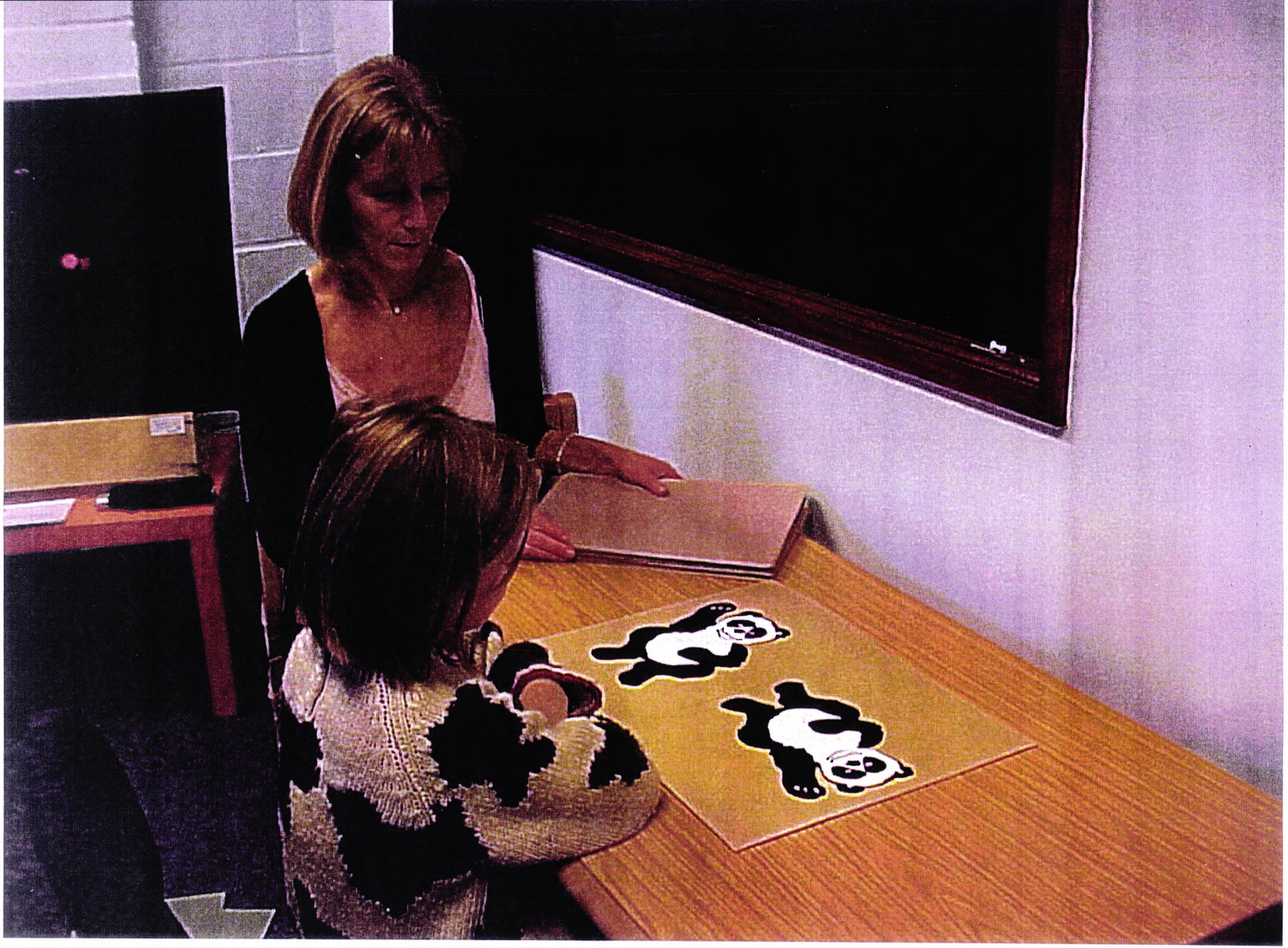


Fig. Engagement in masculine play activities by nationality and sex



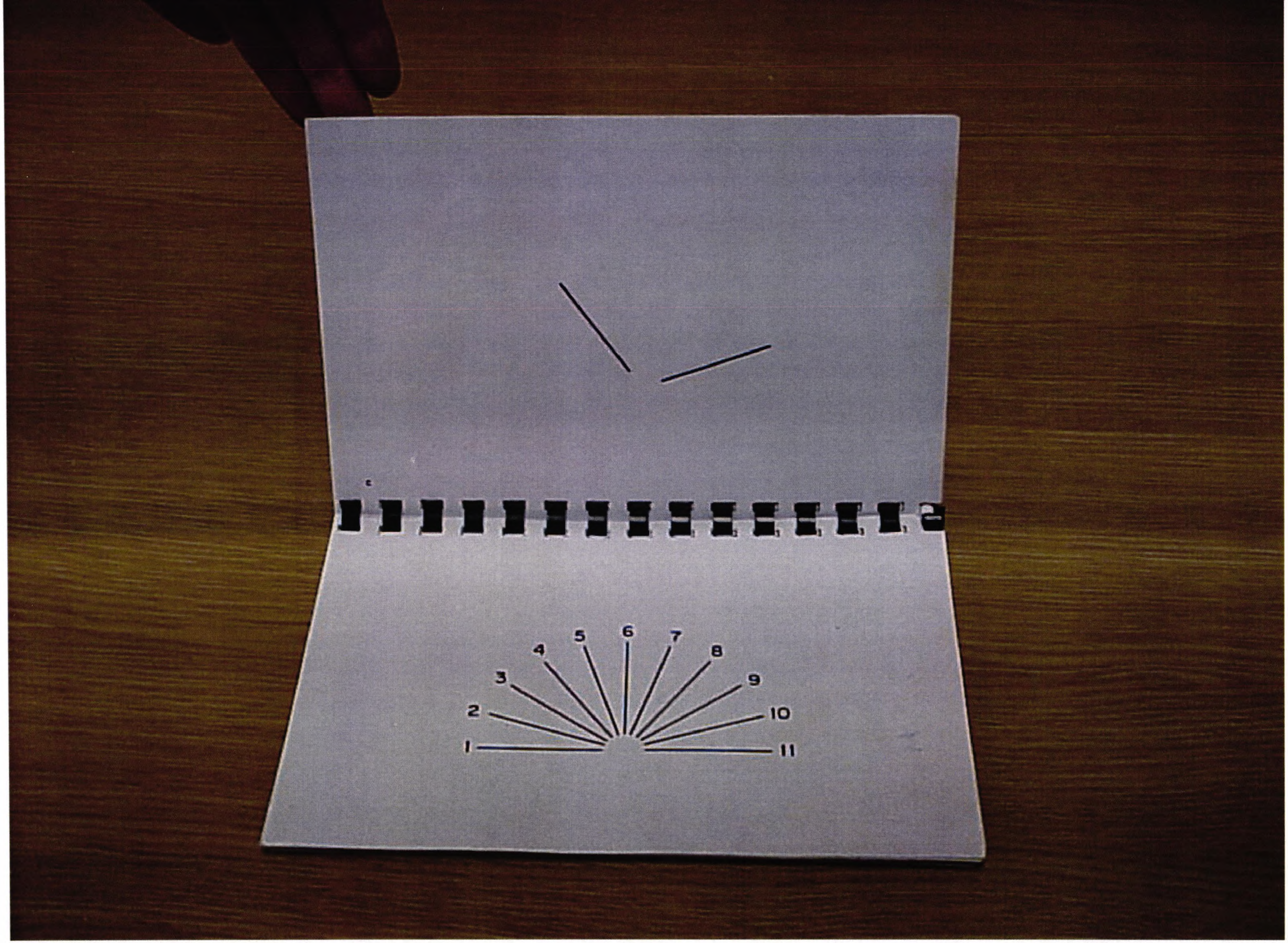
APPENDIX 4

EXAMPLE OF MENTAL ROTATIONS TEST



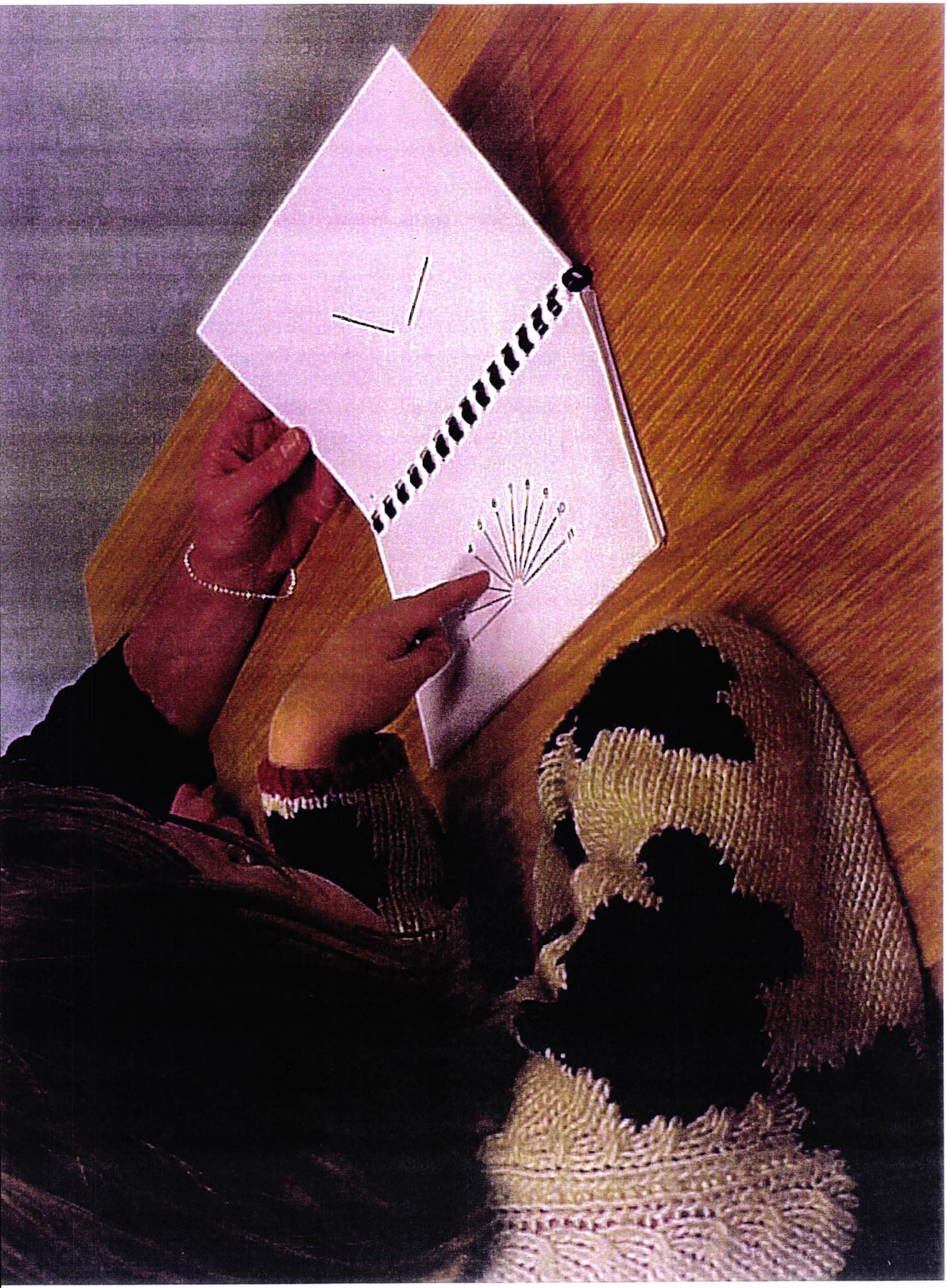
APPENDIX 5

JUDGMENT OF LINE ORIENTATION (SHORT FORM) ODD


1
2
3
4
5
6
7
8
9
10
11

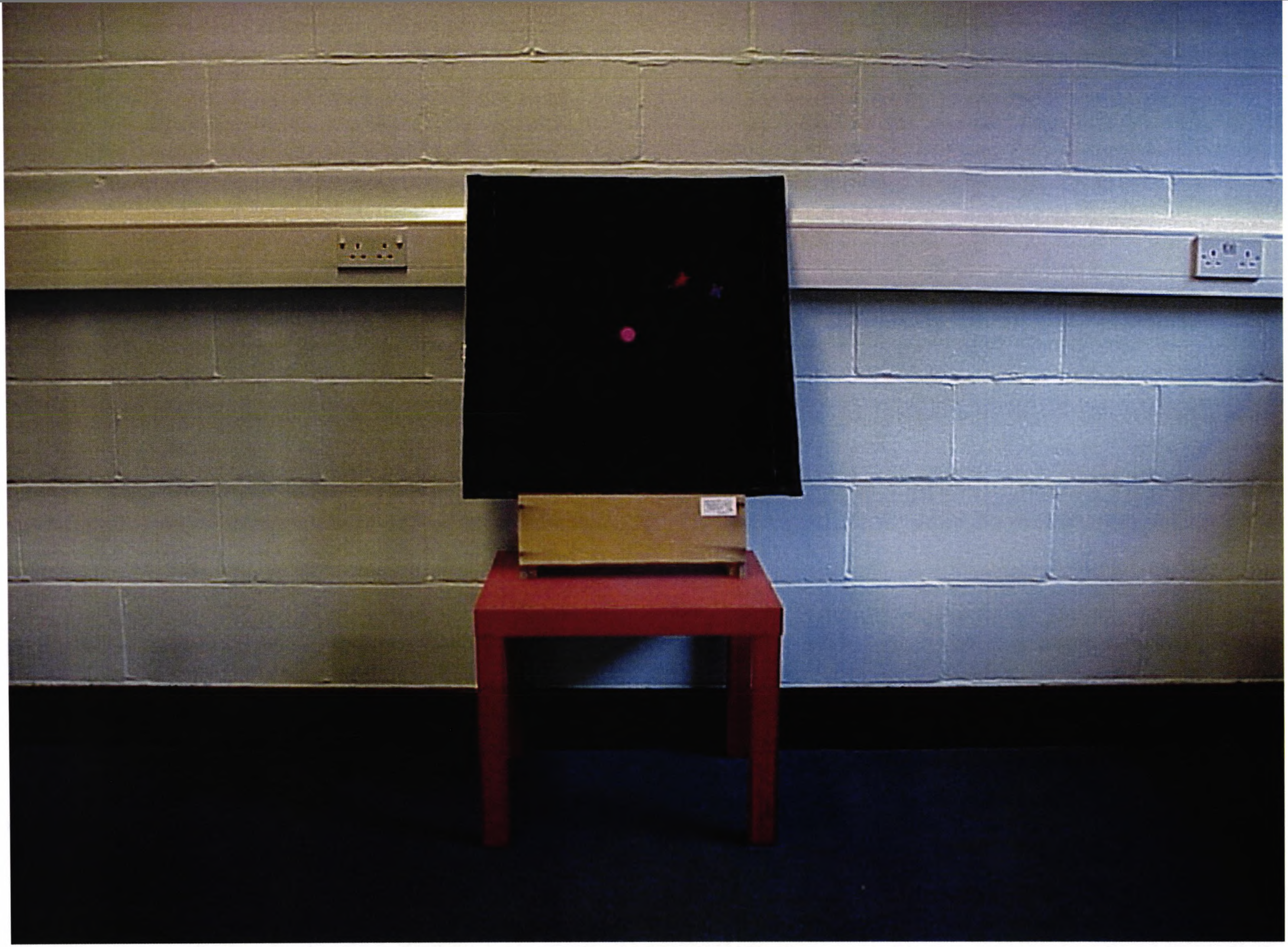
APPENDIX 6

EXAMPLE
JUDGMENT OF LINE ORIENTATION (SHORT FORM)
ODD



APPENDIX 7

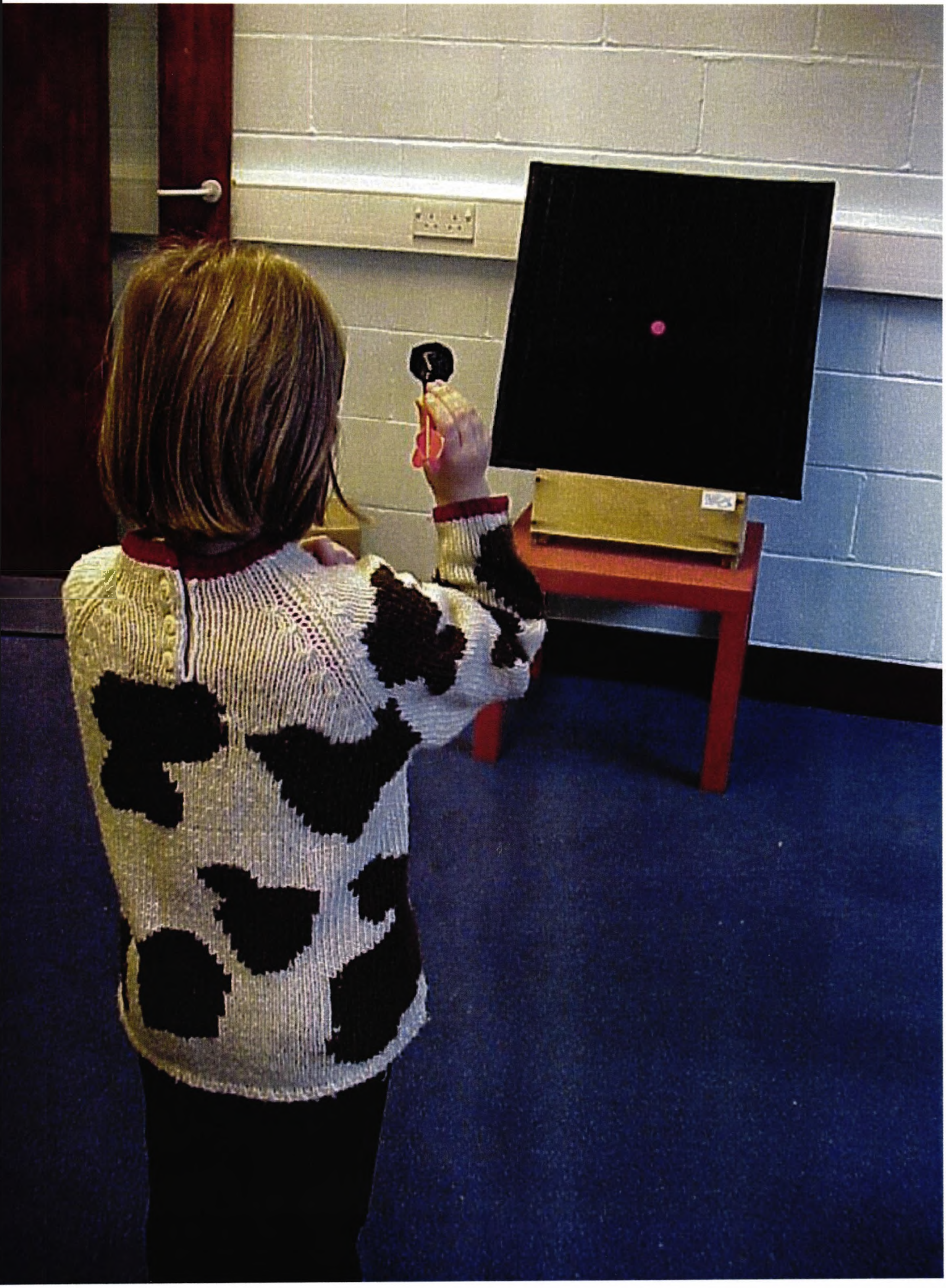
TARGETING TASK



APPENDIX 8

EXAMPLE

TARGETING TASK



APPENDIX 9

MODELLING STUDY - LIST OF ITEM PAIRS

LIST OF ITEM PAIRS FOR MODELLING

Apple - Banana

Table – Chair

Horse – Cow

Book – Comic

Mickey Mouse – Donald Duck

Coca Cola – Lemonade

Watch – Clock

Scarf – Gloves

Kite – Balloon

Pen – Pencil

Rubber – Ruler

Xylophone – Guitar

Rabbit – Hedgehog

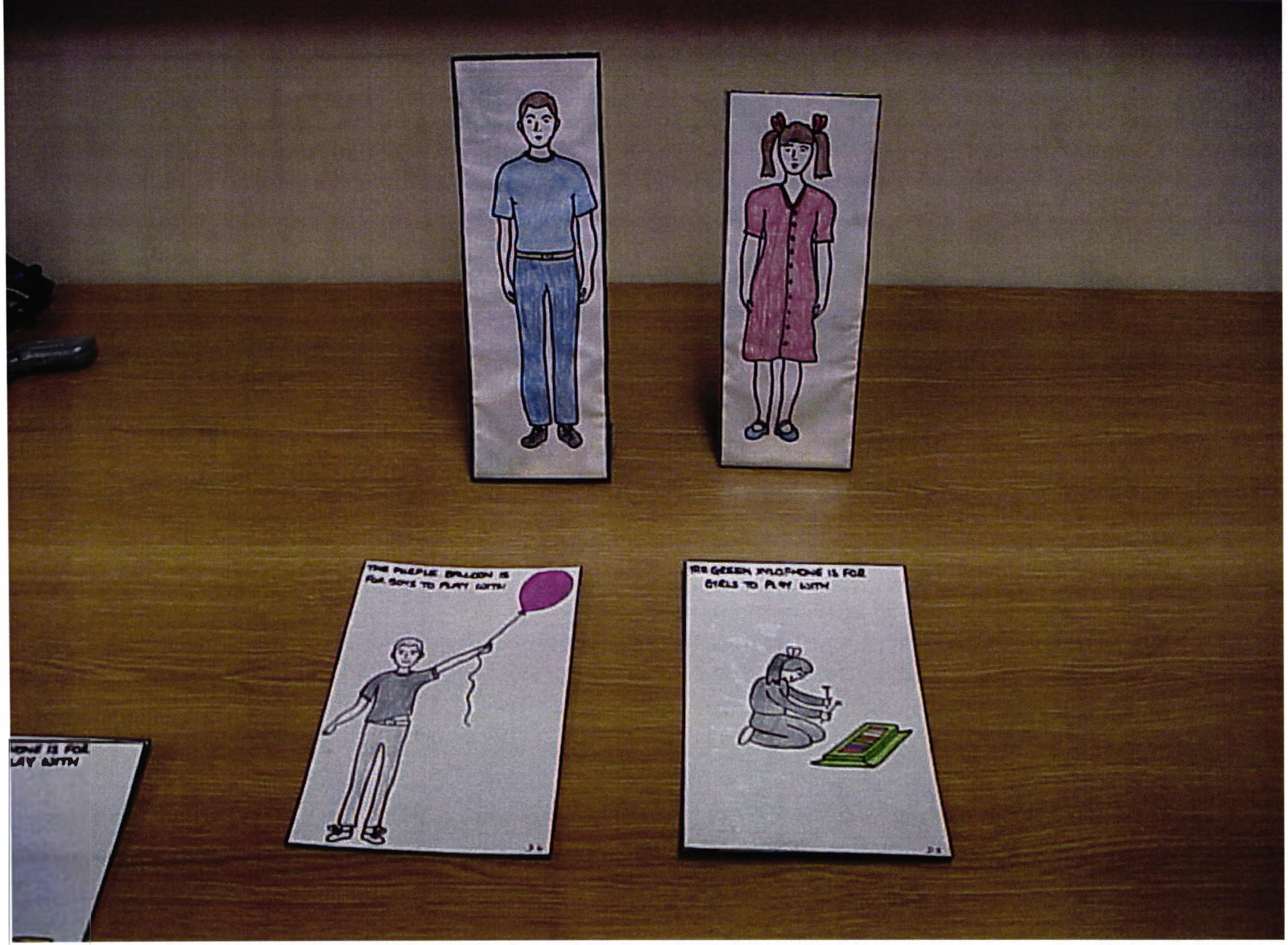
Telephone – Radio

Chocolate – Sweets

Sun - Moon

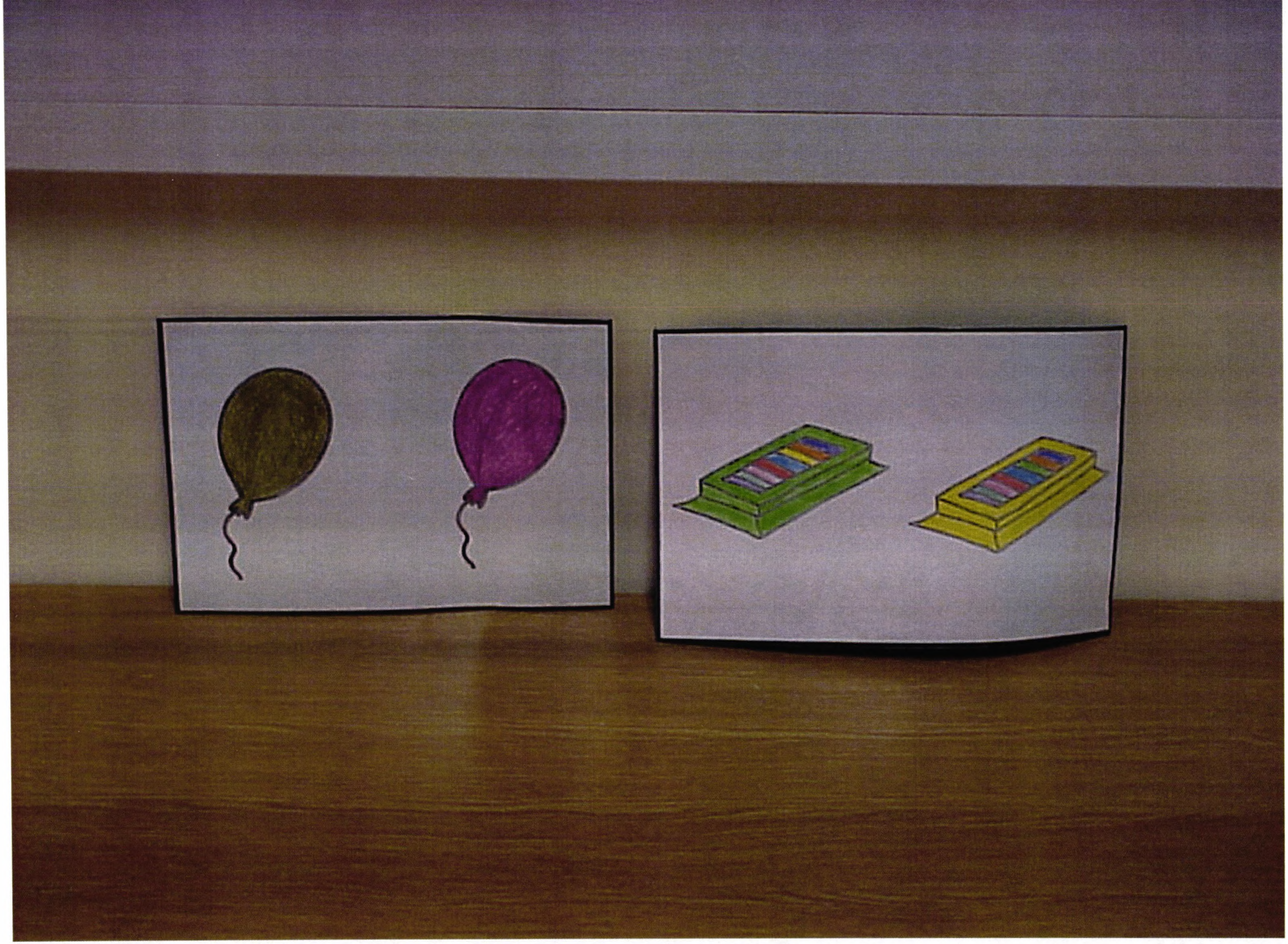
APPENDIX 10

EXAMPLES OF GENDER LABELLING CARDS


THE PURPLE BALLOON IS FOR BOYS TO PLAY WITH
THE GREEN XYLOPHONE IS FOR GIRLS TO PLAY WITH
ONE IS FOR
LAY WITH

APPENDIX 11

PICTURES OF GENDER LABELLING TOYS



APPENDIX 12

THE ROLE OF PEERS AND ADULTS IN SAME-SEX IMITATION BY BOYS AND GIRLS (STUDY SUBMITTED FOR PUBLICATION)

Running head: THE ROLE OF PEERS AND ADULTS

The Role of Peers and Adults in Same-sex Imitation by Girls and Boys

Briony A. Fane, Shana Blair & Melissa Hines

City University, London

Briony A. Fane, Shana Blair, and Melissa Hines, Department of Psychology, City University, Northampton Square, London, EC1V 0HB. Corresponding Author:
Briony A. Fane, e-mail: **B.A.Fane@city.ac.uk**

This research was supported in part by a USPHS grant # HD24542.

We are especially grateful to the children of Hugh Myddleton School, London, E.C.1., for acting as models for us, and to the children of Milton Keynes Primary School, Milton Keynes, Bedfordshire, who took part in the study.

ABSTRACT

We investigated the effect of multiple same-sex peers versus adults on children's imitative behavior. Sixty six, 3-10 year old children (33 boys and 33 girls) were shown a video of 8 male and 8 female adult and child models stating their preferences for 16 gender-neutral item pairs (e.g., horse and cow). They were then shown photographs of the item pairs and asked which one of the item pairs they liked the best. Boys and girls of all ages imitated the preferences of more same-sex than other-sex models. However, only for girls (of all ages) were same-sex peers more influential models than adults. Boys imitated same-sex peers and adults equally. Across all children same-sex imitation increased with age. The findings are interpreted in terms of the different sources of information that boys and girls use to determine appropriate behavior in both adult and peer culture. Other factors that could contribute to the variability in boys' and girls' same-sex peer and adult imitation, including conflict between similarity and power of model, age at which imitation is first seen, and differential gender typed environments, are also discussed.

INTRODUCTION

Imitation is considered an important factor in children's sex role development (the process whereby children come to acquire the behaviors and attitudes culturally defined as appropriate for their sex). Social learning theories (e.g., Bandura, 1969, Mischel, 1970) emphasize the role of observational learning and modelling processes, with the acquisition of gender roles being a product of observing and imitating characteristic behaviors of adults, particularly the same-sex parent. However, reviews by Maccoby & Jacklin's (1974) and Barklay, Ullman, Otto & Brecht (1977) concluded that boys and girls were not more likely to imitate models of the same sex. Thus same-sex imitation came to be viewed as unimportant for sex role development.

Perry & Bussey (1979) argued that this conclusion was premature, suggesting that the previous research on same sex imitation was inappropriate. They contended that in a typical study children are only exposed to a single male or female model and that this is not a sufficient guide for their own behavior. They posited that it was necessary to reformulate how modelling might contribute to sex role development and suggested that children determine what behaviors are appropriate by observing multiple male and female models. Their research confirmed this by demonstrating that children discern what behaviors are appropriate for females and males by observing the behaviors of multiple models. Children then imitate the behaviors of same-sex models. They also found that the more frequently a same-sex model was seen making an item choice, the greater the imitation of that behavior. Thus, the mere knowledge that same-sex adult models make certain choices, different from choices made by the other sex, exerts an influence on children's own choices and is instrumental in shaping sex-appropriate behavior (Maccoby, 1999). Social Learning theories would support this view, that multiple models maximize the probability of same-sex imitation, arguing that collectively they are less likely to be seen as atypical or out of character, but rather are more likely to be seen as behaving in a desirable fashion (Liss, 1979).

Many of the early studies on imitation examined the role of same-sex adults as being the primary models for influencing sex role development. (Maccoby, 1990). However, children also imitate many other people, including non-family adults and other children (Hinde, Easton, Meller & Tamplin 1983, Liss, 1979, Perry & Bussey, 1979). It is widely known that peers also play an important role in the process of learning gender roles. Studies have shown that children serve as significant socialization agents for one another with same-sex peers rewarding sex appropriate behaviors more than sex inappropriate behaviors (Lamb & Roopnarine, 1979).

According to Hinde et al (1983) children differ in the extent to which they direct their social behavior to adults versus to peers. They suggest that one of the reasons for this may relate to previously formed relationships within the family environment, which could influence whether a child interacts with adults or peers. They found that 3-4 year old boys were oriented more towards their peers than girls, while girls tended to interact more with adults than did boys. However, it may be important to note that the adults in the study were female teachers. Thus, sex role development, as Katz & Boswell (1985) argue, may not follow a parallel course for boys and girls. That is, there may be differences in relation to interactions with adults and peers for the two sexes, with boys attending more to peers.

More recently, Harris (1995) has stressed the importance of children's peer groups. Her 'group socialization theory' questions established assumptions about parental influences on children, arguing that the major influence on how children grow up is the peer group. The theory states that children identify with a group consisting of peers, and that they tailor their behavior to the norms of their group. Harris (1995) argues that this identification with a social group is extremely powerful, and peer pressure is a strong influence because it is imposed on the self and not something that is learned. She challenges the notions of 'parent-centered influence', arguing that children greatly influence the behavior of other children, because peers have a much greater effect on behavior than parents do.

As we already know, both boys and girls at an early age divide into sex-segregated groups (Maccoby, 1990). The group socialization theory argues that socialization outside the home takes place in these adult free, gender-group affiliations. An interesting point highlighted by more recent research (e.g., Harris, 1995, Maccoby, 1999) is that adults do not provide a model for sex-segregation, and play no active role in this segregation in children.

A dramatic increase is seen in gender typed preferences during the preschool years (Martin & Little, 1990). However, the developmental changes in same-sex imitation are less clear (Ruble & Martin, 1998). Research has shown that by the end of the preschool period children are more inclined to make same-sex choices (La Freniere, et al 1984). However, there is little information available as to whether age-related changes take place in children's imitative behavior, or whether the course it takes is similar for girls and boys.

The present study investigates the influence of same-sex adults versus peers on the imitative behavior of boys and girls, by comparing the extent to which children model the item preferences of these two groups. In addition, it assesses sex differences in modeling of these two groups and developmental (i.e., age-related) changes in patterns of modeling behavior.

Very young children have not been included in multiple, same-sex modelling studies in the past. Most of the research on imitation of multiple models has been conducted with children in middle-childhood, and there is little research evaluating the age at which children first begin to imitate multiple same-sex models. With this in mind, we included children as young as 3 years.

Three specific hypotheses are tested: 1) that peers are more influential models than adults; and 2) that boys are more influenced by peers than are girls, and, 3) that there are age-related changes in same-sex imitation.

METHOD

Subjects

66 children took part, ranging in age from 3-10 years. They were spread approximately equally across 3 age-groups, with 10 boys and 10 girls ages 3-4 years, 12 boys and 12 girls ages 5-7 years, and 11 boys and 11 girls ages 8-10 years. Children attended a primary school in the Milton Keynes area of Bedfordshire, England. They were randomly selected to participate by their class teacher. The sample was predominantly middle and lower middle class and ethnically diverse.

Stimuli

Videotapes of males and females selecting 16 pairs of gender-neutral items served as the primary stimuli. Items for the 16 pairs were selected based on independent ratings, made by 50 undergraduate students, of 66 potential items, some expected to be gender-typed and some expected to be gender-neutral. Items were rated on a Likert scale of 1 to 7, where (1= extremely feminine and 7 = extremely masculine). All gender-neutral items used in the modelling sequences received average ratings, between 3 and 5 (the gender-neutral range).

8 females (4 women and 4 girls) and 8 males (4 men and 4 boys) acted as models. The adult models were all in their early twenties, and the child models were all 10 years old. All models were Caucasian, to control for any potential effects of ethnicity on children's imitative behavior. The16 pairs of gender-neutral items were gender stereotyped by having all the female models choose the same item from the pair, and all the males

choose the other item from the pair. Item pairs were always of the same category (e.g., a plastic apple and a plastic banana, a plastic horse and a plastic cow). (See Appendix 1 for a complete list of item pairs).

Models (adults and children) were filmed individually approaching each of the item pairs and were asked which item they liked best. They responded both verbally ("I like the .... best") and by pointing to their preferred item. Order of models making choices was counterbalanced by sex. Different counterbalanced sequences were shown in a fixed random order. Four different sequences were shown, with each of the 8 models performing each sequence. In the first sequence, four females and then four males were seen choosing the items. In the second sequence, two males, then two females, then two males and then two females were seen choosing the items. In the third sequence, three males and one female, followed by one male and three females, were seen choosing the items. The final sequence showed one female and then one male (repeated four times) choosing items. Two videos were made showing either the male models choosing first or the female models choosing first. For each of the videos half of the sequences showed child models and half showed adult models. Females endorsing items in video 1 were shown endorsing the opposite items in video 2. Children were randomly assigned to view either video 1 or video 2. Each video was 11 minutes long.

Procedure

Children were shown one of the videos individually in a quiet room in the school. Immediately following viewing, their imitative performance was measured by presenting them with colored photographs of the 16 item pairs and asking them to indicate which one from each pair they preferred. Scores for each child for imitation of same-sex peers and adults combined, could range from 0 (no same-sex imitation) to 16 (100% same-sex imitation), and from 0 to 8 for same-sex imitation of peers and adults considered separately.

RESULTS

Same-Sex Recall

Table 1 here

Means (standard deviations in parentheses) for recall of same- sex adult and peer models are presented in Table 1. A three-way mixed Analysis of Variance (ANOVA), (sex of child x age of child x age of same-sex models) was carried out on girls' and boys' recall of models endorsing items. A main effect of age was seen, F (2, 60) = 15.41, p <.001. Same-sex recall of adult and peer models combined, increased with age (see Table 1). To follow up this significant main effect, post hoc testing using Tukey's HSD revealed that recall increased significantly with age in a linear fashion. A main effect of age of model was also seen, F (1, 60) = 6.06, p = .017. Across all children, same-sex peers were recalled more than same-sex adults.

No other main effects or interaction terms reached significance.

Given the above findings, and the fact that recall of same-sex adult and peer models did not interact with sex or age of child, it would seem that the gender of the model and the age of the model were not differentially remembered by boys or girls.

Same-Sex Imitation

Means (standard deviations in parentheses) for imitation of both same- and other-sex adult and peer models are presented in Table 2, and Fig. 1.

Table 2 here

Fig. 1 here

A 4-way mixed ANOVA (version of video x age of child x sex of child x age of same-sex model) was carried out on girls' and boys' same-sex imitation. For version of video, the main effect was not significant, F (1, 54) = .042, p = .837, indicating that the order of presentation (male models choosing the items first versus female models choosing first) did not contribute to children's imitation. No interaction terms involving this factor were significant. The main effect of age-group did not quite reach significance, F (2, 54) = 2.44, p = .097. However, a polynomial linear trend test for age was significant, F (2, 54) = 4.94, p = .03. Same-sex imitation increased in a linear fashion with age.

For sex of child, the main effect was not significant, F (1, 54) = .584, p = .448, although there was a significant interaction between sex of child and age of model, F (1, 54) = 7.893, p = .007. To explore further the differential imitation seen for boys and girls in their imitation of same-sex peers and adults, bonferroni adjusted, paired sample, t-tests were carried out. Girls imitated more same-sex peers than same-sex adults, t (32) = 4.61, p < .001. In contrast, boys imitated same-sex adults and same-sex peers approximately equally, t (32) = .501, p = .620.

No other interaction terms were significant, and no other main effects were significant.

We observed a significant linear trend for age in same-sex imitation, and the main effect of age approached significance. Also, prior studies with single models have found that older children imitate more than younger children. Therefore we explored the effects of age on imitation further. The linear trend for age was analyzed separately for boys and girls (see Table 2). For girls, the trend was not significant, F = .099, p = .756. For boys, the trend was significant, F = 9.17, p = .005.

Table 2 here

Strength of Imitation

In order to determine if boys and girls differed in the strength of same-sex imitation, analyses were conducted for boys and girls separately, comparing their degree of same-sex imitation to what would be expected based on chance (chance = a same-sex imitation score of 8 overall or 4 for peers and 4 for adults).

Paired t-tests revealed that for girls, imitation of same-sex adults (M= 4.15, SD = 1.75) did not exceed chance, t (32) = .497, p = .623). They did, however, imitate same-sex peers (M = 5.09, SD = 1.67) significantly more than chance t (32) = 3.76, p = .001. Boys imitated both same-sex adults (M = 5.00, SD = 1.77) and peers (M = 4.82, SD = 2.08) significantly more than chance, ts (32)=3.25 and 2.26, respectively, ps <.04.

A third analysis was run to compare same-sex imitation in boys and girls. Independent t-tests revealed no differences in imitation of same-sex adults, t (64) = .587, p = .559.

However, a borderline significance was reached for imitation of same-sex peers, t (64) = 1.96, p = .055. Girls were more likely to imitate same-sex peers than boys were.

DISCUSSION

Same-sex imitation is still 'alive and well' today. Like others, we found that boys and girls are more likely to imitate multiple models of their own sex (Perry & Bussey, 1979; Bussey & Perry, 1982; Bussey & Bandura, 1984).

Our research extends previous findings by including adult and peer models in the same study and by demonstrating that the strength of boys' and girls' imitative behavior differs for models of these two types. Girls imitate same-sex peers more than same-sex adults, while boys do not. Girls also imitate same-sex peers more than boys do. This suggests that same-sex peers may be more powerful than adults as models for girls. Thus, different processes appear to be involved in this aspect of gender role development in boys and girls. Our findings further suggest that when faced with adult models of both sexes, girls do not imitate same-sex models at any more than chance levels. However, it is important to note that treating the age of the same-sex models as a within subjects factor, may have been attenuated been used as a between-subjects factor, t

In addition, our study further extends previous research by including children as young as 3 years of age. We found that the developmental pattern differed for boys and girls. It appears that, at least for girls in this age range (3 – 10 years), the effects are consistent across the ages. Boys, in contrast, show a developmental change, with imitation increasing as they get older.

The preference for imitating same-sex models may be linked to the strength of children's gender segregation in play. Boys play with boys, girls play with girls, showing strong favoritism towards their own gender, in many cases to the point of avoiding interaction with the other gender (Cairns & Cairns, 1994). Thus, they are more likely to observe same-sex play and model their own behavior on this. Gender segregation is a powerful and consistent childhood phenomenon. It also increases with age (Martin, 1994). By 2-3 years of age, children begin to show same-sex over other-sex affiliation (LaFreniere, Strayer & Gauthier, 1984). However, the same authors found that girls aged 2 years sought out same-sex playmates, in preference to playmates of the other sex, 68% of the time, a preference that did not increase with age. For boys, a different pattern was seen, with preference for same-sex playmates only at chance levels at age 2 years, increasing significantly to 75% by 5 years and 6 months. This developmental pattern is similar to that found in our study for modelling, and supports what is widely known with regard to gender role development, that trends vary for boys and girls, with girls showing more gender flexibility than boys (Signorella, Bigler & Liben, 1993).

The finding that girls did not differentially imitate same- versus other-sex adults suggests a possible conflict situation, set up when they observe adult male models, who are 'powerful' but not 'similar' models, versus adult female models, who do not seem to posses the 'power' influence that comes with adulthood for males, but do hold the 'similarity' factor. Social power is stereotypically more characteristic of men in western culture and has been shown to have a strong influence on modelling (Bussey & Bandura, 1984). Male linked behavior usually carries more status and power than female linked behavior. Thus, the fact that same- and other-sex adult imitation was no different from chance for girls may be because of this potential conflict situation having been set up between 'similarity' of the model versus 'power' of the model.

Traditionally, boys' and girls' social environments are structured in such a way that choices are more limited for boys than for girls. Boys' preferences are more channeled towards masculinity, whereas girls are given more latitude in the gender domain. For example, Fagot (1977) found that boys who showed cross-gender preferences received more peer criticism than girls with cross-gender preferences. Smetana (1986) concluded from this, that boys are expected to conform to societal expectations more than girls are. Many studies have shown that boys who engage in feminine activities are viewed more negatively than girls who engage in masculine activities (Martin, 1993). Thus, in line with other socialization influences, our results also suggest that boys are more channeled in their behavior, being more likely to preferentially model men than girls are to model women. This may be another mechanism by which their behavior becomes more sex-typed than that of girls.

REFERENCES

Barklay, R.A., Ullman, D.G., Otto, L., & Brecht, J.M. (1977). The effects of sex typing and sex appropriateness of modeled behavior on children's imitation. Child Development, 48, 721-725.

Bussey, K & Bandura, A. (1984) Influence of Gender Constancy and Social Power on Sex-Linked Modelling. Journal of Personality and Social Psychology, 47(6), 1292-1302.

Bussey, K & Perry, D.G. (1982). Same-sex imitation: the avoidance of cross-sex models or the acceptance of same-sex models? Sex Roles, 8, 773-784.

Cairns, R.B. & Cairns, B.D. (1994) Lifelines and risks. Pathways of youth in our time. In:H.Bee, The Growing Child: An Applied Approach. Second Edition. Longman.

Fagot, B.I. (1977) Consequences of moderate cross-gender behavior in preschool children. Child Development, 48, 902-907.

Harris, J.R. (1995) Where is the Child's Environment: A Group Socialization Theory of Development. Psychological Review, 102 (3), 458-489.

Hinde, R.A., Easton D.F., Meller, R.E., & Tamplin A. (1983) nature and determinants of preschoolers' differential behavior to adults and peers. British Journal of Developmental Psychology 1, 3-19.

Katz, P.A., & Boswell, S. (1985). Flexibility and Traditionality in Children's Gender Roles. Genetic, Social, and General Psychology Monographs. 112(1) 105-147.

LaFreniere, P., Strayer, F.F., & Gauthier, R. (1984). The Emergence of Same-Sex Preferences Among Pre-School Peers: A Developmental Ethological Perspective. Child Development, 55, 1958-1965.

Lamb, M.E. & Roopnarine, J.L. (1979) Peer Influences on Sex-Role Development in Preschoolers. Child Development, 50, 1219-1222.

Liss, M.B. (1979) Variables influencing Modeling and Sex-Typed Play. Psychological Reports, 44, 1107-1115.

Maccoby, E.E. (1990). Gender and relationships: A Developmental Account. American Psychologist, 45, 513-520.

Maccoby, E.E. (1999). The Two Sexes: Growing up Apart, Coming Together. The Belknap Press of Harvard University Press Cambridge, Massachusetts.

Maccoby, E.E., & Jacklin, C.N. (1974). The Psychology of Sex Differences. Stanford, CA: Stanford University Press.

Martin, C.L. (1993). New Directions for investigating children's gender knowledge. Developmental Review,13, 184-204.

Martin, C.L. (1994). Cognitive Influences on the Development and Maintenance of Gender Segregation. New Directions for Child Development. No. 65, 35-51.

Martin, C.L., Fabes, R.A., Evans, S.M., & Wyman, H. (1999) Social Cognition on the Playground: Children's Beliefs about Playing with Girls versus boys and their Relations to Sex Segregated Play. Journal of Social and Personal Relationships, 16(6), 751-771.

Mischel, W. (1970) A Social Learning view of Sex Differences in Behavior. In P.H. Mussen (Ed), Carmichael's Manual of Child Psychology (Vol. 2, pp. 3-72). New York:Wiley.

Perry D.G., & Bussey, K. (1979) The social learning theory of sex differences: Imitation is alive and well. Journal of Personality and Social Psychology, 37, 1699-1712.

Ruble, D.N., and Martin, C.L. (1998). Gender Development. In W.Damon (Ed. in Chief) & Eisenberg N. (Vol. Ed.) Handbook of Child Psychology: Vol. 3: Social Emotional, and Personality Development (5th ed., pp. 933-1016). John Wiley & Sons, Inc.

Signorella, M.L., Bigler, R.S., & Liben, L.S. (1993). Developmental differences in children's gender schemata about others: A meta-analytic review. Developmental Review, 13, 147-183.

Smetana, J.G. (1986). Preschool Children's Conceptions of Sex-Role Transgressions. Child Development, 57, 862-871.

Appendix 1

Apple - Banana

Table – Chair

Horse – Cow

Book – Comic

Mickey Mouse – Donald Duck

Coca Cola – Lemonade

Watch – Clock

Scarf – Gloves

Kite – Balloon

Pen – Pencil

Rubber – Ruler

Xylophone – Guitar

Rabbit – Hedgehog

Telephone – Radio

Chocolate – Sweets

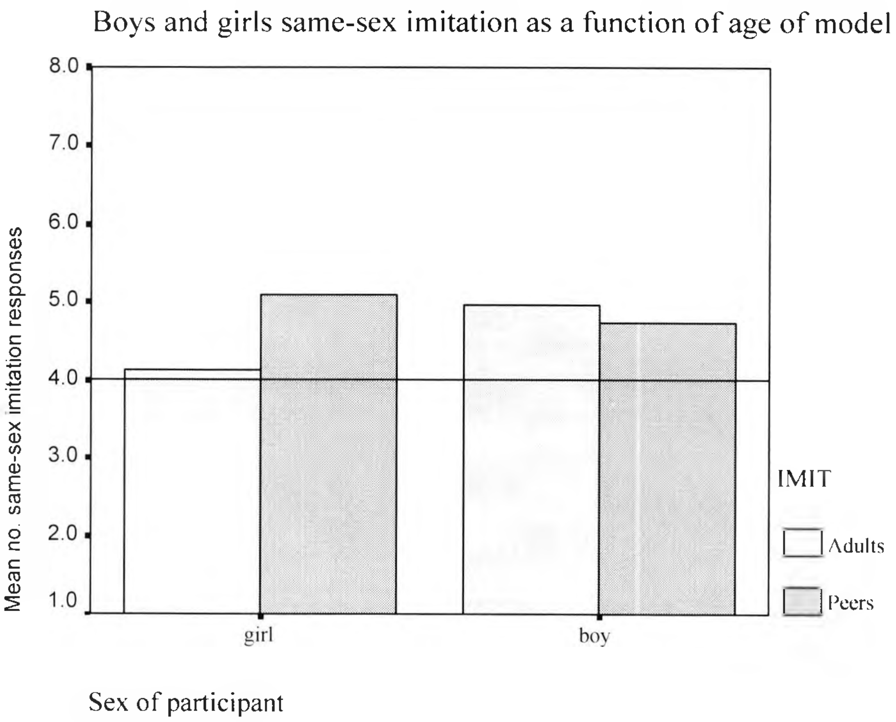
Sun - Moon

Table 1

Boys' and girls' mean number of imitation responses for same-gender models

	Same-gender Adults			Same-gender Peers		
	M	SD	n	M	SD	n
Boys	5.00	1.77	33	4.82	2.08	33
Girls	4.15	1.75	33	5.09	1.67	33

Fig. 1



Boys and girls same-sex imitation as a function of age of model

Table 2

Mean imitation of same-gender models endorsing items by age of child and age of model

	Same-Gender Adults			Same-Gender Peers		
	M	SD	n	M	SD	n
Age of child						
3-4 years	4.10	1.29	20	4.15	2.13	20
5-7 years	4.54	1.93	24	5.25	1.54	24
8-10 years	5.05	2.00	22	5.36	1.81	22

Table 3

Mean recall of same-sex models endorsing Items by age of child and age of model

	Same-sex Adults			Same-sex Peers		
	M	SD	n	M	SD	n
Age of child						
3-4 years	3.65	2.18	20	4.80	2.00	20
5-7 years	5.38	2.60	24	5.92	2.26	24
8-10 years	6.05	1.21	22	7.00	1.11	22