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UNDERSTANDING AND REPEATING WORDS:

EVIDENCE FROM APHASIA.

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ABSTRACT

The goal of this thesis is to identify the underlying impairments in aphasic disorders of auditory comprehension and repetition. The findings are interpreted within a cognitive neuropsychological framework. Models of normal language processing are discussed in the light of this evidence.

Information processing models of the lexicon attempt to specify the stages of processing necessary for auditory comprehension, as well as different routes by which words can be repeated. Twenty fluent aphasic patients were used in the study.

It was found that the patients did show qualitative differences in auditory word comprehension. Five levels of impairment were identified: word-sound deafness, word-form deafness, word-meaning deafness, a central semantic disorder and a disorder specific to abstract words. It was concluded that abstract words are more sensitive to impairment than concrete words.

Word imageability was investigated in more detail in a number of experiments with a word meaning deaf patient (DRB). It was shown that his impairment is one of access from the input lexicon to the semantic system. The impairment results in under-specification in the semantic system, and an extremely robust effect of imageability in DRB's ability to comprehend and repeat auditorily presented words. This effect is not item-specific. Intriguingly, the results also suggest that DRB has an anomia for words of low imageability.

In a subsequent section, the patients' abilities in repetition are investigated. Two routes for repetition are identified, a sub-lexical and a lexical/semantic route. Phonologically related errors arising in the former route tend to be non-words, occur particularly on longer words, and the errors tend to be in the final position of the string. Phonological errors arising in the lexical/semantic route are real words, tend to be higher in frequency than the stimulus items, and occur particularly on shorter words.

The relationship between repetition and auditory short term memory is considered by further experiments with DRB. It is argued that sub-lexical repetition utilises the auditory short term memory system. DRB's sub-lexical repetition and his immediate serial recall are enhanced by lip read information. A model of repetition and auditory short-term memory is presented. It is argued that the system requires different input and output phonological codes, suggesting separate input and output lexicons. With the specification of how lexical information supports immediate serial recall, it is argued that there is no requirement for a direct, lexical, non-semantic route in repetition.

Chapter 1: Repetition

This chapter considers the processes involved in word repetition. In the first section, possible architectures of models of word processing are described. Word repetition may be carried out in various different ways. At least three repetition routes have been suggested: a semantic route, a sub-lexical route and a direct lexical route; such models are the basis for experiments described in Chapter 5. The separability of a semantic/lexical and a sub-lexical route is evaluated, with reference to neuropsychological data. The question of whether there is a direct, lexical, non-semantic route for repetition is only appropriate if there are separate input and output lexicons. Evidence for two phonological lexicons is considered firstly by analogy to evidence for separate orthographic and phonological lexicons. More direct evidence is from repetition priming, dual task experiments, and neuropsychological impairments in repetition. On the far from proven assumption that there are two phonological lexicons, the issue of whether there is a direct lexical repetition route is considered.

The rest of this chapter comprises a short description of dysphasic naming impairments followed by models of short term memory. Since (for at least semantic-route repetition) output processing will be common to repetition and naming, the comparison of patients' performance on these two tasks will be a useful indication of where language breakdown is occurring. It is thus necessary, at least briefly, to review the way that naming errors are thought to arise, and the ways they are commonly analysed. (Errors in repetition will be the focus of chapter 6.)

For models of immediate serial recall in auditory memory, where the relationship between memory and language has been made explicit, there is arguably a close association between repetition and recall. Later in this chapter experiments with normal subjects and neuropsychological data on memory impairments are briefly reviewed. Chapter 7 will present data pertinent to this issue, and the memory literature will be reconsidered more fully in chapter 9.

1.1 The functional architecture of the lexical system.

Information processing models attempt a functional description of language which is unrelated to the neurophysiology of the brain. They were born out of computer models and were devised to describe the flow of information through a system. They constitute a first attempt to integrate separable functions of language (and other cognitive skills) into a working whole, which has claims to psychological reality. These models comprise a number of modules and the connections between them; this modular approach gives a complexity and richness to the description of language processing which not only explains results in cognitive psychology but also is able to predict the diversity of breakdown shown by dysphasic patients.

> *"In such models, the processes in the brain are seen as modular, or distinct in operation, and are symbolised as boxes, the detailed operation of which is in general not specified in detail. The processes are interlinked by directed lines which are intended to indicate that the result of one process is passed on to another process"*
>
> *(Morton 1985)*

There has been a general development from the original (Morton 1969) "logogen" model, comprising few modules (but where those modules have a complex multi-modal address capability) to those which comprise many more modules which can each deal with fewer types of information. The original logogen model postulated a single logogen system which could be addressed from either acoustic or visual input and could produce a phonological code for speech. Information flowing from the logogen system to the cognitive system, and from the cognitive system to the logogen system allowed for comprehension and naming.

The logogen model was devised in part to explain word priming effects (and various properties of logogens were postulated) and had to be drastically revised when Winnick and Daniel (1970) found that there was no priming of a word which had been previously presented in a different modality. Morton's revised logogen model (Morton 1979, Morton and Patterson 1980) comprised three separate logogen systems; one for acoustic input, one for visual input, and one for phonological output.

Subsequently more connections between modules have been demonstrated through the study of language breakdown, and the written modality has been added to the model. There are now two main competing forms of this type of model, plus a more controversial 5-lexicon model. Most current models follow the revised logogen model in having separate phonological and orthographic lexicons.

Patterson and Shewell's (1987) model comprises four lexicons: separate input and output lexicons for both written and spoken information. Allport and Funnell (1981), on the grounds both of economy, and their interpretation of some critical data, suggest that the phonological lexicon is common to both input and output and that similarly there is one orthographic lexicon for input and output. The evidence supporting each of these opposing claims is presented in this chapter.

1.2 Models of repetition.

According to the 1980 version of Morton's "Logogen" model there are three routes by which a word may be repeated (Morton 1980a). All three routes require the incoming acoustic information to be analysed to some specifically linguistic level. The first route takes this abstract auditory representation and converts it into an output phonological form which is held in the "response buffer" in order that the appropriate motor patterns can be assembled at a more peripheral level. This route does not require the abstract lexical representation of the word to be accessed; according to this theory, this is the only route by which novel or non-words can be repeated, and has therefore been called the "sub-lexical repetition route". The second route maps the abstract acoustic representation onto the appropriate word form in the auditory input lexicon which is able to access the word form in the phonological output lexicon. This phonological representation is then held in the respose buffer as in the case of the sub-lexical route. This is "direct lexical repetition" and differs from repetition via the third route, where the input word form does not directly access the output word form but has instead to access meaning in the cognitive system which is used to access the output word form. As this route requires the word to be repeated via meaning, it is "semantic route repetition".

While this particular model is widely cited in the literature, at least in terms of its architectural form if not in terms of the particular mechanisms of access, it is by no means generally accepted that these five modules (auditory analysis, auditory-phonological conversion, auditory input lexicon, phonological output lexicon and response buffer) are functionally separable entities. Allport and Funnell (1981) propose a different model with one common phonological lexicon. This is analogous to their account of reading and writing, where they suggest there is one orthographic lexicon. Also in the sphere of reading, Seidenberg and McClelland (in press) suggest that lexical and sub-lexical reading can be carried out using one processing routine which is sensitive to lexical effects, such as word frequency.

This review will consider the evidence for the separability of lexical and sub-lexical routes, for the existence of one or two lexicons in auditory verbal processing, and for the existence of the "direct lexical repetition route".

1.3 Lexical and sub-lexical repetition - are they separable routes?

In order to evaluate the case for lexical and sub-lexical repetition being separable processes, it is first necessary to consider the obverse of this claim; namely that phonological processing is unitary and that there are no independent input and output processes. Of couse, they must be separable at least at some basic perceptual point, since one processes acoustic information, while the other produces articulatory output. Separability in this sense could be quite peripheral and not specific to phonology. Allport (1984) describes three patients with a "conduction" aphasia and demonstrates that as well as producing phonemic paraphasias in naming they all made errors in tasks requiring auditory discrimination. He suggests that such a remarkable association is consistent with a single phonological code, common to input and output.

Caramazza, Berndt and Basili (1983) describe a similar patient and come to the same conclusion. But patients with a "pure word deafness" appear to have a similar deficit in phoneme discrimination, without the corresponding output problem; if this is so there must be a dissociation between phoneme input and output processing. Caramazza et al counter this argument by suggesting that although these patients' speech might be relatively spared, in fact they nearly all produce some paraphasic errors. This seems unconvincing. The "pure" cases may produce a small number of phonological errors in output (Wernicke noticed them and suggested they were the result of poor monitoring caused by the auditory comprehension deficit), but they have a much more severe disorder in comprehension. They could however have an impairment at a more peripheral level, if it were true that such patients had problems in processing non-linguistic acoustic information (which, as is indicated in chapter two is a matter for debate).

Howard and Franklin (1987) describe a patient, M.K., who can read non-words but is entirely unable to repeat them. Since phonological output is required for reading this level must be intact. He is also unimpaired in phoneme discrimination tests (Franklin, in press). His inability to repeat non-words must therefore be a consequence of a deficit in the processing between input and output (in Morton's model, a deficit in auditory-phonemic conversion). If there were only one system then it would be logically impossible to have a deficit in the process "between" it; M.K. appears to be good evidence against a single phonological processor.

Even if there are separable phonological levels for input and output, the question of whether auditory-to-phonological conversion is independent of lexical processing remains. It has been suggested that people may read non-words by analogy to real words (Glushko 1979; Kay and Marcel 1981). In both oral reading and repetition one can find patients showing clear dissociations between non-word and real word performance. The complete inability to read or repeat non-words with a virtually intact ability to process real words could be explained by a frequency effect. That is, if non-words in the damaged system are considered to be of lower frequency than any real word, then they might never reach a sufficient level of activation to achieve an output. The real words would all be of sufficiently high frequency to be available. However, if that were so then non-words should always be more impaired than real words; this is clearly not the pattern shown in the purest cases of surface dyslexia where non-words are unimpaired while some real (exception) words are misread. It therefore appears that whatever the mechanism is by which the phonology for non-words is constructed, sub-lexical and lexical reading are in some sense separable. Since there are no equivalent "exception" words in repetition the same evidence cannot be adduced; but a similar argument applies for writing to dictation where patterns of surface dysgraphia have been reported (Hatfield and Patterson 1983). *25a If, as several authors have claimed, non-semantic writing to dictation is entirely parasitic on repetition, (e.g. Patterson 1986) then there is a strong case for separable routes for lexical and sublexical processing in repetition.

1.4 Are there separate input and output lexicons?

Orthographic processing

The original version of the logogen model had a single logogen system serving acoustic and visual input and phonological output. There is now general agreement that there are separate phonological and orthographic lexicons, but it is important to understand why this is so before the arguments for one or two phonological lexicons can be evaluated. A series of repetition priming experiments on normal subjects (Winnick and

*An alternative line of evidence for two repetition routes are the dissociations described by Macarthy and Warrington (Brain, 1984). They describe the language impairments of two conduction aphasics and one patient with a transcortical motor aphasia. They demonstrate that the two conduction aphasics, ORF and RAN have impaired word and non-word repetition, especially for longer words, but that their anomic problems do not appear to be at a phonological level. The third patient, ART, makes phonemic paraphasias in naming but is able to repeat words. The patients have a further dissociation in that enforced semantic processing improves performance for the conduction patients but impairs it for the transcortical patient. These results are consistent with the first two patients having an impairment in sub-lexical route repetition and the second a reliance on the sub-lexical route for repetition. Unfortunately Macarthy and Warrington do not report whether ART is able to repeat non-words; this interpretation strongly predicts that this ability should be intact.

Daniel 1970) showed that there was no effect of priming across modalities, except for the very short lived priming effect which is presumed to be arising at a semantic level. Since Allport and Funnell (1981) explicitly state that for their model, priming occurs in the access routes rather than in the lexicon itself, this lack of cross-modal priming does not force them to split the lexicon. However, they give three other pieces of evidence which they believe to show that there must be separate orthographic and phonological lexicons.

Allport and Funnell (1981) describe a patient AL who was only able to match spoken words to written words via a lexical route. They argued that he must either be doing this in the lexicon or in the semantic system. Since he was able to select the correct printed word to match with a spoken word when the alternative word was a semantically related distractor, but not when the two choices were exact synonyms (e.g. DRESS + FROCK), he must have been making the judgment at a semantic level. Furthermore, Allport and Funnell argue that since the spoken word "dress" and the written word FROCK must have accessed their lexical forms (in order to achieve meaning), then these would evidently be <u>different</u> forms if they co-existed in the single lexicon. This seems unconvincing; it is not clear whether AL would have been able to do this task if all the items had been presented in the same modality either, since there may not be the possibility of carrying out operations such as matching at a purely lexical level.

Allport and Funnell's second argument concerns semantic reading errors in deep dyslexia. They accept that in order to make a semantic error it is necessary to have accessed the appropriate word-form corresponding to the stimulus in the orthographic lexicon. Some deep dyslexic patients are reported to be less impaired in naming than reading; naming of course requires the phonological lexicon. If there were only one orthographic/phonological lexicon, then having already accessed the word-form corresponding to the stimulus in the lexicon, the patient should be able to produce the output phonology without having to access the meaning. Thus deep dyslexics would not make semantic errors unless there were separate lexicons for identifying visually-presented word forms and for producing output phonology. (Note: it is in fact not clear that there are patients much less impaired in naming; Howard (1985) compared reading and naming of the same words for 6 deep dyslexic patients and found that none of them had superior naming).

An alternative is that there are two thresholds in the lexicon, one for producing an output to semantics, and a higher one for producing phonological output. In this case, the activation already produced to achieve semantic access may not be sufficient to achieve an output. A problem with this explanation is that initial lexical activation derived from stimulus input should be boosted by activation from the semantic system (epecially in those deep dyslexics who, it is argued, do not have a central semantic impairment), making the correct response the most likely candidate for achieving an output.

Allport and Funnell's final argument argument concerns word meaning deafness and particularly the case described by Bramwell (1897). This patient was often unable to understand a spoken word until she had written it down, when presumably she was able to use orthographic comprehension. Bramwell mentions this occurring with words whose spelling is not predictable from their phonology, such as "Edinburgh". In order to write the word "Edinburgh" to dictation it is necessary to access the orthographic lexical form, since the use of a sub-lexical spelling route would not result in the correct spelling. Thus it would appear that the patient had a problem in getting from the phonological input lexicon to meaning but not from the orthographic input lexicon to meaning. If these two lexicons were in fact the same, then this would be nonsensical.

Repetition priming experiments

The evidence for or against a single input/output phonological lexicon is much less clear. Allport and Funnell (1981) cite an experiment by Gipson which showed that, for normal subjects, producing spoken output for a word does not prime auditory recognition of that word. Allport and Funnell argue that since priming has to occur at the point of access, naming would not prime recognition even if there is a single lexicon.

However, subsequent experiments by Gipson (1986) and Monsell and Banich (Monsell 1987) indicate a much more complex picture of priming effects than this initial result suggests.

Gipson (1986) studied the effect of various repetition priming tasks on the ability to recognise words presented in a background of pink noise. In the first experiment, subjects had to detect the number of syllables in a spoken word, printed word or picture name. Seeing the picture or the word did not subsequently prime word recognition. This of course could be interpreted as evidence for two lexicons, since the syllable judgment presumably requires only the output phonological form to be accessed. However, Gipson follows Allport and Funnell (1981) in believing that priming occurs at the level of access rather than in the lexicon itself.

Gipson goes on to use the same test of word recognition in noise preceded by conditions in which the subjects either heard words, read words aloud, read aloud non-word pseudohomophones of the test words, or decided which of two printed non-words was a pseudohomophone. He found that reading words produced no facilitation relative to the control condition where the spoken words had not been previously encountered. The pseudohomophone decision task primed subsequent word recognition, but significantly less than hearing the word. Pseudohomophone reading, however, appeared to be an extremely effective prime.

Monsell and Banich (Monsell 1987) studied the effect of repetition priming on auditory lexical decision. Similarly to Gipson's results, they found that any task which required the production of "inner speech" primed subsequent lexical decision performance to some extent. But tasks where the subject either said the word out loud, or mouthed it, were as effective as hearing the word spoken by the experimenter. (The exception to this is the oral reading condition in Gipson's experiment: however he points out that subjects were encouraged to read as quickly as possible without worrying about errors. It may be that, under these conditions, the subjects are not "listening" to their own speech. If the experiment was re-run, with an emphasis on correct production, and perhaps with the real words mixed with non-words, this explanation would predict a priming effect for auditory word recognition.)

Monsell's (1987) interpretation of this pattern of results is that peripheral feedback is a more effective prime than feedback at a phonological level. However, since repetition priming is a specifically lexical effect, it is difficult to see why peripheral and phonological priming should have this differential effect, since according to Monsell's (1987) model, both should access the lexicon from input phonology.

Although these are intriguing results, they do not resolve the issue of separate input and output lexicons. If priming actually occurs within the lexicon, the single lexicon model is not tenable, since all these different types of prime should produce the same effect. Allport and Funnell's (1981) argument for priming at the level of access also fails to explain the differential effects of peripheral and phonological level priming, but the two lexicon model fares no better in this respect.

A dual task experiment

Shallice, McLeod and Lewis (1985) devised a dual task experiment, for normal subjects, which specifically addressed the issue of separate input and output lexicons. They argued that if subjects were able simultaneously to carry out two tasks, one of which tapped input lexical phonology while the other tapped output lexical phonology, then these must be represented separately. This logic of course relies on the assumption that the same system is unable to process two sources of information at once; but Shallice et al tested this by combining their input and output tasks with others supposed to use the same lexicon, and which they therefore predicted should produce significantly greater dual-task decrements.

The critical dual task combination required the subjects to read words out loud while they listened to a string of words until they heard a proper name at which point they were to stop reading. The subjects made 10% more errors on these tasks when doing them together than when doing them separately. Compared to the control dual tasks (i.e. combinations designed to rely on the same lexicon), where subjects were essentially only able to attend to one task at a time, this 10% represented an extremely small decrement. Shallice et al argued that the name detection task was processed via the input lexicon, whereas oral reading occurred via the phonological output lexicon. Unfortunately, there were very few words with exceptional spelling-to-sound correspondences; words with regular correspondences could have been read via the sublexical reading route, which would mean that the phonological output lexicon was not required. However among the small corpus of exception words there were no "regularisation" errors, so this suggests that the reading was being done lexically.

The control task combinations were the same oral reading task paired with a phoneme detection task (for example the subjects had to listen to a string of words until they heard the phoneme /l/), and the name detection task paired with a shadowing task. These pairs were to be equivalent to combining the oral reading and name detection tasks, except that each control task pair required processing by the same lexicon: the phonological output lexicon in the case of the first control and the auditory input lexicon in the second. The phoneme detection task obviously entails a much greater processing load than the other tasks, which might explain the decrement in this case. In an attempt to rule out this interpretation, Shallice, McLeod and Lewis demonstrated that there was no decrement in performance when these tasks were paired with a complex (non-linguistic) visual task. To mix shadowing with auditorily presented name detection is certainly not equivalent to the original combination in that shadowing requires more peripheral processing in an identical channel, which might cause greater interference.

Although this dual task experiment does seem good evidence for separate input and output lexicons, choosing appropriate control tasks is evidently problematic.

The last source of evidence from normal studies, for this obviously vexed question, is an analysis of speech error data by Fay and Cutler (1977). They propose that if processing in a two lexicon model is to be maximally efficient, then the input lexicon will be arranged phonologically since that is the form of access, and the output lexicon, which is by contrast accessed from the semantic system, will be semantically organised. Speech errors arising at the level of the output lexicon should therefore be semantically related to the target; errors which are phonologically related to the target must be generated at a more peripheral level and should therefore be largely non-words. An analysis of their speech error data shows that most phonologically related errors are in fact real words, and they argue that this suggests that the output lexicon is in fact organised phonologically; and since this happens to be how the input lexicon ought to be organised, then the obvious explanation is that they are one and the same lexicon.

Apart from the fact that this theory is making very large assumptions about the nature of lexical representation, there are other ways of explaining the fact that most phonological errors are real words. For example, non-word errors may be generated, but edited out, as suggested by the work of Motley, Baars and Camden (1983). Similarly any kind of interactive account would predict that even if the error was generated post-lexically, it would be likely to be a real word because lexical items will receive more activation from the interaction between levels of processing (Stemberger 1985).

Repetition impairments

Neuropsychological evidence is equally controversial. The most obvious way to show that the input and output lexicons are separate is to demonstrate that a patient has a deficit in one while the other remains intact. In practice this has proved to be a difficult task, since it is necessary to establish that the deficit is within the lexicon itself and not in its access. For example, the fact that a patient has an auditory comprehension impairment, but no impairment of naming would not be evidence for separate lexicons, since the comprehension impairment could be in the access to the semantic system from the lexicon. If information in the lexicons is distributed, then it would be extremely difficult to distinguish between an access and a store deficit. If the lexicon contains local, non-distributed representations, then such a distinction could in principle be made.

Shallice (1987) suggests a number of criteria which indicate loss of representations (i.e. impairment within the lexicon itself), for example that there should be within item consistency and that the items should not be primable. Item consistency (assuming it is not 100% consistency) could be attributed to other factors, such as word frequency or imageability. If the impaired lexicon was generally degraded in some way, rather than missing specific items, then the system could be primable despite the fact that the impairment is actually specific to the lexicon. In the orthographic domain, Coltheart and Funnell (1987) have attempted to compare the errors made in input and output in the reading and writing of a patient, but have found the exercise fraught with difficulty for these very reasons. Butterworth, Howard and McLoughlin (1984) looked at a group of dysphasics and found a significant correlation between the number of semantic errors in naming and the number of errors in word comprehension, but again the level at which these deficits are operating is unclear.

The most compelling evidence from neuropsychology is the fact that some patients make "semantic" errors in repetition, similar to the semantic paralexic errors made by "deep" dyslexic patients. (Goldblum 1979, Morton 1980b). Allport and Funnell (1981) considered semantically related errors in oral reading to be good evidence for separate orthographic and phonological lexicons. Why then is an equivalent symptom in repetition not evidence for separate auditory input and phonological output lexicons?

In order for a patient to produce a repetition error which is related in meaning to the stimulus word, the word-form in the input lexicon has to be accessed; otherwise it would not be possible to access any meaning, let alone precisely the correct one. If there is only one phonological lexicon, then once having accessed the word form it should be available for output. However, a "threshold" model like the logogen model allows for the possibility of two separate thresholds within a logogen (Morton 1980a); so in an impaired system there might be sufficient activation for an output to semantics but not for the higher threshold to output phonology. Thus repetition could only be achieved via the semantic system. A difficulty with this account is that if the word form for output has to be accessed in the same lexicon where initial threshold has already been reached for the correct word, then this should increase the chance of activation from the semantic system achieving the higher threshold required for output. The single lexicon account would need not only to assume that required thresholds differ according to the subsequent location of processing, but also that all patients producing semantic errors in repetition have a central semantic, as well as a lexical impairment. (This does not seem to be true for all deep dyslexic patients, e.g. P.W. (Patterson 1979).)

According to Marslen-Wilson and Tyler's (1980) "cohort" model, or a "cascade" model such as that proposed by McClelland (1979), partial information in multiple entries at each level of processing begins activating possible candidates at subsequent levels of processing (Marslen-Wilson 1987). It would therefore be possible to activate semantic candidates for a response before all the appropriate auditory information had been processed; a semantic error could be produced despite the fact that there was insufficient phonological information about the target word for a direct output response. The assumption then has still to be made that the input phonological information is somehow insufficient to achieve activation for output, given that there may be partial activation from semantics for this word also, which again should mean more activation for the correct word than the semantically related error.

There is no completely compelling evidence to support the notion that there are separate input and output lexicons. Repetition priming experiments are inconclusive in this matter, although the dual task experiment of Shallice, McLeod and Lewis does support the two lexicon model. Since the major evidence for separate orthographic and phonological lexicons given by Allport and Funnell (1981) is the occurence of semantic paralexias in deep dyslexic reading, it is difficult to see why they do not find the occurrence of semantic errors in repetition more convincing.

On the assumption that there are separate input and output lexicons, what is the evidence for a third repetition route, operating lexically, without accessing semantics?

1.5 Direct Route Repetition?

Direct route reading

Three routes have been described by which printed words can be read aloud (Coltheart 1985). The semantic route requires the meaning of the word to be accessed; the sub-lexical route accesses sub-word sized bits of phonology from orthographic segments and is the route by which novel, or non-words are read. The third is a direct lexical route from the visual input lexicon to the phonological output lexicon. The ultimate demonstration that such a route existed would be a patient with grossly impaired reading comprehension with an ability to read aloud all real words correctly, including irregular words, but a complete inability to read non-words. Unfortunately such a case has never been described. There are, however, dyslexic patients reported who, it is argued, are relying on such a route for oral reading. Two different types of cases are relevant here.

WLP (Schwartz et al 1980) had extremely poor comprehension, but made few errors in oral word reading. She was able to read non-words, so could have been reading via the sublexical route; but Schwartz et al argued that in that case she should have regularised words with exceptional spelling-to-sound correspondences (as do "surface" dyslexics, Patterson et al 1985). In fact in the corpus they give, she did regularise a small number of exception words; so that this is not an entirely convincing demonstration of direct lexical reading.

Funnell (1983) describes a patient, WB, who was entirely unable to read non-words, but who read, on average, 90% of real words correctly. Funnell argued that he could not be reading all real words via the semantic route, since he had difficulty in distinguishing the meanings of semantically similar words, and had quite a severe anomia. If he were reading via this route, not only would his reading be much worse overall than the 90% he achieved, but he should also make a proportion of semantically related errors. From a large corpus, Funnell only found 2 items which were possible semantic paralexias, and these were questionnable. The other possible way of explaining his good reading, without recourse to a direct lexical reading route, would be that he is combining information from the semantic and sub-lexical routes at output, which could have the effect of editing out semantically related errors, since they will be phonologically distant from the target. However, WB seems to be getting very little phonological information from non-words; his errors are mostly failures to respond or a response which bears no phonological relationship to the target. The combined route explanation therefore seems difficult to sustain for this patient's reading. W.B. is good evidence for a direct lexical reading route.

Indirect evidence for such a route is shown by Coltheart's observation of a surface dyslexic patient, AB, who on occasion defined an irregular word as its homophone; eg ROUTE -> "what holds the apple tree in the ground and makes it grow" (Coltheart et al, 1983). If the patient was reading this sub-lexically one would expect that on some occasions he would produce a definition appropriate to the regularised pronunciation (e.g. in this case, the word ROUT). The fact that AB has defined the word's homophonic mate shows that his comprehension is based on a phonological rather than an orthographic code for the stimulus word; but since it is an irregular word, the claim is that he must have generated its phonology via the lexical system.

Direct route repetition

In oral reading, then, there is at least some evidence to support the postulate of a direct route from lexical orthography to lexical phonology; what evidence is there for repeating spoken words via a lexical route without accessing semantics?

Once again, the best evidence would be a dysphasic impairment where there was a complete inability to repeat non-words, no impairment in repeating real words but a severe impairment in comprehending those words. Such a patient has not been convincingly described; this may be partly because such a patient would also have to have a severe impairment in written comprehension; otherwise s/he should be able to convert output phonology to orthography and comprehend the orthographic representation.

Patterson describes a patient G.E. who she demonstrates is using a lexical, non-semantic route to write words to dictation (Patterson 1986). According to the model proposed by Patterson and Shewell (1987), writing to dictation via this route requires direct lexical access from the auditory input lexicon to the phonological output lexicon and thence to the orthographic output lexicon. There is no route directly from the auditory input lexicon to the orthographic output lexicon. The evidence for this is rather slight, mainly resting on the fact that a connection between the phonological and orthographic output lexicons is necessary to account for homophone errors in spontaneous writing (e.g. there/their confusions). If writing to dictation is parasitic on repetition, then G.E. (paradoxically for one entirely unable to repeat) is by implication good evidence for the existence of a direct lexical route in repetition.

Wernicke (1874) described "transcortical sensory aphasia"; a syndrome of intact repetition with impaired auditory comprehension and fluent, anomic speech. Gardner and Winner (1978) studied a group of patients with transcortical sensory aphasia and found that they repeated words better than non-words; but the patients were not studied in sufficient detail to rule out the possibility of combined information from semantic and sub-lexical routes. Davis et al (1978) studied patients with transcortical mixed aphasia (also known as isolation syndrome), where both comprehension and spontaneous speech are severely disrupted, but again repetition is spared. When the patients were asked to repeat sentences containing syntactic errors, although they did not appear to be able to understand the sentences, they tended to correct the errors. Such corrections are difficult to explain if repetition was occurring only at a sub-lexical level; but again it is difficult to draw conclusions from these experiments without knowing how severe were the dissociations between phonology and semantics.

The evidence for a direct lexical repetition route is less substantial than that for a direct lexical reading route. This may, however, merely reflect the fact that fewer experiments have addressed the issue. There is some evidence for separate input and output lexicons for repetition, but it is by no means conclusive. The existence of a sub-lexical route is well-established, but little is known of the properties of such a route.

In the next section impairments in naming will be reviewed, since impaired lexical/semantic repetition will reflect the properties of auditory comprehension and naming. Other properties of repetition may then reflect sub-lexical processing.

1.6 Impairments of naming

Naming requires the correct semantic specification for the word which is used to access the phonological form from the phonological output lexicon; this phonological form is held in the response buffer in order for an articulatory pattern to be assembled.

The ability to name is generally tested using picture naming which also requires the correct identification of the picture and access to the appropriate semantic information for the picture.
Various types of error are made in dysphasic picture naming:

1) No response.
2) A semantic error, which is related in meaning to the target.
3) An unrelated real word error; a word which has no obvious semantic or phonological relation to the target.
4) A phonological error which is conventionally defined as a response which shares at least 50% of its phonemes with the stimulus.
5) A neologism which is a non-word with no obvious phonological relation to the target.
6) A phonetic error (ie in dyspraxia) - this level

of processing is omitted from the model in figure 2.1 as being peripheral to central language processing; generally the properties of phonetic errors have not been related to other areas of functioning using a cognitive neuropsychological methodology.

No response errors

When a patient fails to make any response at all in picture naming, it is extremely difficult to extrapolate a point of breakdown. However, if a patient has a severe anomia, which is characterised by (a) no-response errors rather than related errors, (b) success on only a few high frequency words, (c) consistency of performance for the same item on different occasions and (d) no significant facilitation from cues, then there is good reason to think that entries in the phonological output lexicon may be degraded. Patterson and Shewell's patient, G.A., seems to fit this description (Patterson and Shewell 1987).

Semantic errors

One reason for a naming error might be inadequate semantic representation of the concept to be named.

The paper by Butterworth et al (1984) showed that all their group of anomic patients (whether fluent, non-fluent or conduction) also made errors in fine comprehension tasks. This might suggest that at least some patients who appear to have an output anomia do in fact show a central semantic deficit when testing is sufficiently sensitive. However, in Howard et al's (1985) facilitation experiments, on a task of pointing to named pictures in the presence of semantically related foils, the majority of the patients made no errors in picture pointing although they made many errors in naming. (This was despite the fact that some of the errors they made in naming happened to correspond to the semantically related picture foils used in the comprehension task.) For these patients at least, a central semantic deficit cannot explain their picture naming problems.

If the central semantic system is intact, then semantic errors may be caused by an inadequate specification in the address to the phonological output lexicon. This notion is supported by Howard and Orchard-Lisle's (1984) finding with their patient, JCU: when unable to name a picture, she was not only helped by a correct phonemic cue (indicating that a partial representation was already available); but she also tended to make semantically related errors in response to an <u>incorrect</u>

phonemic cue [picture of a THUMB: /f/ -> "foot"] indicating that other semantically related items had been activated in the output lexicon.

Unrelated real word errors

Like no response errors, it is very difficult to trace the genesis of unrelated real word errors. There are several possible accounts, and it is likely that they all apply. For example, these may be mixed errors (e.g. a phonological error on a semantic error) which have defeated the ingenuity of the experimenter. They may be highly frequent words generated as "fillers", rather in the manner of Butterworth's explanation for neologisms (see below). A large proportion of them appear to be perseverations from earlier responses.

Phonological errors

There are two types of explanation for phonologically related errors: either they are another form of access problem to the phonological lexicon (Butterworth (1985) claims that there is no evidence that partial phonological forms can exist in an abnormal phonological output lexicon), or the response buffer is unable to hold the phonological form for long enough to produce the complete phonological form for speech. Miller and Ellis (1987) argue that a response buffer problem should mean that phonemes at the beginning of the response would be better preserved than phonemes at the end of the word. They analysed the errors of their patient, RD, and found no such effect. The notion that semantic and phonological errors derive from a common access problem is attractive since they invariably co-exist at least to some degree in anomic patients.

Neologisms

One clear genesis of neologisms is the mixture of a semantic error and a phonological error. Howard et al (1984) cite the following examples from a large corpus;

WEB -> /spaIdId/ (via spider)
bull -> /hoks/ (via ox)

It may be that if we had sufficient information about the intervening errors, then all neologisms could be explained thus; but there are many that defy obvious analysis. Butterworth (1985) suggests that in jargon patients, who produce a very high proportion of neologisms with no obvious relationship to the target, there is a "random phoneme generator" which fills the spaces where words are unavailable.

Both reading and repetition impairments produce errors which can be categorised in the same way as naming errors (Coltheart et al, 1980; Howard and Franklin, 1988). A comparison of such errors in a group of aphasic patients, across all three modalities, will be presented in chapter 6.

Conduction aphasia and short term memory impairments are closely related (Allport 1984); in later chapters I will attempt to make this relationship more explicit. The next section comprises a brief review of models of auditory short term memory and of neuropychological impairments of short-term memory.

1.7 Auditory short-term memory

A two-stage model of immediate serial recall

It is generally agreed that there is a specific working memory system for auditorily presented information. Baddeley's (1986) model consists of a phonological input buffer and a rehearsal loop. He argues that the buffer must be at the level of input because there appear to be short term memory patients who are poor at matching span tasks, have fluent speech and are impaired at immediate serial recall (e.g. KC, Allport

1984; JB, Shallice and Butterworth 1977; and PV, Vallar and Baddeley 1984), all of which are explicable in terms of an impaired phonological input store. Other patients are good at matching span tasks but have impaired output; these would be patients with an impairment of rehearsal (e.g. R.C.; Allport 1984).

Baddeley argues that the two components of the system are able to explain the differential effects of articulatory suppression in normal subjects. Immediate serial recall is reduced for phonologically similar items, whether presented auditorily or visually (Conrad and Hull 1964). Articulatory suppression removes this effect for visual presentation, but not for auditory presentation (as long as suppression does not continue through the recall phase; Baddeley, 1986). Immediate serial recall is also reduced for longer words; but articulatory suppression removes this effect irrespective of modality of presentation. Baddeley argues that phonological similarity is indicative of the functioning of the phonological input store, whereas word length is a feature of the rehearsal loop (Baddeley 1986). He also argues that auditory short term memory must be operating at a phonological rather than a semantic level since for immediate recall semantic similarity does not affect performance. The fact that visually presented items are affected by phonological similarity but not with articulatory suppression is because visually presented information can only be coded into the store via the rehearsal loop, and the rehearsal loop is blocked with the items for suppression. The fact that unattended speech also affects visually presented serial recall (Salame and Baddeley, 1982) is, he argues, simply because speech has obligatory access to the working memory system.

A three-stage model of immediate serial recall

Morton in his (1970) logogen model includes a response buffer for phonological output. The output has to be buffered to deal with the eye/voice span (Morton 1964) and the ear/voice span (Treisman and Geffen 1967). This buffer is specifically related to lexical processing in Morton's model; Baddeley does not relate his working memory system to lexical processing, despite the fact there are strong lexical influences on immediate serial recall (the span for non-words is around 3 (Brener 1940), but almost twice that for real words). Originally the rehearsal loop was related literally to articulatory rehearsal, but this proved to be untenable when it was found that anarthric patients could have normal auditory short term memory (Baddeley and Wilson, 1985, Vallar and Cappa,1987).

Like Morton, Monsell (1987) relates auditory short term memory to a model of lexical processing. His model has both input and output buffers, with a loop in between them. He suggests that phonological similarity effects can arise in either buffer. The system provides feedback to auditory comprehension via the "inner ear". Monsell points out that there must be a more peripheral feedback pathway which processes speech at a less abstract (e.g. featural) level. He proposes two different types of memory (Monsell 1984). "Type I" memory is persisting activation in the normal processing units; for example in the lexicon. "Type II" memory holds "novel structures" for a limited amount of time in a "limited-capacity representational space": this is the kind of memory that would be held in a buffer or store.

Dysphasia and impairments in auditory short term memory.

In Howard and Franklin (1987) two surface dyslexics are described; EE appeared to rely to some extent on "inner speech" to comprehend visually presented words: MK, although able to phonologically recode written words for output, was unable to use inner speech to access auditory comprehension. This was indicated by his inability to define written pseudohomophones by anything other than "approximate visual access"; he was at chance at pseudohomophone detection and was much worse at written rhyme judgments than spoken ones, despite being normal at homophone matching. In Howard and Franklin (in press) it is argued that MK has a severely impaired rehearsal loop, and that he behaves like a normal does under articulatory suppression. Suppression in normal subjects does not affect homophone matching (Baddeley and Lewis 1981), or auditory rhyme judgements (Wilding, unpublished), but does affect written rhyme judgments (Besner, Davies and Daniels, 1981). It also affects pseudohomophone detection , unless the pseudohomophones are presented at a slow rate (Besner, Davies and Daniels, 1981). MK's auditory matching span was affected by phonological similarity, but visual matching was not, which is again the pattern for normals under articulatory suppression.

As already mentioned, neuropsychological data have been an important influence on short term memory models; "pure" short term memory patients have been reported who appear to have input short term memory and output short term memory features. For example Allport (1984) describes a patient, RC, with an impaired digit repetition span and non-fluent speech but good performance on matching span tasks, who therefore appears to have an output memory problem. By contrast Allport describes JD, who has fluent speech but is impaired on probe tasks, suggesting an input locus for his short-term memory impairment. In their review of 21 short term memory patients Caplan and Waters (unpublished manuscript), identify 4 categories of disorder; a phonological input impairment, a phonological store impairment, an impaired articulatory loop and a "central phonological processing disturbance".

Short term memory deficits have been associated with "conduction" aphasia, where auditory comprehension is intact, but repetition is severely impaired (Goodglass and Kaplan 1972). Shallice and Warrington (1977) have suggested that there are two forms of conduction aphasia. One is associated with impaired speech production, irrespective of task. The other is associated with impaired auditory short term memory, and here the impairment will be specific to repetition while naming will be relatively spared. Allport (1984) argues against such a dichotomy.

Most "deep dyslexics" are described as having reduced auditory short term memory. In his review of deep dyslexic cases Coltheart reports 10/12 patients having impaired auditory short term memory (Coltheart 1980a).

Such an association would be explicable if auditory short term memory were necessary for phonological recoding of orthographic material. Since MK has an extremely impaired auditory short term memory (Howard and Franklin, in press), but as a mild surface dyslexic (Howard and Franklin 1987) is overly reliant on phonological recoding in reading, this is not tenable. One is forced to the conclusion either that all dysphasics have impaired short term memory, which seems unlikely (e.g. Damasio and Damasio 1980), or that the auditory short term memory system has to fractionate sufficiently to account for different symptom complexes.

The repetition impairments of a group of fluent aphasic patients will be presented in Chapters 5 and 6. Later chapters will address the issue of the relationship between word repetition and auditory short term memory (and their impairments) in more detail.

Chapter 2: Auditory comprehension

In order to understand a heard word, it is necessary to use auditory information to access semantics. Since the relationship between these is quite arbitrary (except in the case of onomatopeic words), there must be some kind of analysis of the acoustic input, to address some kind of abstract representation of the word. In this chapter, three broad stages of processing in auditory comprehension will be discussed; auditory analysis, lexical access and semantic access.

Auditory Analysis (Morton and Patterson 1980) is used to describe the pre-lexical analysis of speech sounds; since the mechanisms of this analysis are as yet obscure, this is a suitably neutral term with which to begin. A brief review of issues in speech perception is presented. Experiments on lip reading are considered, both as being relevant to issues of speech perception, and because the relationship between lip reading, repetition and immediate recall will be addressed in this thesis. Neuropsychological studies of impairments of auditory analysis concern the study of the syndrome known as "word deafness".

Lexical access is taken to mean the process by which abstract representations of words (or morphemes) are activated. Evidence for properties associated with this stage of processing arises from experiments on repetition priming and lexical decision as well as from neuropsychological data.

Semantic access is the process by which the abstract representation of the lexical form maps onto the meaning of the heard word. In the third section of the chapter, issues of semantic organisation are considered, particularly with reference to the concreteness/abstractness dimension. Evidence for a specific impairment between lexical and semantic levels of processing is reviewed.

2.1 Auditory Analysis

Phonemes or features?; evidence from studies (and theories) of normal speech perception.

Studdert-Kennedy (1974) suggested that there are four stages in speech perception: auditory, phonetic, phonological and lexical/semantic. Klatt (1980) has developed a model where spectral representations of acoustic information map directly onto lexical forms. Which (if either) is the better description of auditory analysis?

Analysis of acoustic information in order to recognise phonemes is by no means a straightforward business; for example there are not discrete time segments of acoustic information which map directly onto phonemes. Rather, co-articulation means that features corresponding to more than one phoneme will appear at the same time (Lieberman et al 1967). Furthermore there is no invariant relationship (Chomsky and Miller 1963) between acoustic information and phonemes, in that each phoneme may have several allophonic variants, which are used context-sensitively.

This has led some authors (Klatt 1979, Marcus 1981) to suggest that analysis of the whole unit is less problematic than having to segment strings at a pre-lexical level. Church (1987) disagrees, making a convincing case for the idea that allophonic variation can help in parsing the acoustic string. If the rules of allophonic variation are known, the presence of a particular variant could be used, for example, to detect word boundaries. Knowledge of phonotactic constraints (Kiparski 1981) can be similarly applied.

Many experiments in the field of speech perception have looked for evidence of phonetic "features" in auditory analysis (Eimas and Corbit, 1973). The problem with many of these experiments is that tasks which appear to require processing at a feature level in fact only require peripheral auditory processing (Pisoni and Luce 1987).

The psychological reality of a "phonemic" level of processing largely rests on the normal ability to segment strings in terms of phonemes, for example in rhymes (Treiman 1983). Speech errors often consist of phoneme exchanges (Fromkin 1973), which is strongly suggestive of some kind of phonological unit operating; but since this is speech production, it may well be represented at an output level but not a perceptual level. Indeed Morton and Long (1976) suggest that phoneme detection occurs after lexical access; Foss and Blank (1980) attempt to refute this by showing that phoneme detection can be done in non-words. Since non-words also have an output form it is hard to see the logic of this refutation. More persuasive are speech misperceptions (Bond and Garnes 1980) which involve misperceptions of units smaller than the word. Such misperceptions, even when they are apparently phoneme transpositions, might however be equally well explained by errors at a feature level.

Elman and McClelland's TRACE 1 model (1984, 1985) used acoustic features to activate phonological representations which in turn activated lexical forms.

This appeared to work well, albeit for a small number of items, but as it is a simulation, this of course is not evidence for psychological reality.

Thus, despite a large literature on the subject, there is really very little evidence to suggest whether auditory analysis consists of a phonetic feature analysis only (or even more low-level perceptual analysis) or a phonetic feature and a phonological level of analysis.

2.2 Lip reading

Although it does seem that patients can have specific, even "pure" impairments at the level of auditory analysis, it is not clear whether these impairments dissociate into phonetic and phonological impairments as would be predicted by Studdert-Kennedy's model (1977). The problem is to specify how impairment at either level would differentially impair speech processing. One way of assessing the "modality specificity" of the input would be to investigate the relationship of lip reading to speech perception.

It has long been realised that normal speakers are able to comprehend speech in background noise much better if they are allowed to lip read (Sumby and Pollack 1954).

More recently it has become clear that lip reading has a more fundamental role in comprehending speech, despite the fact that it is perfectly possible to comprehend speech which is heard only, as long as no background noise is present.
Reisberg, McClean and Goldfield (1987) found that speech perception was perfect with audition alone, but that a semantically complex message was better understood with lip reading.

McGurk and Macdonald (1976) showed that when normal subjects heard and saw different phonemes simultaneously, what they believed they "heard" was influenced by their lip reading (the "fusion illusion"). So for example if they saw /ba/ and heard /ka/ they tended to report it as /da/.

Kryster (1970) found that in noise subjects were able to discriminate on the basis of voice and manner of articulation, but not place; place is obviously the distinctive feature which lip reading can disambiguate.
Mills (1987) reported that visually handicapped children were slower than normal children at acquiring sounds with clearly visible articulation.

So lip reading is not just additional and separate information which is used only in special circumstances. It appears to access an abstract code, that is, a code which is amodal rather than purely acoustic. This is confirmed by Campbell and Dodd's (1980) finding that recency in immediate serial recall was abolished by a purely lip read suffix following auditory presentation (and vice versa), whereas an orthographic suffix does not affect recency. Campbell (1987a) also found that a mouthed suffix did not affect lip read recency as much as an auditory suffix, suggesting that lip reading is combining with phonological input rather than with articulatory information.

Campbell (1987b) concludes that:

> *"recency and suffix effects arise at a stage of processing for recall where the common phonological code, enjoyed "automatically" by heard and lip read material, is activated."(p.249)*

She suggests that this is occurring at a higher level of processing than Crowder and Morton's (1969) "precategorical acoustic store", since a suffix in a different voice to that known to belong to the person being lip read had an equally disastrous effect on recency.

Work on lip reading does suggest that there is a pre-lexical, abstract (in that it is amodal as to origin) representation of auditory information. The nature of this representation, and the exact level at which lip read and auditory information combine, is far from clear.

2.3 Word deafness

Cases of word deafness have been reported in the literature for over a hundred years, since Kussmaul's description of a patient in 1877 (Goldstein 1974). Unfortunately, it is very unusual for (exactly) the same experiment to have been done on more than one patient; this, coupled with the fact that word deafness is almost certainly not a unitary disorder, has meant that results are confusing and even paradoxical. The term "word deafness" itself has been used in a number of different ways. All these definitions appear to refer at least to an inability to comprehend language which is specific to the auditory modality, with no peripheral hearing loss.

"Pure word deafness" can be taken to mean that the patient's language system, i.e. his reading and writing and speaking, are all normal and the only deficit is in auditory comprehension. Because repetition and writing to dictation require auditory processing, they will be severely affected (Hemphill and Stengel 1940).

Other authors use the term "pure word deafness" to specify that the problem is at a peripheral phonemic or prephonemic level (Allport 1984).

Buchman et al (1986) suggest that for a patient to be word deaf, he must only have problems in processing language sounds; his ability to recognize non-verbal sounds should be unimpaired (to distinguish word deafness from auditory agnosia) and his neurophysiological ability to respond to tones should be normal (to distinguish it from cortical deafness). However in a review of 34 cases they found that most patients reported did have some other form of auditory perceptual impairment. Nevertheless, there are dissociations reported which may suggest that processing of verbal and non-verbal sounds are functionally independent tasks. Michel et al (1980) describe a patient who was cortically deaf; they demonstrated that there was an absence of late auditory evoked potentials in this patient, who had bilateral brain damage. This would correctly predict that the patient's impairment should not be specific to speech sounds. One of the three cases studied by Buchman et al was reported to have normal nonlinguistic comprehension. However, one wonders if tests such as discriminating between English and non-English speakers, and distinguishing a car engine noise from the noise of a door opening, require the same degree of sensitivity of processing as discriminating two phonemes which differ by one distinctive feature. Shoumaker et al (1977) found that although their patient could recognize non-linguistic sounds, he was unable to recognize tunes; whether this is a more sophisticated non-linguistic acoustic task, or whether it requires very different processing, is open to question.

Ziehl (1886) distinguished between word sound deafness ("wortlauttaubheit") and word meaning deafness ("wortsinntaubheit"). Word sound deafness was an inability to process auditory/phonetic information, and was necessarily associated with disorders in repetition and writing to dictation. Word meaning deafness was an inability to derive the meaning of the word and was distinguished from word sound deafness by the patient's ability to repeat and write to dictation without impairment.

Is word deafness a "pure" syndrome?

Although many authors define word deafness in these terms, when they go on to report their actual cases it becomes clear that the criterion of an absence of other language deficits is generally not strictly applied (Buchman et al 1986). Even though word deafness may dissociate from other language deficits, this does not mean that it cannot coexist with those deficits, particularly since word deafness is often described in its "pure" form as being a resolved Wernicke-type aphasia (Saffran et al 1976). It certainly seems perfectly valid to diagnose word deafness as a symptom rather than just a pure syndrome, particularly if the assessments used are sufficiently detailed to give an adequate differential diagnosis.

Is word sound deafness "Pre-phonetic"? Various authors have attempted to look at the characteristics of the phoneme perception problem in word sound deafness, to establish the level at which processing is breaking down. Saffran et al (1976) found that their patient had more difficulty detecting voice contrasts than place ones and suggest that this is pre-phonetic because while it is systematic, it does not correspond to normal difficulties in categorical perception. That is, the problem in detecting voice contrast cannot be explained by a shift to a different locus on the Voice Onset Time continuum.

Auerbach et al (1982) found preserved categorical perception in their patient, and the patient had more difficulty discriminating phonemes differing by fewer distinctive features. However auditory evoked potential studies suggest that their patient also had a prephonemic disorder. It may be that word sound deafness can occur in either a prephonetic or a phonetic form; if this were convincingly demonstrated it would be of considerable importance in terms of the number of processes involved in speech perception. Unfortunately there is at present no sufficiently specified theory of what constitutes prephonetic and phonetic processing to make differential diagnosis possible.

2.4 Lexical access

Theories of how information is processed in the language system are heavily influenced by experiments on lexical access. Normal studies of lexical access consist of work mainly in two experimental paradigms: lexical decision and repetition priming. Much of the work has been carried out using written stimuli rather than spoken; its relevance to auditory lexical access will be evaluated. Finally neuropsychological impairments in lexical access will be reviewed (again the majority of these involve studies of impaired reading).

Theories of information processing

Since Morton's "logogen" model (1968; 1969) was first introduced a major class of information processing theories have held that information can be activated in parallel. Serial models such as Forster's "Autonomous Search Model" (Forster 1976) cannot account for the fact that words in context can be recognised before sufficient sensory information has been analysed to uniqely identify a particular word form (Tyler and Marslen-Wilson 1982). Other aspects of theories of processing are more controversial; for example whether processing at one level has to be completed before information can be activated at the next level (McClelland 1979), whether there is interaction between levels (Frauenfelder and Tyler 1987), and whether representations are distributed (Hinton et al 1987). Of course it is very difficult to assess the relative merits of general theories, and more appropriate to consider specific models. These three issues will therefore be discussed with reference to the "Logogen model" (Morton 1970), "TRACE" (McClelland and Elman 1987) and the "Cohort model" (Marslen-Wilson and Tyler 1980, Marslen-Wilson 1987).

In Morton's model, logogens are local (i.e. non-distributed) representations with resting levels of activation. The higher the frequency of usage of the word, the less activation is required for the logogen to "fire". Each time a logogen "fires" it causes a lowering of the threshold level. Thus is the model able to explain both frequency and priming effects. Partial activation does not access higher levels; that is, there is only one output from the system. However, there is feedback from the cognitive system to the input logogens, allowing for top-down processing.

TRACE is quite a different type of model, in that it is a computer simulation of a particular aspect of language processing; it does, however, aim to "mimic" real life processing. It belongs to a particular family of models, known as "interactive activation" models (Rumelhart and McClelland 1982). This particular model attempts to describe auditory comprehension only as far as lexical access; it has no semantic component. In TRACE, partial information at one level accesses information at the next level, and information between levels interacts in an excitatory fashion. Representations are again non-distributed.

TRACE is programmed to "recognise" only 211 words, proceeding from the feature level, via the phoneme level to lexical access. With more representations, it is not clear that there would only be one candidate word arrived at, and there is no attempt to build in frequency effects. However the model easily accounts for coping with a noisy system, and for mixed errors; indeed such a highly interactive system may well mean that (for both an impaired and an unimpaired system), errors will be of all types. Emergent properties claimed for this model are:

1) a tendancy towards categorical perception.
2) lexical feedback effects.
3) an ability to parse word boundaries.
4) despite a heavy influence of word beginnings, an ability to recover from initial distortion.
5) an ability to cope with elision.

It is not clear whether the first two are emergent properties, or whether they are actually part of the initial design; neither is it clear whether properties 3-5 would still be true for a much larger set of items.

The original version of the cohort model comprised a "lexical level" of non-distributed representations. Information was initially processed in a way corresponding to the temporal nature of auditorily presented speech, but once the initial segment had activated the cohort, top down processing could influence selection. Because a word could be recognised once its recognition point (ie the point at which it is disambiguated from all other words) was reached, and more quickly in context, it was argued that an autonomous search model could not account for lexical access. Because the beginnings of spoken words such as "captain" and "captive" were equally good associative primes for visual lexical decision on the word SHIP (Marslen-Wilson 1987), it was argued that partial activation between levels was occurring.

Elman and McClelland suggested that a potential problem for the cohort model was the emphasis on activation of the initial phoneme; this had bottom up priority, and it was only once this phoneme had activated some information that context could affect access. Elman and McClelland pointed out that since it is possible to "hear" a word even when the initial phoneme is distorted, this is not tenable. Marslen-Wilson (1987) argues that since cohorts are accessed directly from acoustic feature information rather than via a phonological level, that even in noise there may be sufficient acoustic information to activate the system correctly.

The original cohort model took no account of word frequency, suggesting that those frequency effects found were a function of particular experimental tasks, and that on-line processing was not affected by word frequency. Subsequently Marslen-Wilson (1987) and Tyler (1984) found that frequency did affect early processing; thus the revised cohort model allows different representations to have different resting levels of activation.

The greatest problem for the initial model was that, because it had both excitation and inhibition between the semantic and lexical levels, it predicted that subjects would make errors with anomalous sentences, such as "John drank the guitar"; in fact although subjects are significantly slower in recognising "guitar" in this condition it is a very small effect, in the order of 20 milliseconds.

The new model, like TRACE, specifies that there is no inhibition between levels; although this allows for the recognition of anomalous words, it also means that there may no longer be just one candidate left in the cohort before selection takes place. Marslen-Wilson suggests that there may not even be interactive excitation, and that all the context effects can be explained by partial activation accessing higher levels, and context acting within level. This corresponds to a "feed-forward cascade" (McClelland

1979) or autonomous (Norris 1982; 1986) model.

Properties of the input lexicons

On some theories, the orthographic and auditory input lexicons represent stores of, possibly words, but more likely morphemes (Murrell and Morton 1974). Priming and lexical decision tasks have traditionally been used to investigate lexical processing. Experiments looking at effects of Priming experiments have distinguished two types of effects. One is a short-lived "associative" priming (Meyer et al 1975), which is modality independent (Swinney et al 1979) and occurs at the semantic level. Repetition priming is longer lasting, by definition word-specific, modality specific (Morton 1979, Winnick and Daniels 1970) and appears to be occurring at the lexical level. Reaction times in such experiments are affected by word frequency (Kirsner et al 1983). For written words, the physical properties of a stimulus do not affect priming, indicating that priming is occurring at an abstract level. So the effect survives changes in the orientation of words (Kolers 1976), shifts between case (Scarborough et al 1977) and changes in handwriting (Morton 1979).

In a written lexical decision experiment, James (1975) found that reaction times were longer for abstract infrequent words, suggesting that lexical decision may not be carried out at a purely lexical level. Although this was not a particularly well-controlled study, the effect has now been replicated (Anne Edmundsen, personal communication).

In auditory lexical decision tasks, as reported earlier, Marslen-Wilson (1987) found that frequency affected early processing of auditorily presented words. There is a clear difference between written and spoken lexical decision, in that there is no consistent effect of word-length in visual lexical decision on real words (Fredricksen and Kroll 1976), though there is an effect of item length on the rejection of non-words(Young and Ellis (1985)). Reaction times in auditory lexical decision relate to each word's recognition point, or in the case of a non-word, the point at which there are no possible lexical candidates (Marslen-Wilson 1987).

2.5 Impaired Lexical Access

Surface dylexics were originally reported as having a severe deficit at this level (Coltheart et al 1983). In fact other (though perhaps milder) surface dyslexics have been found with normal ability in visual lexical decision (Goldblum 1985, Howard and Franklin 1987).

Since there is no meaning attached to lexical units, only word frequency should affect performance on lexical decision, if it is a purely lexical task (Howard 1985). However some patients, such as the deep dyslexic patient DE (Patterson 1979) have been reported to show a significant advantage in lexical decision when the real words presented are concrete, rather than abstract. Other deep dyslexic patients show the same effect but only for less familiar words (Rickard 1986).

This perhaps indicates that lexical decision is not the purely lexical task it was thought to be; DE, whose semantic knowledge for abstract words is impaired, may base lexical decisions on his intact knowledge of the meanings of concrete words, thus rejecting meaning-impoverished abstract words irrespective of whether they are in his orthographic input lexicon. Some deep dyslexic patients do not have impairments in lexical decision (e.g. P.W.; Patterson 1979), or at least only slight impairments (Coltheart 1980a). This may be, as argued in the case of P.W., because his semantic system is intact, there being an output locus for his impaired semantic route reading.

Alternatively, it may be that it is possible to base lexical decision on representations in the orthographic input lexicon, but that semantic information may be utilised under certain conditions or by certain subjects/patients.

Howard and Franklin (1988) describe a patient, M.K., who is impaired at the level of lexical access for spoken words, although able to access written lexical forms. Like D.E. he is more likely to make errors in lexical decision if abstract words are used. His impairment of lexical access (= word form deafness) is not only indicated by impaired auditory lexical decision; he also tends to comprehend words as if they were other, phonologically related words; he makes phonologically related real word errors in repetition; and he is worse at repeating shorter words than long ones.

Access to semantics

Central semantic representations?

In order to understand a spoken or a written word, information from the selected lexical item in the modality specific input lexicon must access the meaning in the semantic system. Likewise an object recognition system must be able to access the meanings of objects. According to the model in Figure 2.1. there is one semantic system which is common to all modalities. Information in the semantic system accesses the phonological output lexicon in order to produce names of words.

There is little agreement on the form of the semantic system, except in that it would have rather different properties from those attributed to lexicons. For example it is unlikely that there is a one-to-one correspondence between a word-form and its meaning (Morton and Patterson 1980); rather, semantics will consist of sets of features, or properties, from which a context-specific meaning will be computed. No particular theory of semantic organisation is predominant, although "hierarchical" models (Shallice 1987) and "feature models" (Clark and Clark 1977) both have their advocates, while Coltheart (1980b) has

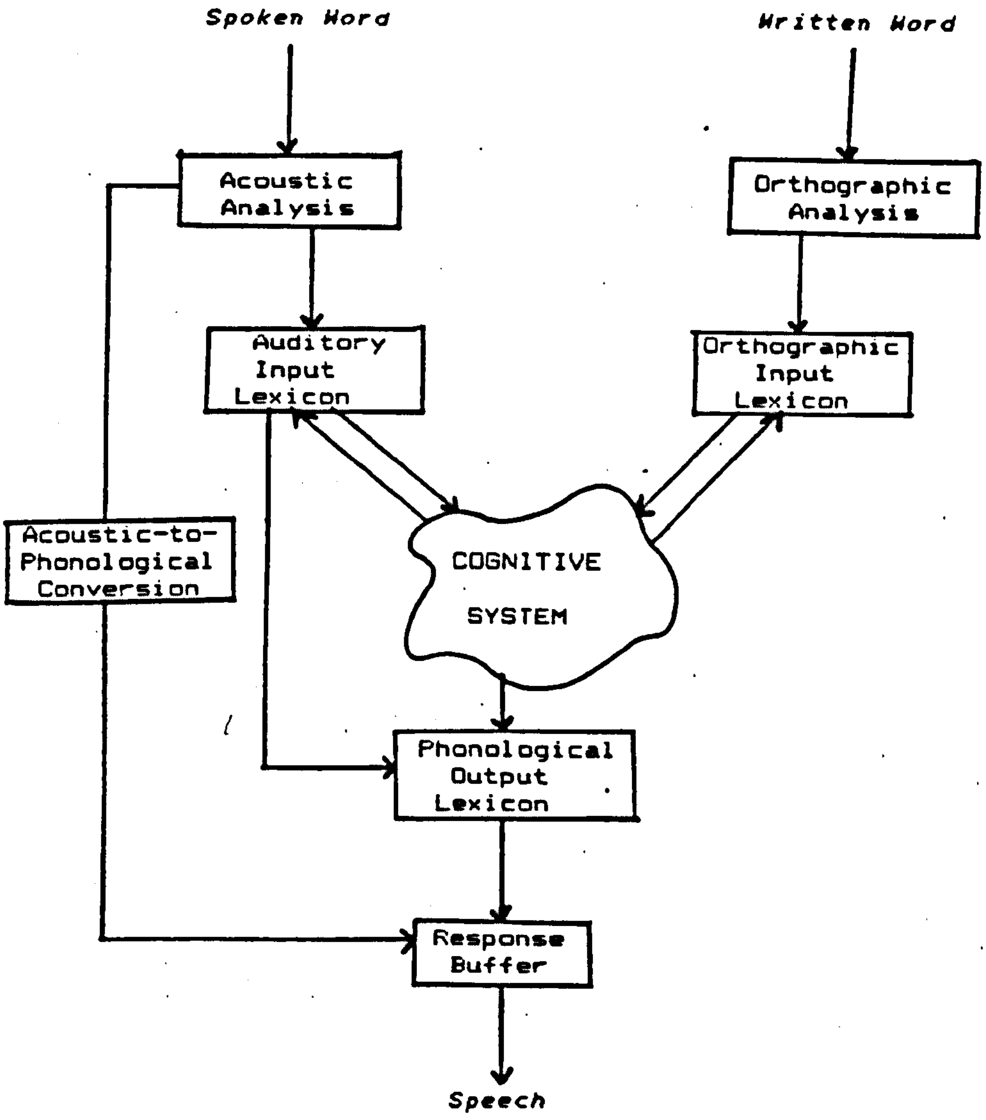

Figure 2.1: comprehension and repetition.

(Adapted from Patterson and Shewell (1987).)

suggested that both types of organisation co-exist.

Central semantic impairments

A controversial issue is whether there are separate semantic systems related to separate types of input, most particularly whether there is a "visual-semantic" system distinct from a "verbal-semantic" system (Shallice 1987, Riddoch et al 1988). The piece of evidence most quoted in support of this idea is the existence of patients known as "optic" aphasics (Lhermitte and Beauvois 1973). The claim is that although these patients have no visual agnosia, their picture naming is worse than their use of object names in spontaneous speech, their ability to name to definition or their tactile naming. In fact, in the case of one of the best-known patients, Jules F. (Lhermitte and Beauvois 1973), the only evidence that the patient is not agnosic is that he is able to gesture the functions of pictured objects. Since gestures by no means indicate a complete specification of the semantics for the picture (Riddoch et al 1988) and since Jules F. produced errors in picture naming which are visually related to the target, there must be a good case for the claim that this patient is indeed a visual agnosic; this syndrome of "optic aphasia" is unconvincing.

Warrington and Shallice (1979; also Shallice 1987) believe that it is possible to differentiate between patients who have a problem in accessing intact semantic information and patients for whom the semantic representations themselves are degraded. If the semantic representations are degraded, they argue that:

1) There should be consistency of performance item by item.

2) Priming will not improve performance.

3) Superordinate information will be more likely to be spared than attribute information.

4) Word frequency will be a "major factor" in predicting which items are lost.

5) More time given for the response will not increase the liklihood of the response being correct.

Points 1, 2 and 5 seem potentially useful, although the existence of such a patient has never been convincingly demonstrated. Point 3 could only apply to a hierarchical model of semantic organisation. Since at least some of the effects of word frequency are lexical rather than semantic, frequency effects will not distinguish between impairments at these two levels. When Shallice and Warrington describe an access problem, they still mean a problem within the semantic system. A problem in the procedure whereby the input lexicon accesses the semantic system they label a "partial transmission failure". It is not made explicit how these two types of access problem would be differentially diagnosed, although presumably the latter could be modality specific.

Semantic access impairments

Word meaning deafness has been reported less frequently than word sound deafness; a notable exception is the recently republished case-history by Bramwell (1897, reprinted with an introduction by Ellis, 1987). The data given by Bramwell are rather anecdotal and there is no evidence of single word comprehension impairment given in the paper (indeed when asked to point to named objects the patient made no mistakes); but her ability to repeat sentences which she appeared unable to understand does suggest this is word meaning deafness.

More recently Kohn and Friedman (1986) have distinguished three types of word deafness: word-sound deafness associated with impaired writing to dictation, and two types of word deafness which are associated with essentially unimpaired writing to dictation; pre-access and post-access word deafness. In pre-access word deafness the patient is able to write to dictation using a pre-lexical phonological to orthographic route; this means he will should correctly write words with a predictable sound-to-spelling correspondence, but will tend to misspell words with exceptional correspondences. In post-access word deafness the lexical form of the word is derived for spelling, and therefore all words should be spelled correctly, including exception words. This is a compelling argument, if such patients exist; but again this is an indirect way of describing the level of word deafness, and if a patient is unable to write to dictation it is not possible to make a diagnosis.

Kohn and Friedman (1986) present two patients, one, L.L., showing pre-access word deafness and the other, H.N., showing post-access word deafness. But they only cite 8 words where H.N. shows behaviour indicative of word deafness, and their diagnosis of a post-access deficit rests on his successful writing of "knee", "thigh" (irregular spellings) and "hair" (ambiguous spelling). Similarly, with patient L.L. they only cite 11 words which were not comprehended. L.L. could spell words if they had been comprehended but had difficulty spelling all words which were not comprehended, which could have been due to deficits other than an input lexical one.

Word class effects and semantic errors

The fact that deep dyslexics make semantic errors has been explained in two ways. The first is that not only are they forced to read via meaning because they have no sub-lexical route available, but that there is some damage to the semantic route itself. The other explanation is that a "normal" semantic system is unable to differentiate between words with similar meanings, and without some kind of direct or sub-lexical route to obtain the exact word by using a phonological check, it will always produce errors. It seems unlikely that the second explanation can explain all deep dyslexics' semantic errors, which are generally sub-ordinate or associative errors rather than synonyms; but the issue remains unresolved (Ellis 1984).

Many patients have been reported as having a particular problem in comprehending abstract words and functors (Warrington 1975), and Warrington (1975,1981) also describes patients who are better at comprehending abstract words than concrete ones. Non-fluent patients are more likely to produce content words than functors, whereas fluent patients are more likely to produce functors than content words. The production of fluent patients may actually reflect a bias towards words of high frequency (Ellis 1985) which would not necessarily be indicative of a semantic impairment.

There does however seem to be something "different" about the semantic realisation of concrete and abstract words. An extreme form of this would be a belief that they were represented in two different semantic systems, but there seems little evidence for this (Riddoch et al 1988). A particular difficulty with functors sometimes co-occurs with a problem with abstract words, and may simply reflect that functors themselves are highly abstract (Ellis 1984).

2.7 Concrete/abstractness and category specificity.

Many instances of category specific impairments in patients with dementia, or other non-vascular pathology have been reported (e.g. Sartori and Job 1988), most notably by Warrington and her colleagues (e.g. Warrington and McCarthy 1983; Warrington and Shallice 1984). Such impairments could of course indicate that the semantic system is organised in terms of categories, which would be support for a hierarchical model of semantic organisation (Shallice 1987; Warrington 1975).

However, Warrington and McCarthy (1983) point out that there may be more general differences between the types of category on which these patients show dissociations. V.E.R. (Warrington and McCarthy 1983) comprehended more food and flower words correctly than names of household objects, while S.B.Y. and J.B.R. (Warrington and Shallice 1984) were both better at comprehending object names than names of living things. Warrington and McCarthy (1983), suggest that household objects tend to be understood in terms of their functional properties, whereas living things tend to be understood in terms of their sensory properties. S.B.Y. is worse at comprehending concrete than abstract words, so this could account for his deficit with words whose meanings are distinguished by sensory properties. This argument is only tenable, however, if V.E.R. shows the opposite effect. This is difficult to determine, since V.E.R. obviously has a complex constellation of impairments; but she is worse at verbal than visual comprehension tasks.

For patients with vascular lesions at least, if there is a difference between concrete and abstract words, it is invariably the abstract class that is differentially impaired (indeed this is one of the cardinal features of deep dyslexia; Coltheart 1980a). This would lead one to conclude that abstract words are more difficult to comprehend, perhaps in terms of enjoying less redundancy of information than concrete words, or requiring more highly specified information for complete access. How can this be reconciled with the finding that S.B.Y. (Warrington and Shallice 1984), C.A.V. (Warrington 1981) and A.B. (Warrington 1975) are all worse at comprehending concrete words than abstract ones?

A possible explanation lies in the difference between a modality specific access deficit and a central semantic deficit. If abstract words are indeed more "difficult" then access deficits will always show an impairment in the direction of abstract being worse than concrete words. For example, degree of abstractness might determine how much information is required to specify a word unambiguously. Thus there would be more redundancy of information for concrete words, which would then be less affected if reduced information were available. However if the semantic system itself comprises different "subregions" (for example, one sensory and one propositional, e.g. Shallice 1988), any of which could be differentially impaired, then a central deficit could show an effect in either direction.

This explanation of course predicts that no *modality-specific* deficit will result in an advantage for abstract words over concrete words. There is no description of a patient having the opposite impairment; that is, a modality-specific impairment for concrete words, with no abstract word impairment. (Warrington 1981 describes a patient as a "concrete word dyslexic", but this is not meant to imply a patient with a modality-specific disorder; indeed Warrington demonstrates that C.A.V. also has imapired auditory comprehension.)

2.2 Predicted impairments in auditory comprehension

Relatively little work has been done on specifically investigating different levels of impairment in the auditory comprehension of words. This will be the focus of chapters 3 and 4. An information processing model, such as described in Patterson and Shewell (1987), an adaptation of which is shown in Figure 2.1, makes specific predictions about auditory comprehension deficits:

1) A deficit in the acoustic analysis of speech sounds (word sound deafness) will be specific to language and will therefore dissociate from comprehension of non-speech sounds. (The actual form of this analysis

is not well specified).

2) A deficit in accessing the lexical level can occur even when acoustic analysis is unimpaired, and will manifest as a tendancy to "hear" a word as if it were a phonologically similar word. This is the level of deficit which Kohn and friedman call "pre-access", but which Howard and Franklin (1988) refer to as "word-form deafness".

3) Patients may have an impairment specific to the auditory modality but also specific to the level of meaning: the patient will be able to identify the word-form. Being specific to the auditory modality it will involve no impairment of the central semantic system, this system being modality-independant.

4) Patients with "word sound deafness" will also have impairments in repetition and writing to dictation, which will be at least as severe as the problem with phoneme discrimination, but could be worse if additional deficits exist.

5) If the sub-lexical repetition route is unimpaired, then repetition could be normal in patients with both "word form" and "word meaning" deafness. As Kohn and Friedman (1986) postulate, writing to dictation should be normal in word meaning deafness (assuming the

lexical route is operating), and normal for nonwords and words predictable in sound to spelling correspondences in word-form deafness.

6) If the sub-lexical repetition route is also impaired, then all word deaf patients will have impairments of repetition and writing to dictation; the word-form deaf patients will tend to make errors which are phonologically related to the stimulus item, and the word-meaning deaf patients will tend to make errors which are semantically related to the stimulus item.

7) As well as these modality specific impairments, some patients' auditory comprehension problems will be associated with an impairment of semantics in all modalities, indicating a central semantic impairment.

CHAPTER 3: Levels of impairment in auditory comprehension

Cognitive neuropsychological models of lexical processing, such as those which have evolved from Morton's "logogen model" (1969), offer a detailed account of stages leading to word comprehesion, and make explicit the relationships between written and spoken comprehension and word repetition. Assessment paradigms developed in the field of acquired dyslexia offer ways of assessing levels of impairment (and intact processing) directly. This chapter describes the assessment of 20 fluent aphasic patients using this kind of theoretical model.

Lexical processing is expressed diagrammatically in Figure 2.1 (chapter 2) (adapted from Patterson and Shewell 1987). In order to comprehend a spoken word the auditory information has to be analysed into speech sounds (Auditory Analysis), which are then used to access the word form in the Auditory Input Lexicon which is in turn used to access the word's meaning in the Cognitive System. Reading comprehension is achieved by an equivalent but separate route which analyses letters (Visual Analysis),and uses this information to access the word form in the Orthographic Input Lexicon which is then used to access the meaning in the Cognitive

System. In this model the Cognitive System is common to all modalities; thus an impairment in the Cognitive System will affect both spoken and written comprehension, but a more peripheral impairment will only affect that modality.

At least five possible types of auditory comprehension impairment can be predicted using this three-level model. (See figure 3.1).

Word sound deafness: This is the level of impairment corresponding to that traditionally describing the pure word deaf; as it may also be used to describe a patient who has other unrelated impairments, however,it should be considered as a symptom rather than a syndrome, the latter implying a whole range of associated deficits. (The same is true for the other types of word deafness described below). If a patient has a severe impairment in analysing speech sounds, this will impair performance on all auditory comprehension tasks, since s/he will be functionally deaf for speech. A mild impairment at this level would mean that s/he would be impaired at all tasks requiring accurate knowledge of the incoming phonology, but in the absence of any other impairment s/he would be able to use context to aid understanding where the task permitted this. An impairment at this level would be indicated by an

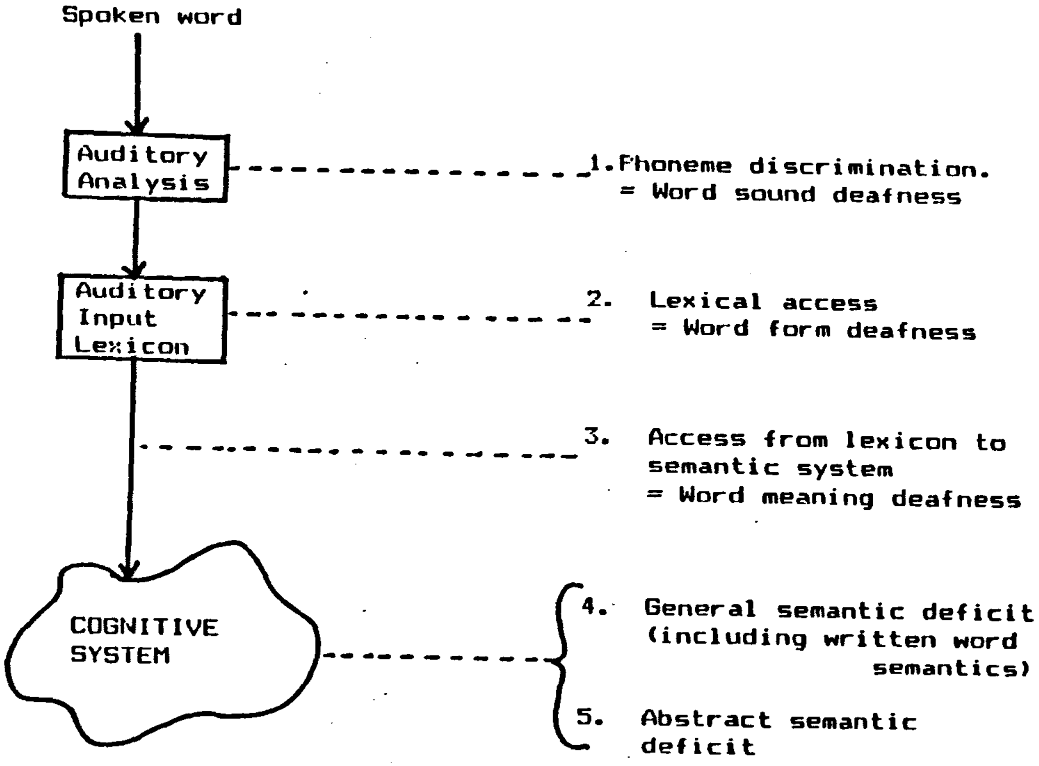

Figure 3.1: Five levels of impairment in auditory Comprehension

inability to discriminate phonemes. Since, at least in the absence of lip-read information, all repetition routes require speech sound analysis, repetition in these patients will be at least as severely impaired as their phoneme discrimination ability.

Word form deafness: If a patient is unable to access the word form correctly, then s/he will tend to hear a word as another word which is phonologically similar to the correct word. This is the level of impairment described by Kohn and Friedman (1986) as "pre-access word deafness". This level of impairment will interfere with access to meaning for similar sounding words, even though the patient can tell that such words do not sound identical. Again, context, when present, may facilitate access to the correct word form.

Word meaning deafness: When a patient is able to access the word form correctly, as evidenced by unimpaired lexical decision, but is still unable to comprehend words, there must be a problem with word meanings. If the patient is able to comprehend the same word presented in a written form, then the problem is modality specific. This constitutes an impairment in the procedure by which the word form accesses the meaning, rather than an impairment at either the word-form level or in central semantic representations (Shallice 1987). In order to establish such an impairment, it is necessary to administer a test which requires the patient to use semantic knowledge; the test must be administered both in spoken and written form, so that a direct comparison may be made.

General semantic deficit: If the patient makes errors of meaning in both written and spoken forms of a semantic test s/he could have a central disorder of verbal semantics; but this would also predict an anomic deficit, since, according to the model used, the same system is used to access output word forms for naming. An impairment in visual semantics could also be associated with this level of deficit, but the question of whether [or not] visual semantics are represented independently of verbal semantics is controversial (cf. Riddoch et al 1988) and will be considered later in this chapter.

Abstract semantic deficit: It is well-documented, particularly in the acquired dyslexia literature (Coltheart, Patterson and Marshall 1980), that some patients make significantly more errors in comprehending abstract words, or words of low imageability, than in comprehending concrete, or highly imageable words. Thus it should be possible for a patient to have a problem in comprehending spoken abstract words although able to comprehend spoken concrete words. An impairment at this level would be indicated if a patient, given a semantic task containing (otherwise matched) sets of abstract and concrete items, was significantly worse at comprehending the abstract words.

To summarize, it is predicted that the following will be found:

Patients' auditory comprehension may be impaired because of a deficit at any of the above levels (and possibly at more than one level).

There will be no necessary correspondence between spoken and written comprehension (except where there is a central semantic impairment).

An impairment at the level of auditory analysis will necessarily lead to an impairment in lexical access, but an impairment in lexical access could occur in a patient with intact auditory analysis.

A severe impairment of either auditory analysis or word form access will affect semantic access; but in a task where contextual cues are available, these may compensate for a mild peripheral impairment.

This chapter presents the results of a range of comprehension assessments on a group of fluent aphasic patients. Phoneme discrimination tests are intended to identify word sound deaf patients; lexical decision tests to identify word form deaf patients. Semantic tests carried out in spoken, written and picture modalities will identify higher-level impairments.

3.1 SUBJECTS

Information regarding the patients is shown in TABLE 3.1. Twenty patients were used in the study. They were all referred by speech therapists as having fluent speech and impaired comprehension, and were between one and three years post onset when testing began. All the patients who were referred were included in the study. Eighteen of the patients had had a cerebro-vascular accident, one had a dementia and the other patient had a head injury from a road traffic accident. Their ages ranged from 52 - 83 years (mean age 70.7 years) and they had all attended school until at least the age of fourteen.

TABLE 3.1

SUBJECTS

Patient	Sex	Age	Time P.O.	Aetiology	Occupation
D.R.B.	M	55	1.5 years	CVA	Travel agent
A.Ba.	F	73	1 year	CVA	Hotel Manager
A.By.	F	79	5 years	CVA	Housewife
E.C.	F	75	2.5 years	CVA	Housewife
F.C.	M	84	3 years	CVA	Civil Servant
A.D.	F	80	6 months	CVA	Seamstress
A.H.	M	65	2 years	RTA	Factory worker
M.H.	F	77	1.5 years	Dementia	Commercial Artist
N.H.	F	80	3 years	CVA	Housewife
D.I.	M	52	1 year	CVA	Bank manager
C.J.	M	75	1 year	CVA	Businessman
K.J.	M	49	3 years	CVA	Actor
M.K.	M	69	2 years	CVA	Oil consultant
C.L.	M	83	1 year	CVA	Not Known
D.M.	M	71	3 years	CVA	Barrister
F.M.	M	65	2 years	CVA	Engineer
I.M.	M	72	1 year	CVA	Store Administrator
E.S.	M	74	3 years	CVA	Estate agent
E.W.	M	64	1 year	CVA	BT Telephonist
V.W.	M	72	1.5 years	CVA	Antiques Dealer

3.2 Auditory Input Tests

Forty Item CV Test

To assess the patients' ability to analyse speech sounds a phoneme discrimination test was devised. The experimenter said two syllables (one per second) of the form [consonant + /a/] and the patient had to judge whether or not they were identical. There were 20 identical pairs (e.g. /sa/, /sa/), 10 non-identical pairs where the consonants differed by three distinctive features (place, manner and voice; e.g. /sa/,/ba/), and 10 where the consonants differed by just one of these distinctive features (e.g. /sa/,/za/).

(The results are shown in TABLE 3.2)

This test was administered to 18 of the 20 patients (all except CL and ABy). Three patients, EW, ES, and AD were severely impaired (.70, .70 and .73 respectively). The remaining patients scored between .83 and 1.00. Another test of phoneme discrimination was given to six of the patients.

Thirty Six Item CVC Test

A more difficult test of phoneme discrimination was taken from a set of tests devised by Kay, Lesser and Coltheart (in press). It comprised 36 pairs of non-words, 18 of which were identical. The other 18 varied methodically in terms of site of contrast (initial, final, or metathetic) and in terms of type of contrast (voice, place, or manner)

This test was also administered to six normal subjects who scored between 1.00 and .86 (mean score = .95) All six patients scored within the normal range except for E.S., confirming the previous findings for these six cases.

If phoneme discrimination is testing "auditory analysis" then an impairment will affect repetition as well as comprehension. If the impairment is at a feature level it should be sensitive to particular parameters of phonological similarity; in this case the patients would make more false positive errors in phoneme discrimination tests where the phonemes differ by one distinctive feature, rather than by three distinctive features.

TABLE 3.2

Phoneme Discrimination Tests: proportion correct.

Patient	CV Test	CVC Test
E.W.	.70	--
E.S.	.70	.58
A.D.	.73	--
A.By.	--	--
M.K.	.90	.94
E.C.	.93	.94
A.H.	.92	.94
C.L.	--	--
A.Ba.	.85	--
F.M.	.83	.89
C.J.	.85	.97
N.H.	.85	--
M.H.	--	--
K.J.	.95	--
D.M.	.93	--
F.C.	.90	--
V.W.	1.00	--
D.I.	1.00	--
D.R.B.	.98	.89
I.M.	1.00	--

Normal range for CVC test = .86 - 1.00 (mean .95

TABLE 3.3

Number of errors of various types in the CV test of auditory discrimination

	Patient			
	E.S.	E.W.(1)	E.W.(2)	A.D.
Miss	3	8	10	2
FP: 1 distinctive feature	5	2	6	3
FP: 3 distinctive feature	4	2	2	6

TABLE 3.3 shows the results for the three impaired patients; none of these patients makes more errors on phonemes differing by one distinctive feature.

Thus there appears no effect of phoneme similarity. However, both ES and AD have severely impaired repetition (see Chapter 5) and auditory comprehension, suggesting that they are indeed word sound deaf. EW however is only mildly impaired at repetition , if at all, and as will be seen later in this chapter performs better on lexical decision and semantic tests than either of the other two patients. His auditory short term memory is good relative to the group of patients as a whole, so an inability to hold the two syllables cannot explain his apparent difficulty in phoneme discrimination. As can be seen from TABLE 3.3 the CV test was readministered to confirm his poor performance; he made more errors than on the first administration. He was asked to repeat the syllables from the CV test; he repeated 76/80 correctly. It would appear that EW has a particular problem with the task of phoneme discrimination, rather than being word sound deaf; the cause of this problem is not clear.

"Easy Lexical Decision Test"

This test was devised by Coltheart (1980). The 25 real words contained in the test are short, highly frequent and highly imageable and the 25 non-words were made by changing one phoneme in each of the real words. All 20 patients were given this test on one occasion in the auditory modality and on another occasion in its written form. This was partly in the hope that, even if the patient is very impaired in the spoken form of the test, good performance in the other modality would at least show that s/he has understood the task correctly; this is an important consideration with patients with auditory comprehension impairments! The other purpose was to examine the extent to which impairments in lexical decision are modality specific; if lexical decision requires semantic access, then those patients with a central semantic impairment should be impaired in lexical decison irrespective of modality.

The results (proportion correct, separately for words and non-words) can be seen in TABLE 3.4. (d' for lexical decision for all patients can be seen in Appendix 2). As predicted the two word deaf patients ES and AD are both severely impaired in auditory lexical decision* (overall proportions correct =.68 and .77, respectively); they are both significantly better at written lexical decision (.92 and .98). As discussed above, EW, who does not appear to be word deaf despite his poor performance in the phoneme discrimination test, performs relatively well in the lexical decision test, scoring .92 in the auditory version and .98 in the written.

In addition 3 of the patients who performed normally in the phoneme discrimination tests were impaired in auditory lexical decision. These are MK, EC and AH. These patients were all significantly better at written than auditory lexical decision (McNemar Test; $p<.005$); they can be classified as word form deaf.

* Despite the fact that AH and EC both have large d primes in the Easy Lexical Decision Test, the fact that they also perform poorly on the 320 item lexical decision test, but are able to do the task correctly in its written form do suggest that they are impaired at this level.

TABLE 3.4

Lexical Decision Tests: proportion correct.

	Easy Lexical Decision				Image x Frequency	
	Auditory		Visual		Lexical Decision	
Patient	Word	NWord	Word	NWord	Word	NWord
E.W.	.96	.88	1.00	.96		
E.S.	.84	.52	1.00	.84	.94	.18
A.D.	.60	.96	.96	1.00		
A.By.	1.00	.28	.76	.28		
M.K.	.68	.68	1.00	1.00	.89	.63
E.D.	.96	.58	1.00	1.00	.79	.66
A.H.	1.00	.72	1.00	.88	.92	.58
C.L.	.96	.64	.96	.60		
A.Ba.	1.00	.96	1.00	.85		
F.M.	1.00	.80	1.00	.88	.94	.88
C.J.	1.00	.92	1.00	.84	.98	.91
N.H.	.96	.88	.92	.68		
M.H.	1.00	.96	.96	.72		
K.J.	.96	.96	.64	.96		
D.M.	.88	1.00	1.00	1.00		
F.C.	1.00	.96	.32	.68		
V.W.	1.00	.92	1.00	1.00		
D.I.	.96	1.00	1.00	1.00		
D.R.B.	1.00	.96	1.00	.96	.99	.98
I.M.	1.00	1.00	--	--		

CL and ABy were both impaired in auditory lexical decision but were also impaired in written lexical decision, so it is unclear whether they simply misunderstood the task, or whether they have a word-form problem in both modalities. Unfortunately neither patient was given the phoneme discrimination tests so it is impossible to say whether they had more peripheral auditory problems, although in CL's case at least, this seems unlikely, since he is able to repeat non-words. ABy scores at chance in both modalities so a plausible conclusion is that she misunderstood the task.

The remaining patients scored between .90 and 1.00 on the auditory lexical decision test. FC and MH were both significantly worse at written lexical decision (McNemar Test; FC: $p<.001$; MH: $p<.05$), but this is perhaps unsurprising since they both have letter identification problems, and are letter-by-letter readers.

Lexical Decision Test - 320 Item Test

In order to confirm these findings, the six patients who were given the CVC phoneme discrimination test were also given a more difficult lexical decision test.

This test uses the 160 word imageability x frequency list devised by David Howard (unpublished) for the real words, and the 160 non-words were made by changing one phoneme in each of the real words. The real words are equal sized sets from four different ranges of imageability ratings. Within each set are twenty high frequency words and twenty low frequency words.

This additional test confirmed that the patient described as word sound deaf (ES), and the three word form deaf patients (MK, EC and AH) are all impaired at lexical decision, whereas DRB, who performed normally on the other tests, performed normally on this one also.

James (1975) found that normal subjects' response times for visual lexical decision are affected by imageability and frequency, in that there is a slower response for words that are both infrequent and abstract. Do these patients show the same pattern in their error performance? TABLE 3.5 shows the number of misses for each type of word. ES makes very few misses; he rather makes a large number of false positive errors, so his responses are unilluminating in this respect. AH, EC and MK make more misses, but an analysis of the predicted and observed results for each

TABLE 3.5

Errors in Imageability x Frequency Lexical Decision Test (N = 160 each for words and non-words).

	Patient				
	E.S	M.K.	E.C.	A.H.	F.M.
False positives	131	27	55	73	56
Misses:	9	17	33	7	9
High Imageability/ High Frequency	1	2	7	0	1
High Imageability/ Low Frequency	1	6	7	3	1
Low Imageability/ High Frequency	4	3	7	2	4
Low Imageability/ Low Frequency	3	6	12	2	3

patient indicates that all interactions fail to reach significance: neither is there any main effect of either variable. This may still be because of an insufficient number of misses; MK did show an effect of imageability in the Rickard (1986) lexical decision test, in which the words vary orthogonally in imageability and familiarity. This test contains even more items than the one used here.

The sixth patient given the 320 item lexical decision test, FM, was also impaired, and had a slightly low score on the Coltheart test, suggesting that he may also be a word form deaf patient. Like ES the majority of his errors were false positives.

3.3 Semantic Tests:

The patients were given the Synonym Matching Test devised by Coltheart (1980). It requires the patient to listen to two words and decide whether they have similar meanings. To establish whether patients had a semantic problem in neither, one, or both of the two modalities, this test was carried out both in written and spoken form. Half of the test items use words which are highly imageable (for example "flower-wedding", "flower-blossom"); the rest are matched with them in word frequency, but are low imageability words (for example "realm-compassion", "realm-kingdom"). Thus it is possible using this particular test to establish whether patients are more likely to make errors in the comprehension of low imageability words. The synonym matching test also has the advantage of not requiring the patient to comprehend pictures, which would bias the result in the case of a visual agnosic patient.

To compare visual and verbal semantic ability, Howard and Patterson's Palm Trees and Pyramids Test was administered , initially in the version using three pictures and several weeks later in the version using one spoken word and two pictures. This test comprises a stimulus item (either a word or a picture) which has to be matched to an item related in meaning from a choice of two (also either words or pictures). The two response items are themselves related in meaning, so quite a fine sematic judgment (as well as a good deal of world knowlege) has to be used for correct responses. For example, for the stimulus "web" there is a choice of "bee" or "spider".

The results for both the synonym matching test and Palm Trees and Pyramids can be seen in TABLE 3.6.

(See Appendix 3 for details of testing)

Synonym Matching

All patients made more errors than a group of normal controls, irrespective of whether or they had more peripheral impairments. (Mean score for 9 control subjects = .99, range .96 - 1.00; Anne Edmundsen, personal communication). One patient KJ is significantly worse at (high imageability) written synonym matching (.68) than spoken (.97), despite not being severely impaired at written lexical decision; DRB is significantly worse at spoken synonym matching than written, despite no impairment in auditory lexical decision, suggesting that KJ is written word meaning "blind" and DRB is spoken word meaning deaf.

Eight of the nineteen patients tested made significantly more errors to low imageability items in spoken synonym matching than in the high imageability items. Another 5 patients showed a significant effect of imageability when spoken and written versions were taken together. All patients made more errors on the low imageability than the high imageability items. This supports the view that low imageability words are somehow more "difficult" than high imageability words.

TABLE 3.6: Semantic Tests (UTA = unable to attempt)

	Synonym-Matching				Pyramids and Palm Trees	
			Spoken			
	Spoken	Written	High Im	Low Im	Picture	Spoken
(N)	(76)	(76)	(38)	(38)	(52)	(52)
E.W.	.91	.81	.97	.84	.92	.96
E.S.	.71	.84	.79	.63	.98	.67
A.D.	UTA	.68	UTA	UTA	.69	.65
A.By.	.78	.71	.87	.68	.61	.61
M.K.	.77	.99	.86	.68	1.00	.86
E.C.	.95	1.00	1.00	.89	.92	.88
A.H.	.75	.80	.92	.58	.88	.71
C.L.	.88	UTA	.95	.82	.50	.60
A.Ba.	UTA	.84	UTA	UTA	.90	.88
F.M.	.84	.92	.92	.76	.94	.92
C.J.	.79	.79	.84	.74	.79	.73
N.H.	.63	.63	.74	.53	.44	.79
M.H.	--	--	.66	--	.50	.79
K.J.	.89	--	.97	.82	.92	.92
D.M.	.91	.91	1.00	.82	.88	.88
F.C.	.74	UTA	.89	.58	.69	.75
V.W.	.89	.95	.95	.84	.92	.83
D.I.	.88	.92	1.00	.76	.98	.98
D.R.B	.75	.97	.89	.60	.96	.92
I.M.	--	.87	--	--	1.00	.90

Palm Trees and Pyramids

All twenty patients were given this test. MH and NH were both significantly worse at the three picture version, whereas two of the wordform deaf patients, MK and AH, and the word sound deaf patient, ES, were significantly worse at choosing one of the two pictures to go with a spoken name than the three picture version.

The model that has been used to predict levels of impairment has one semantic system, which means that if the patients are severely impaired at synonym matching in both modalities, and make semantic errors in naming, suggesting a central semantic impairment, then the patient should also have an impairment for visual semantics. Given that it appears possible to have an impairment in access to the semantic system (ie word meaning deafness) it is very difficult to differentiate between models with one semantic system and those with separate visual and verbal semantics systems. If all verbal modalities are affected without a visual agnosia being present then supporters of a unitary semantic system could argue that such a patient happened to have access impairments in all modalities. If visual and verbal semantic impairments occur in the same patient, then supporters of separate semantic systems could argue that such a patient had an impairment in both systems.

It is therefore of interest to see what patterns of impairment are shown in this group of patients. Five patients are severely impaired at both written and spoken synonym matching; they all make semantic errors in naming. These are CL, ABa, CJ, NH, and FC. Four of these patients are impaired at both versions of Palm Trees and Pyramids and the impairments on both versions of the test are equal; NH is severely impaired at both, but significantly more impaired at the three picture version. The only other patient who is significantly worse at the picture version is MH, who has more peripheral visual processing problems (see Appendix 4 for examples of her picture copying); unfortunately NH's visual processing abilities were not further assessed.

The patients who are significantly worse at the spoken word to picture version than the three picture version of Pyramids and Palm trees are, as was mentioned above, all patients with more peripheral auditory processing problems. There is no evidence that any of the patients who have a central semantic impairment for concrete words have normal visual semantics.

3.4 Levels of impairment?

Looking at the tests as a whole, if auditory comprehension were a highly interactive process , then one might expect there to be just one deficit with different degrees of severity. Problems with auditory discrimination might represent the most severe impairment, lexical decision problems the next and semantic problems alone the least severe impairment. If that were the case then word sound deaf patients should get the lowest scores on the semantic tests, and word form deaf patients the next lowest scores. The patients were therefore categorised into word sound deaf, word form deaf, and others; single factor ANOVAs were carried out on the results of the phoneme discrimination, lexical decision and synonym matching tests to see if there is a main effect of patient type. If it is a highly interactive system, then there would be a main effect of patient category with every test. If however there are in some sense separable levels, then there should be a main effect of patient type on lexical decision, in that both word sound deaf and word form deaf patients will be worse than other patients, but there should not be a main effect of type on the semantic test.

Table 3.7

The effect of patient type on performance

(Scores represent mean performance for each patient group on each test)

	Phoneme Discrim	Lexical Decision	Synonym Matching Hi Image	Lo Image
Word-sound deaf	.708	.790	.753	.657
Word-form deaf	.917	.747	.957	.623
Other	.910	.956	.876	.684
F value (df=2,13)	17.0	17.4	1.3	0.2
Significance	p<.005	p<.005	ns.	ns.

TABLE 3.7 shows the means for each category for each patient type. There is of course a significant effect on phoneme discrimination because this was the way the categories were defined. But as predicted, there was also a significant effect of patient type on lexical decision, in that word sound deaf patients are also poor at this task. There was no significant difference between types of patient on the synonym matching test.

3.5 Context effects in word comprehension

Because E.C. and M.K. made a substantial number of errors in tests with phonologically related foils it seemed apparent that there was some kind of biasing occurring, since it was highly unlikely that their impaired systems would by chance access precisely those items which were given in the tests. It was therefore decided to investigate this further. E.C. was given the binary judgments (semantic) test, created for DRB (see next chapter). She heard a word and had to match it to 1 of 2 written words, the correct item being a synonym and the incorrect one being unrelated. (e.g. "wise" matched to CLEVER or OUTFIT). The test was administered twice, once where the written words were presented first, and once where the spoken word was presented first. It was predicted that if "top-down" processing was occurring, then she would be significantly better in the condition with the written words first, since this is the less impaired modality (she has no impairment for written lexical decision or written synonym matching). In fact there was no difference between the two conditions (written first: 157/200, spoken first: 152/200). This suggests that top down processing is not being used, but rather that there is activation of the semantic system by incomplete lexical information.

This does not however rule out the use of top-down information from semantics to the auditory input lexicon; the critical test for this is one which includes phonological foils. The word to picture matching test described in Chapter 4 was given to both E.C. and M.K. There were three conditions; where the stimuli were all written, where the spoken word was heard first and where the written words were seen first.

The patient was required to hear (or for the control condition, see) a word and match it with a synonym (e.g. "slacks" -> TROUSERS). One of the foils in each case was a synonym of a word phonologically related to the stimulus (in this case LOTS [a synonym for "stacks"]). Both EC and MK have, I have argued, impaired access to the auditory input lexicon. Therefore when they hear the stimulus word ("slacks"), they will either (1) access the correct word-form, (2) access an incorrect word-form, or (3) access degraded information, which is unable to access a specific meaning.

Without any biasing information from the visual input system, it is unlikely that an error in accessing the auditory word-form would happen to correspond to the foil's synonym (i.e. "stacks"). Presumably, "smacks", "slats", "slams" and "lacks" could all be equally likely errors. If information were processed "top-down" from the semantic system to the auditory input lexicon, then the *prior* presentation of the written foils would increase the likelihood of that particular phonological error being accessed. However, if the written foils are presented *after* the stimulus word has been heard there should be fewer "phonological foil" errors.

In a system where multiple outputs are possible from the auditory input lexicon to the semantic system, then all the words partially activated will activate some meaning in the semantic system, and the written words will bias the response irrespective of order of presentation.

The results can be seen in TABLE 3.8. There was no effect of order of presentation, suggesting that there is no top-down processing to the auditory input lexicon, but rather that context effects are explained by partial activation from the lexicon activating partial information in the semantic system.

TABLE 3.8

Synonym judgments: written to written word, spoken to written word and written to spoken word.

(Word to word synonym judgments test with semantically and phonologically related foils)

	Written -> written	Spoken -> written	Written -> spoken
E.C.			
correct	47	37	33
phon. errors	1	13	13
semantic errors	12	9	11
no response	0	1	3
M.K.			
correct	51	32	34
phon. errors	2	15	11
sem. errors	7	13	15

In this chapter it was shown that, as predicted, there are clearly dissociable levels of impairment in auditory comprehension. At least one patient (ES) has a severe impairment at the level of auditory analysis.

Three patients, while unimpaired at tasks requiring auditory analysis, are word-form deaf. Other patients, while unimpaired at all input phonological tasks, are impaired at tasks which require semantic processing.

When word-form and word-sound deafness were taken into account, patients had one of two kinds of semantic impairment. Either they had a particular impairment for words of low imageability; or they had a more severe impairment, which affected both high and low imageability words and visual semantic processing. This is compatible with there being an amodal semantic system, where abstract words are more sensitive to impairment than concrete words. The fact that the word meaning deaf patient (DRB) appeared to have a greater difficulty with low imageability words supports the latter notion. DRB's word meaning deafness is the subject of the next chapter.

CHAPTER 4: Abstract word meaning deafness.

In the previous chapter it was noted that in the synonym matching test all patients made more errors on low imageability words than high imageability ones. Obviously imageability is an important factor in word comprehension, as indeed has been shown in deep dyslexia (Coltheart et al 1980).

From the results of the synonym matching test, one patient, DRB, appears to be word meaning deaf; moreover he appears to be abstract word meaning deaf in that he is significantly worse at low imageability words, but only in the auditory modality. It is perhaps surprising, since imageability is a function of meaning, that such an impairment should be modality specific rather than central. This chapter will investigate DRB's impairment for low imageability/abstract words more fully.

4.1 DRB - Tests of Imageability

Table 4.1 shows the results of a number of tests given to DRB for auditory comprehension, repetition and writing to dictation. Some of the tests have also been presented as tests of written comprehension or oral reading for the purposes of comparison.

Auditory comprehension tests

The results of the synonym matching test were given in Chapter 3; he showed a significant imageability effect in spoken presentation (F.E., z=3.28), but his performance was normal on the written version (.98 overall).

Kay's (unpublished) semantic association test was also given in both spoken and written forms (although in both cases the responses were written words since there are four choices). The patient hears or sees one stimulus word, and has to choose the response word closest in meaning from a choice of four; the foils are a more distantly semantically related word and two unrelated words. Thus this requires more specific semantic information than the synonym matching test; but the use of written words as responses will make it easier for DRB. He scored .93 on both the high and the low imageability versions of the test when the stimulus word was written (this represents only one error on each) and achieved the same score on the high imageability items with spoken stimuli. He was however significantly worse at the low imageability spoken -> written version (.47, F.E., z=2.35). This supports the view that his written word comprehension is unimpaired and that he is poor at auditorily comprehending low imageability words.

Shallice and McGill's abstract word to picture matching test (unpublished) was also carried out with written and spoken stimuli. This test requires the patient to select the picture corresponding to the stimulus word from a choice of four pictures. The abstract word items are more difficult in that whereas the concrete words correspond directly to the picture (eg wigwam -> picture of a wigwam, propellor -> picture of a propellor), for the abstract words it is necessary to make inferences to select the correct picture (eg skill -> someone playing a musical instrument, democracy -> a group of people all with their hands raised). It is therefore unsurprising that while DRB made no errors on the concrete items when written, he scored .83 on the written abstract items; although this performance is in fact significantly worse than for the concrete items (F.E., z=1.85), it is well within normal performance for this test. (Warrington 1981 reported mean normal performance for abstract items as .86).

In the spoken word condition, he was good at the concrete words (.97) and significantly worse at the abstract words (.47, F.E., z=3.85); since this abstract score is so much worse than for the written version it cannot be attributed to a difficulty with making the inferences; and thus this test again supports DRB's

TABLE 4.1

Patient D.R.B.: evidence for abstract word deafness

	Spoken stimuli		Written stimuli		cell
	Hi Im	Lo Im	Hi Im	Lo Im	(n)
TEST					
Comprehension					
Synonym Matching	.95	.61	1.00	.95	(38)
Semantic Association Test	.93	.47	.93	.93	(15)
Abstract Picture-Word Matching	.97	.47	1.00	.83	(30)
Associations:					
Imageability x Frequency List	.93	.43	1.00	.90	(40)
Repetition					
Howard Image x Frequency	.75	.13	1.00	.95	(40)
Kay Image x Frequency-first	.78	.08			(40)
-second	.90	.18			(40)
Howard 200 item Image - first	.92	.47			(100)
" - second	.94	.52			(100)
Writing to Dictation					
Howard Image x Freq	.98	.45			(40)

having an abstract word meaning deafness.

DRB was given a list of words, both spoken and written, to which he was to produce single word associations. The list used was Howard's 80 item imageability x frequency list (see Chap 5 for details). Whether the responses were acceptable word associations was decided by a judge who was not told either the purpose of the experiment or the modality of stimulus presentation. Examples of correct items are:

Written presentation	Spoken presentation
RADIO -> wireless	"radio" -> TV
CLAY -> plasticine	"clay" -> wax
CULT -> Marx	"cult" -> ghost
DEBUT -> the first	"theory" -> idea

When the words were presented in written form he scored 1.00 on the high imageability words and .90 on the low imageability words. Thus he is able to produce an associate to most of these words when written. However, when he heard the words he scored .95 on high imageability words and .45 on low imageability words (F.E., z=4.61). The majority of incorrect responses were no responses.

Tests of repetition and writing to dictation

Because DRB is repeating and writing to dictation, for at least some words, via semantics (since he cannot repeat or write non-words and makes semantic errors in repetition and writing to dictation), it is instructive to see if there is an effect of imageability in these tasks. He was given three different lists to repeat: the Howard imageability x frequency list which had been given for word associations, the 80 item imageability x frequency list from the PALPA (Kay, Lesser and Coltheart in press) and the 200 item imageability list described in Howard and Franklin (1988).

The Howard imageability x frequency list was also given as an oral reading test, but since he is only a mild surface dyslexic it is unremarkable that he made very few errors. He repeated .75 of the high imageability words correctly and .13 of the low imageability words (F.E., Z=2.35).

The other two tests were each given to DRB twice, and each time there was a large difference between the high and low imageability words (all tests using the Fisher Exact; on the PALPA test, administation 1, z=6.07 $p<.001$; administration 2, z=6.24 $p<.001$; on the 200 item test administration 1, z=6.74 $p<.001$;

administration 2, z=6.51 p<.001).
DRB was asked to write the Howard imageability x fequency list to dictation; again there was a large effect of imageability (z=4.91 p<.001).

All these tests are compelling evidence that, while DRB is relatively unimpaired at auditory comprehension of high imageability words, he has a severe impairment for low imageability words. Written word comprehension appears normal.

4.2 Does DRB have an auditory input impairment?

Since, as will be demonstrated in subsequent chapters, DRB is unable to repeat non-words and also benefits from lip reading in repetition, it may seem a plausible argument that he is not in fact word meaning deaf, but has a more peripheral auditory input problem. This could explain the imageability effect in two ways; either that an auditory input problem will affect low imageability words more because they are more "difficult" to access even in the normal system; or that he also has a central semantic impairment for low imageability words, which he cannot compensate for in the auditory modality because of the auditory input problem, but which he can compensate for, perhaps by repeated attempts, in the written modality, where there are no peripheral problems. (Of course, even if DRB's auditory impairment problem is post-lexical, the latter possiblity still applies.)

TABLE 4.2

Does D.R.B. have an auditory input impairment?

	D.R.B.	M.K.	(N)
Phoneme Discrimination			
CV syllables	.95	.90	(40)
CVC non-words	.89	.94	(36)
Lexical Decision			
Easy Coltheart Test	.98	.68	(50)
320 item test	.96	.86	(320)
" written	.98		

Since there is no normal control data for many of the tests described, DRB's performance will be contrasted with that of MK, who has been shown in Howard and Franklin (1988) to have an impairment in auditory word-form access, and an imageability effect for both spoken and written input.

TABLE 4.2 shows DRB's and MK's performance on tests of phoneme discrimination and lexical decision. Both patients score within the normal range on the phoneme discrimination tests, and Howard and Franklin (1988) have argued that MK has no impairment at the level of auditory analysis despite, like DRB, being entirely unable to repeat non-words.*

In the auditory lexical decision tests, however, their performance is very different. On both the easy lexical decision test and on the 320 item test, which contains low imageability words, DRB's performance is unimpaired in either the spoken or written versions of the tests, whereas MK is severely impaired in the spoken version of both tests.

An impairment in lexical decision is not the only evidence for MK's word form impairment. When asked to define the Howard imageability x frequency list he defines a proportion of the words with a definition appropriate for a phonologically related word (eg "pardon" -> grass [?via garden]). DRB does not do this; his errors are no responses. In repeating this list, while 14 of MK's errors were real words which

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* A problem for this interpretation is that the matching required for phoneme discrimination tests could be carried out at a much earlier stage in auditory processing, or that MK's impairment may be pre-lexical but simply not apparent in such a simple task.

TABLE 4.3

Effect of length in repetition and comprehension

		D.R.B.	M.K.
Letter length [n=20 per cell]			
repetition:			
3 letter (Mean phon = 2.60)		.85	
5 letter (Mean phon = 3.75)		.95	
7 letter (Mean phon = 5.65)		.75	
9 letter (Mean phon = 7.45)		.80	
Syllable length [n=30 per cell]			
repetition:	1 syllable	.70	.73
	2 syllable	.67	.63
	3 syllable	.70	.90
definition:	1 syllable		.77
	2 syllable		.90
	3 syllable		.97

Syllable length x abstractness [n=30 per cell]

		DRB rep.	DRB def.
Hi Image	1 syllable	.63	.87
	2 syllable	.67	.93
	3 syllable	.67	.90
Lo Image	1 syllable	.00	.17
	2 syllable	.03	.23
	3 syllable	.00	.20

were phonologically related to the target, DRB produced only 3 such errors; on the other hand, while DRB makes 33 no response errors, MK makes none. MK makes more errors in repetition on shorter words than longer ones. This is because longer words have fewer neighbours so there is more redundancy of information for word form access. TABLE 4.3 shows both patients' performance in repetition and comprehension tests with words of differing length.

The first test comprises list of words of 3,5,7, and 9 letters, matched for imageability and frequency (the mean phoneme length for each list is given). There is no significant difference in DRB's ability to repeat these different lists.

The second test is of 1,2 and 3 syllables, again matched for frequency and imageability. DRB was given the list to repeat; MK was given it for repetition and on another occasion for definition. Again DRB's performance does not differ across lists of different syllable length, whereas MK is significantly better at the 3 than the 1 and 2 syllable lists both for repetition (1+2 vs. 3 syllable, F.E. Z= 1.98, $p<.05$) and definition (Jonkheere Trend Test, z= -2.548, $p<.01$). The third test again comprises lists of one, two and three syllables, but this time words of high and low imageability are contrasted; again all sets are matched for frequency. MK was not given this list, DRB was given it for repetition and on another occasion for defining. In both cases there was a clear effect of imageability but no effect of syllable length.

The final expression of MK's word form deafness is his difficulty with comprehension tests where there are phonologically related foils.

TABLE 4.4

Comprehension tests with phonological distractors

	DRB	MK	[N]
Picture word matching with phonological foils:	.90	.75	[40]
Spoken/written word matching with phon & sem foils:	.75	.53	[60]
semantic errors	8	13	
phonological errors	5	15	
Picture decision test:	.93	.69	[388]
misses	4	3	
semantic errors	16	39	
phonological real word errors	4	39	
phonological non-word errors	3	39	

His performance on three such tests is contrasted with that of DRB in TABLE 4.4. The first test is from the PALPA (Kay et al, in press). The patient hears a word and has to point to the corresponding picture. There are two picture foils, both of phonologically related words. (e.g. "fan" with pictures of fan, van, man). MK made more errors than DRB (10 vs. 4), but this difference failed to reach significance (McNemar, p=.073).

The next test was one where the patient heard a word and had to point to the word closest in meaning to it from a choice of four written words. The foils are a more distantly related semantic item, a word which is a synonym of a word phonologically related to the stimulus item, and a word semantically related to this word.

eg "theme": correct -> TOPIC
semantic -> IDEA
phonological -> ROBBER
semantically related to phon foil -> VANDAL

Both patients made semantic errors on this task (the stimulus items had a range of imageability) but DRB produced only 5 phonological errors, while MK produced 15. The final test in this section is the picture decision test (Howard and Franklin 1988). The items from the Hundred Picture Naming Test were used, excluding three items which had no phonologically related real words (thermometer, mermaid and stethoscope). The patients saw a picture, heard a word and had to say whether the word was the correct name for the picture. There were four conditions: for example, for the picture of an iron, the correct word, "iron", a semantically related word, "press", a phonologically related real word, "lion" and a phonologically related non-word, "bion".

The results show that DRB performs much better on this test than MK (.93 vs. .69). As TABLE 4.4 shows both make very few miss errors; each makes a number of semantic errors; but the striking difference is in terms of the number of errors in the two phonological conditions.

Clearly, these three tests indicate that DRB does not have the severe impairment in auditory comprehension tests with phonological foils which characterises MK's performance. All the tests in this section indicate that DRB shows none of the characteristics of word-form deafness which are shown by MK. On the other hand MK has an abstract word comprehension problem in both modalities; there is no evidence to suggest that DRB has any impairment in written comprehension. DRB's impairment is in the access to the semantic system rather than in the semantic system itself or in an earlier stage of processing. He has abstract word meaning deafness.

4.3 Abstract Anomia

DRB, despite being unimpaired on picture naming tests, appears anomic in conversation. What evidence is there that he is anomic for words of low imageability?

Concrete word naming

DRB scored 95/100 on the Hundred Picture Naming Test. The errors comprised 2 semantically related and three phonologically related words:

thermometer -> "temperature"
pepper -> "Italy tomato"
hoof -> "hooth"
mermaid -> "merdraid"
pyramid -> "P. I. L - it's gone"

With the Graded Naming Test he scored 11/30 which is slightly below the normal range for his age; but 11 of his errors were phonologically related non-words (e.g. sundial -> "sundaim"); if these are counted as correct he is within normal range. Thus his only problem in picture naming appears to be in phonological output. That this is at the level of phonological ouput is confirmed by the fact that he is slightly impaired at homophone matching, which for non-words at least must reflect a post-lexical deficit (see Table 4.5).

TABLE 4.5

Homophone matching - Coltheart (1980).

irregular words	45/50
regular words	45/50
non-words	40/50

Obviously, since low imageability words are by definition not picturable, it is difficult to test abstract naming directly.* Three lines of evidence will be investigated; one is an imageability effect in oral reading; the second a discrepancy between auditory comprehension and repetition; and the third DRB's performance on naming within categories.

*(Unfortunately since DRB has a syntactic comprehension impairment affecting both modalities, naming to definition is an inappropriate task.)

Imageability and oral reading

DRB was given the Parkin (1982) list of words of differing degrees of "regularity" for oral reading. As can be seen in Table 4.6 there was a small but significant effect of regularity (Jonkheere Trend Test, $z=2.28$, $p<.05$), and at least 8 of the errors were regularisation errors (eg BOUGH -> /bof/, REGIME -> /rIdʒim/, INDICT -> /IndIkt/), indicating that for some words at least, he is reading via a sub-lexical route. Since I have argued that his written comprehension is unimpaired, why is he a surface dyslexic?

TABLE 4.6

Parkin reading list

regular words	32/33
minor corresponances	28/33
OPD	25/33

Jonkheere Trend Test $Z = 2.28$, $p<.05$

Since DRB is not impaired at concrete word naming, then the only impairment that could be forcing him to use the sub-lexical reading route is an abstract naming impairment. This would mean that he would tend to misread words that both have exceptional spellings and are of low imageability. The list of words devised for MK and described in Howard and Franklin (1988), where regular words of high and low imageability are matched with irregular words of high and low imageability was read by DRB. The results can be seen in TABLE 4.7. As predicted there is an interaction between regularity and imageability. To confirm that

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TABLE 4.7

Howard's Regularity x Imageability List

	Read		Comprehended (word associations)	
	Low Image	Hi Image	Low Image	Hi Image
Regular	.89	.95	.85	.99
Irregular	.69	.95	.95	.95

---

this was not an impairment in reading comprehension, DRB was asked to give word associations to the same words. These were given to a judge for marking, as described earlier for the imageability x frequency words. He made very few errors and there was no effect of imageability.

Of the incorrect responses, some were idiosyncratic (e.g. DREAD -> "of Sue" [= the experimenter!], CLOVER -> it's today with an S [it was St Patrick's Day] and others were no responses (e.g. PARE, CAUCUS)

Repetition vs. auditory comprehension

The Shallice and McGill abstract word to picture matching test was readminstered, and immediately afterwards DRB had to repeat the word. The correct picture was selected for half of the low imageability items (11 items when corrected for chance), but only one was correctly repeated. The errors were no responses; even if the word had not been fully comprehended , some aspect of meaning must have been accessed on at least half the trials. Therefore even if the correct word could not be produced one might expect <u>some</u> semantic errors rather than <u>all</u> no response errors.

TABLE 4.8

Shallice Abstract Picture Matching Test

Comprehension vs. Repetition.

	Picture pointing		Repetition
Concrete words	1.00		.77
Abstract words	.53	(.37)*	.03
Emotion words	.40	(.20)*	.00

* = corrected for chance.

Naming within categories

In order to investigate more directly DRB's ability to produce words with a greater range of imageability a category naming task was devised. The 10 categories, which can be seen in TABLE 4.9 were chosen to include some likely to elicit high, and some low imageability words. For example the "animals" category should produce imageable words, whereas "good qualities" should elicit words difficult to image. This category naming test was given to DRB and to a control subject, DO, matched for age and educational attainment. The test was also given to a "pure" anomic patient MW, who has good auditory and written comprehension (personal communication, Lyndsey Nickels) and to MK. A normal subject matched to these two patients was PK.

Both the patients and the subjects were given two minutes to produce as many words as they could for each category. The three dysphasic patients were also given the category names in written form to maximise their understanding of them.

TABLE 4.9

Mean Imageability Ratings for within category naming (excluding "inappropriate" words)

	Group Mean	D.O.	D.R.B.	M.W.	M.K.	P.K.
Animals	6.03	5.95	6.19	5.79	5.99	6.22
Colours	5.56	5.62	5.68	4.96	5.85	5.59
Professions	4.75	4.38	4.95	5.34	**	4.91
Countries	4.65	4.70	4.73	4.60	4.65	4.60
Politics	4.32	4.04	4.55	4.48	4.57	3.71
Emotions	4.19	3.80	4.75	4.40	**	4.23
Sciences	3.87	4.15	**	**	**	3.61
Religions	3.76	3.50	4.06	3.88	**	3.63
Good Qualities	3.60	3.67	3.81	**	**	3.34
Bad Qualities	3.32	3.30	**	**	**	3.23

** = 3 or less appropriate responses

All the words produced by all five subjects were randomised and given to 11 normal subjects to rate for word imageability. The instructions given to the subjects on how to rate the words were taken from Pavio et al (1968), and their ratings were on a scale from 1-7 where 7 is the most imageable. In TABLE 4.9 the mean imageability ratings are given for each subject for each category.

All the words produced by the subjects within each category were randomised and 5 normal subjects were asked to rate how good an example each of the words was for that category. This rating was on a scale from 1-3. Words were considered to be good examples of a category if their total score on the rating was 13 or

TABLE 4.10

Number of names produced for 5 most imageable categories vs. 5 least imageable categories

	D.O.	D.R.B.	M.W.	M.K.	P.K.
Acceptable names					
Most imageable	108	93	54	69	113
Least imageable	46	19	15	4	39
Unacceptable names					
Most imageable	18	12	8	44	19
Least imageable	16	15	5	64	36

over (maximum score = 15). The results of the five categories with the higher mean imageability ratings were added together to make the five most imageable categories; the others were added together to make the least imageable categories. TABLE 4.10 shows the number of acceptable and unacceptable names produced by each subject.

All subjects, whether control or dysphasic, produce more acceptable names in the most imageable categories than the least imageable categories, again some support for the idea that low imageability words are more "difficult". DRB produces 93 words in the imageable categories; his control, DO, produces only slightly more; 108. However DRB produces proportionately less words in the least imageable categories, and this is a significant difference (F.E., z=2,27)

MK produces far fewer responses even in the most imageable categories than the control subject, PK, but again produces significantly fewer words in the less imageable categories (F.E., z=3.42). MW produces the fewest number of words overall but the proportion of responses between most and least imageable do not differ significantly from PK (F.E. z=0.46). Thus it would appear that both MK and DRB have a particular problem with producing abstract words. That this is not the invariable pattern for anomic deficits is indicated by the fact that MW is equally impaired for both imageable and less imageable categories.

MK makes a very much larger number of unacceptable responses than the other subjects, and while many of the other subjects' "unacceptable" words are actually just unusual exemplars (eg DO's "coati-mundi" for an animal or MW's "the Wee Frees" for a religion), many of MK's responses were extremely inappropriate (eg "pedal" for an animal - or does he mean -footed?)

MK's performance was compared with that of PK. For each subject, the number of words in each category rating score (1 - 15) was calculated and a Rank Sum Test was carried out. MK's produced significantly more words than PK with a low category rating (z=7.427 p<.001). This suggests that he has a comprehension problem in both modalities (he was given the category names in both written and spoken form) and is unable to understand the categories themselves. He seems to have a central semantic problem since all modalities are affected.

Imageability ratings for the correct words obtained from DRB and DO were used for a multiple regression to look at the correlation between (a) categories, (b) whether DRB or DO, and (3) the imageability of the responses. Predictably there was a large effect of category when the difference between subjects was partialled out (F= 86.88 df 1,263 p<.005), but there was also a significant effect of difference between subjects when the effects of category were partialled out (F= 6.429 df 1,263 p<.01). The latter result indicates that, for all categories, DRB produces words of higher imageability than DO, confirming that DRB has an abstract word anomia.

These results suggest that MK has a central semantic impairment, which necessarily affects abstract words since they are more vulnerable. DRB has an access problem from the auditory input lexicon to the semantic system and from the semantic system to the phonological output lexicon, which again results in a particular problem with abstract words.

4.4 Word class, item consistency

Effects of parts of speech

Many deep dyslexics are worse at reading function than content words. When imageability is controlled, MK does not have a significant advantage for content words in repetition; is this also true for DRB? He repeated the Howard content vs. functor list, where the words are matched for imageability rather than frequency (there is no evidence that DRB has a frequency effect), as well as a list of verbs and nouns matched for imageability (Allport and Funnell, 1981). The results can be seen in TABLE 4.11; there is no difference between performance on content words and functors or on verbs and nouns.

TABLE 4.11

Word class effects in repetition

content	functor
35/50	33/50

verbs	nouns
17/30	17/30

Word consistency in repetition

Shallice (1987) differentiates between an access problem and a central problem with loss of representations. In the latter, damage should be item specific, yielding highly consistent performance across repetitions of the same test. Inconsistency could also be a function of a different type of damage to the semantic system, or damage to a system which is distributed. In any case, since I have argued that DRB's impairment is one of access, there should certainly not be a high degree of item consistency in his performance. The problem is to decide what constitutes sufficient item consistency to indicate loss of representations; if each meaning representation were to be either completely preserved or completely destroyed, then there would be 100% item consistency for items. If parts of the meaning representation are lost, then if everything else were held constant, the same input should produce the same output (or lack of it) and again consistency would be 100%. However if the output is also affected by other aspects of processing, such as partial working of a sub-lexical route, which would itself be inconsistent, then such a representational loss would would not produce 100% consistency. Further, if it is accepted that some words will be more likely to be correct than others, for example because of their imageability, then even an access problem should produce a small effect of consistency. If effects of imageability are partialled out, any remaining effect could still be explained by other factors which affect performance. And even a high degree of item consistency is not necessarily incompatible with an access deficit.

DRB repeated the 200 item list twice as described in the first section of this chapter. In terms of imageability, the best estimate for each item being correct on one occasion was calculated. On the assumption that the probability of being correct is a function of imageability alone, the probability of being correct twice, once and neither time was calculated, to give the expected number of items for each case. The actual values show significantly greater consistency than expected, (χ^2[2] = 11.91, $p<.01$); however as stated above it is not clear how this result should be interpreted. (See TABLE 4.12).

TABLE 4.12

200 high vs. low imageability words: item consistency

	Both corr.	One corr.	None corr.
Expected (image effects partialled out)	107.65	63.69	28.65
Actual	121	37	46

Alternative evidence for the fact that DRB has an access problem was obtained by investigating the information he had available for words he was unable to repeat. A "binary judgements" test was devised: DRB was asked to repeat a word, and if he was unable to repeat it, he was then given two written words from which to select a synonym for the word he had heard. The list of 200 high versus low imageability words was used for this test; synonyms were generated for all words, and then these synonyms were randomly assigned as foils for each judgement. Since when asked to define a word or repeat it, the majority of DRB's errors are no responses, it might be expected that he has no information about the word he has heard but cannot repeat. However, if the access is impaired in such a way as to give insufficient information to produce a sufficiently specific meaning on which to base a response (especially in view of his anomia), but still accesses some meaning in the semantic system, then his performance on the binary judgements test should be better than his repetition.

DRB was in fact surprisingly good at this task; of the 136 words he was unable to repeat, he was able to select 131 synonyms correctly. Although in defining he only gets .45 of low imageability words correct, he clearly has some information even about those words he is unable to define. This does support the view that the impairment is one of access which leads to an underspecification in the semantic system.

Levels of imageability

All the tests of imageability so far carried out have contrasted words of high imageability with words of low imageability, as if there were only one value for each. Imageability values are in fact necessarily a continuum because they are obtained as ratings. If there were separate abstract and concrete semantic systems, however, and in DRB's case the concrete system was intact but the abstract system was impaired, there might be an imageability value below which DRB would be severely impaired (i.e. comprising those words whose meanings are represented in the abstract semantic system) and above which he would make no errors (i.e. comprising those whose word meanings are represented in the concrete semantic system). He was therefore given a repetition test of 160 words with varying levels of imageability, divided equally into words of high and low frequency. The results can be seen in TABLE 4.13.

The test was administered twice and in both cases there was an overall decline in performance as imageability decreased, rather than a cut-off point. The proportion correct for high and low frequency words was collapsed for these scores; uncollapsed, it can be seen that there is no consistent effect of frequency.

This result is not compatible with completely separate concrete and abstract semantic systems, although it is compatible with systems which have a more complex relationship.

TABLE 4.13

Levels of imageability

Image Rating	Proportion Correct 1st.Test	2nd.Test	Total	Average both tests Hi Freq	Lo Freq
6.5-6.0	.90	.95	.925	.95	.90
6.0-5.5	.80	.90	.850	.85	.85
5.5-5.0	.50	.75	.625	.65	.60
5.0-4.5	.25	.50	.375	.45	.30
4.5-4.0	.25	.40	.325	.35	.30
4.0-3.5	.25	.40	.325	.55	.10
3.5-3.0	.20	.35	.275	.40	.15
3.0-2.5	.05	.30	.175	.10	.25

Imageability vs. other properties of words

To establish whether DRB's repetition impairment is best characterised in terms of imageability rather than other factors, a test was devised to assess the relative importance in his performance of imageability, concreteness, age of acquisition, familiarity, log frequency, and phoneme length. Gilhooley and Logie (1980) present a list of words with all these ratings (excepting phoneme length). 400 words were taken from this list which were two-syllabled and rated as having only one meaning in their written form. DRB was asked to repeat the 400 words, as was MK. Since MK made far fewer correct responses he was asked to repeat the list twice, and for him performance on both administrations was used in the analysis.

TABLE 4.14

Correlation matrix for DRB's repetition performance versus word properties

Correlation matrix for DRB:

Image	1.0						
AofA	-.71	1.0					
Fam	.42	-.74	1.0				
Conc	.73	-.35	-.01	1.0			
LogFR	.19	-.47	.75	-.12	1.0		
Length	-.18	.10	.07	-.31	.12	1.0	
DRB correct	.54	-.49	.27	.53	.15	-.24	1.0
	Image	AofA	Fam	Conc	LogFR	Length	DRBCorr

A correlation matrix for DRB's performance on this test is shown in TABLE 4.14. A multiple regression was carried out to see which of these word properties influenced DRB's repetition. The effects of each word property were "dropped" in turn while the others were held constant. The f-ratios for change are shown in TABLE 4.15. (It should be noted that since the dependant variable is right/wrong then this maximum value for the correlations will be less than 1)

DRB's performance is significantly affected by concreteness, age of aquisition and length (TABLE 4.15). The effect of length, which is an exceedingly small affect may simply be attributable to the fact that none of the other factors correlate significantly with word length. Concreteness is significant rather than imageability because imageability correlates highly with both concreteness and age of aquisition. It is thus not possible to determine from this analysis whether DRB's performance is affected more by imageability or by concreteness. The age of aquisition effect is unexpected; it is not clear whether this is a property of additional importance in DRB's repetition, or whether it is the same mechanism as is producing the imageability/concreteness effect. Perhaps the word property which indicates semantic "difficulty" is not exactly concreteness or age of aquisition but rather some as yet unthought of property which would be a better predictor of difficulty than either of these.

Even more surprisingly, MK shows no significant effect of any factor when all the others are held constant; this perhaps reflects the fact that he has more levels of impairment than DRB.

TABLE 4.15:

The effect of imageability, age of acquisition, familiarity, concreteness, frequency and phoneme length on repetition.

F-ratio for change (df 1,393)

Patient	Image	AofA	Fam	Conc	Freq	Length
MK	2.25	1.96	1.12	0.02	3.45	3.74
DRB	0.18	17.61	0.00	39.64	1.17	5.01

In an earlier section I argued that DRB's significant item-specific consistency in repetition could be explained in terms of various properties of those words. Although there was still consistency when imageability effects had been partialled out, could this effect be accounted for by other properties? DRB was once more asked to repeat the first 160 items in the test described above. Using these results and their initial

administration, a multiple regression was again carried out. In terms of all the variables the best estimate for each item being correct on one occasion was calculated. On the assumption that the probability of being correct is a function of this set of variables alone, the probability of being correct twice, once and neither time was calculated, to give the expected number of items for each case. The expected values are contrasted with the actual values in Table 4.16. The expected values do not differ significantly from the actual values (Chi Square [2] = 1.93 n.s.).

<u>TABLE 4.16</u>

<u>Item consistency vs. word variables</u>

	Both correct	One correct	Neither correct
Expected	31.49	54.24	74.27
Observed	36	43	81

When all the relevant properties of words (and not just imageability) are taken into account, the effect of consistency can be accounted for in terms of those properties. Thus there is no evidence for impairment to specific items; this is compatible with an access impairment.

In this chapter DRB's word meaning deafness has been investigated in some detail. It was shown that his auditory comprehension problem could not be attributed to an impairment in auditory analysis or word form access, since he performs at a normal level with tests of phoneme discrimination and lexical decision, and there is no effect of phoneme length in word comprehension. MK, by contrast, has a word form deafness, and is more impaired at comprehending shorter words. Neither does DRB have a central semantic impairment; again in contrast to MK, he has no impairment in the comprehension of written words. This was indicated by his ability on synonym matching tests, a word to picture matching test, and word association tests. All these tests indicated that DRB's word meaning deafness was much more severe for words of low imageability.

Although many of DRB's errors in response to low imageability words were no response, it was found that he did have some information about a word he was unable to repeat in that he was able to carry out a gross semantic judgement immediately after the failure to repeat. There was no item consistency in his repetition of words, once the relevant variables (age of acquisition and concreteness) were taken into account. His performance gradually became more impaired as word imageability decreased.

It was argued that DRB also has an anomia for low imageability words. He is worse at repeating low imageabilty words than he is at comprehending them; he makes regularisation errors on reading low imageability words despite being able to comprehend them, and is impaired generating instances of categories for low imageability words.

Many of the experiments carried out to investigate DRB's auditory comprehension actually used tests of repetition, since he appears to be repeating via the semantic route. In chapter 7, his repetition impairments will be considered in more detail.

CHAPTER 5: Routes to repetition

This chapter addresses the issue of whether there is more than one route for repeating words. At first sight, it seems obvious that there is at least a route for repeating directly from acoustic input to phonology, since it is perfectly possible to repeat novel or non-words, and a route via meaning, since dysphasics have been reported who make semantic errors in repetition.

However, some models of reading have proposed that non-words could be read by analogy with real words, and parallel distributed processing models such as the one described by Seidenberg and McClelland (in press) have shown, in some sense at least, that a single route can "read" both real words and non-words and yet be sensitive to lexical properties such as word frequency. With highly interactive, distributed models, it would be possible that impairment at any level would lead to the same set of (mixed) errors. It thus seems apposite to reconsider the notion that language tasks might only be quantitatively and not qualitatively impaired. So the first section will address the possibility that the group of patients all have a greater or lesser impairment to a single repetition system.

If there are qualitative differences in patient's repetition impairments, indicating separable routes, one which is capable of repeating non-words and one which depends on accessing meaning, there are still a number of forms that the model could take. A two route model could consist of a sub-lexical route and a semantic route, so that words are either repeated by assembling phonology from the acoustic input (without accessing lexical information), or by accessing meaning which in turn addresses the output phonology. This account would predict that lexical-semantic factors such as imageability would only affect the semantic route. The other route (by which non-words are repeated) may, as in the Seidenberg and McClelland model of reading, be sensitive to frequency (or to something correlated with frequency).

Models such as that described by Patterson and Shewell (1987) propose that there are three routes for repetition: the sub-lexical route, presumably not sensitive to lexical factors; the direct lexical route which requires lexical access but not semantic access, and will therefore be sensitive to frequency; and the semantic route, which depends on lexical access and uses the word-form to access the meaning representation in the cognitive system, and will therefore be sensitive to frequency and imageability.

The extent to which a sub-lexical route is independent of lexical/semantic processing will be addressed both in the current chapter and in chapter 6. This chapter also addresses the issues of whether there are seperate input and output lexicons and whether there is a direct, lexical, non-semantic route as indicated in the Patterson and Shewell model.

The twenty patients, who were described in chapter 2, were given tests of repetition, reading and picture naming tasks. Their ability to repeat non-words is compared with their ability to read and write them. The patients' performance on a list of words varying in imageability and frequency is described. This is compared with the patients' scores on another test of word repetition in order to ascertain whether their word repetition performance is stable.

A number of analyses are then presented to determine whether there is indeed a sub-lexical system, insensitive to the properties associated with a lexical semantic route. These analyses

1) determine whether performance in non-word repetition is predictive of performance in real word repetition.

2) compare frequency effects in repetition and naming, taking into account patients' ability to repeat non-words.

3) determine whether overall performance on repetition is predicted by the size of the imageability effect in repetition (assuming that an imageability effect is an indication of semantic route impairment).

In the last section patients are grouped according to their ability to repeat words and non-words. Evidence for direct lexical route repetition is inferred by determining whether between group differences can be explained by other factors.

5.1 A comparison of repetition, reading and writing to dictation of non-words

This test comprised twenty items consisting of three, four and five phoneme pronouncable strings which were derived from twenty real words by changing one letter/phoneme. The patients were not allowed to lip-read, but were permitted to ask for a non-word to be repeated. On other occasions the patients were given the same list of non-words either in a written form to read or in a spoken form to write to dictation. (Errors for the repetition task are given in chapter 6)

TABLE 5.1

Repetition, Reading and Writing to Dictation of Non-Words

(n = 20)

Patient	Repetition	Reading	Writing to dict.
E.W.	.75	.25	.40
E.S.	.00	.85	.00
A.D.	.20	.10	.00
A.By.	.10	.10	.00
M.K.	.00	1.00	.05
E.C.	.35	.00	.00
A.H.	.75	.95	.50
C.L.	.65	.10	.00
A.Ba.	.50	.00	.00
F.M.	.30	.30	.00
C.J.	.80	.75	.35
N.H.	.20	.00	.00
M.H.	.95	--	--
K.J.	.45	.00	.00
D.M.	.50	.65	.10
F.C.	.65	.10	.00
V.W.	.75	1.00	.70
D.I.	1.00	.95	.90
D.R.B.	.00	.85	.00
I.M.	.75	.85	.00

RESULTS

Proportion of non-words correct for each of the three tasks is given in TABLE 5.1. On non-word repetition, the twenty subjects range from perfect (DI) to zero performance (DRB, MK, ES).
Performance on repetition of this task does not correlate significantly with reading non-words (r = -0.33). If all non-word processing depended on some central common mechanism, then any difference between oral reading and repetition, which also share a common output phase, would have to be accounted for by auditory or visual input problems. Data from the patient who has auditory input problems, E.S., the two patients who are letter by letter readers, C.L. and M.H., and three patients who have impaired written lexical decision were all excluded from the results and the scores for repetition and oral reading were re-correlated. The correlation still failed to reach significance (r = 0.11), suggesting that visual and acoustic information access assembled phonology independently. Repetition and writing to dictation of non-words are highly correlated (r = 0.77). Figure 5.1 shows repetition scores plotted against scores for writing to dictation; it can be seen that the two scores correlate because repetition scores are always as good as, or better than writing to dictation scores,

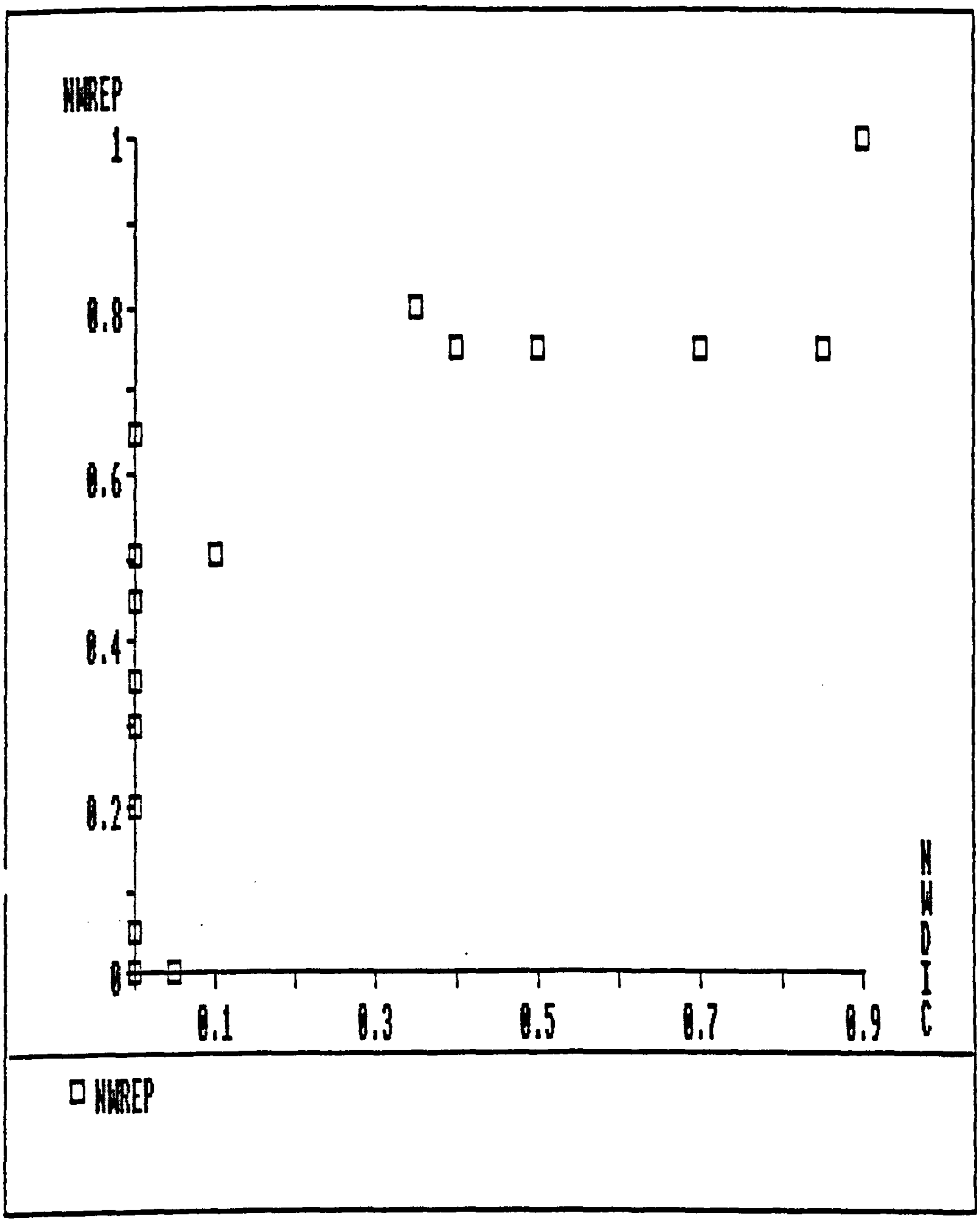


Figure 5.1: Repetition x writing to dictation of non-words.

which is evidence for the claim that sub-lexical writing to dictation is dependent upon phonology.

5.2 A comparison of word repetition, reading and naming

Imageability x frequency list.

This test comprises 80 words; twenty are high frequency, high imageability; 20 low frequency, high imageability; 20 high frequency, low imageability and 20 low frequency, low imageability This test was given to the twenty patients for repetition and to nineteen of the patients (not M.H.) for oral reading. Errors in the repetition test are given in chapter 6.

RESULTS

The proportion of words correctly read and repeated is shown in TABLE 5.2 For word repetition as in non-word repetition, there was a considerable range of performance from all correct (C.J., V.W.) to only 2 words correctly repeated (E.S.). The correlation between word reading and repetition did not reach significance ($r = 0.20$); this is unremarkable given the poor correlation between non-word reading and repetition, and the within patient differences between auditory comprehension and written comprehension

Table 5.2

Repetition, Reading and Naming

Patient	Imageability x Frequency		RANT	
	Reading	Repetition	Repetition	Naming
E.W.	.975	.99	.90	.45
E.S.	.825	.03	.10	.20
A.D.	.275	.51	.83	.20
A.By.	.40	.26	.58	.38
M.K.	.925	.45	.55	.90
E.C.	.275	.37	.40	.25
A.H.	.96	.82	.90	.63
C.L.	.39	.96	.93	.30
A.Ba.	.225	.69	.60	.18
F.M.	.96	.91	.85	.63
C.J.	.91	1.00	.93	.73
N.H.	.44	.71	.73	.50
M.H.	NT	.96	NT	NT
K.J.	.24	.91	.98	.48
D.M.	.975	.96	.95	.58
F.C.	.16	.86	.90	.60
V.W.	.96	1.00	1.00	.75
D.I.	.99	1.00	1.00	1.00
D.R.B.	.975	.44	.78	1.00
I.M.	.90	.99	.95	.45
(n)	(80)	(80)	(40)	(40)

Described in Chapter 3.

Only one patient was significantly more likely to make errors on low than high frequency words (A.H., hifrequency = 34/40, lofrequency = 25/40). Three patients made significantly more errors on low than high imageability words as measured by the Fisher Exact test:

E.C. High 20/40, low 10/40, $z= 1.85$, $p<.05$
N.H. High 31/40, low 22/40, $z= 1.85$, $p<.05$
D.R.B. High 30/40, low 5/40, $z= 4.97$, $p<.001$.

One of these patients (DRB) made semantic errors in repetition; there were two other patients who made semantic errors; MK did not show an effect of imageability in this particular test but has done so in many others (Howard and Franklin, 1988), and E.S. was only able to repeat two of the words correctly and so was at floor. None of the patients who made semantic errors in repetition were able to repeat any non-words.

Repetition and naming test (RANT)

Another test was given for repetition, which could be directly compared with the same items given for picture naming. This consisted of forty items presented once for picture naming and once for repetition. The frequency of the words used ranged from 283 ("feet") to 1 (e.g. "kite) with mean frequency 37.3. The proportion of words correct in each test is shown in TABLE 5.2. The relationship between repetition and naming will be addressed in a later section.

RESULTS

To assess the patients' stability of performance in repetition tasks, a regression was carried out to see if performance on repetition of the RANT correlated significantly with performance on repetition of the imageability x frequency list. Obviously the former test contains only picturable items, so it was anticipated that it might yield better performance; but if the patients' repetition performance were stable, then ability on one test should be highly predictive of ability on the other. This indeed turned out to be the case; there was a highly significant correlation ($r = .91$, $F = 81.279$, df 1,17 $p < .005$), and as predicted, the value of the intercept differs significantly from 0 (t (17) = 2.61 $p < .05$) because performance is better overall on RANT.

5.3 Sub-lexical versus semantic repetition?

Word vs. non-word repetition

A regression analysis was carried out to see if there was a significant correlation between performance on the imageability x frequency word repetition test and performance on the non-word repetition test. If sublexical and lexical routes are independent, then patients will show differential effects of impairment to one or other of the routes; that is, there will be patients with impaired sub-lexical processing but intact lexical processing and vice versa. If there is one route which is quantitatively impaired to different degrees in different patients, then performance on one task will be highly predictive of performance on the other.

There was a significant correlation ($r = .714$) between word repetition and non-word repetition ($F = 38.963$ df 1,18 $p < .005$). All patients made more errors in the non-word repetition test, except for DI who was at ceiling on both tests. Although this would seem to support the single route model, on reflection there may be reasons why such a result is obtained which are not incompatible with other models.

If it is accepted with a two-route model that real words can be repeated either lexically or sublexically, then real word repetition will always be at least as good as non-word repetition; it will never be the case that a patient with a low score in the real word test will have a high score in the non-word test. The opposite case should occur, where non-word repetition is severely impaired but real word repetition is normal, and the fact that no patient in this group shows such a pattern is at least some of the source of the significant correlation. The reason why there is no such patient in those described here might be that there is only one route to repetition and therefore that such a patient could not exist; a more likely explanation is that these patients were initially selected on the basis of their having comprehension problems. On a two-route model, if a patient has a severely impaired sub-lexical route, then her/his word repetition will reflect any comprehension problems and therefore also be impaired. Thus further evidence must be considered to resolve this issue.

Frequency effects in repetition and naming.

If there are separate lexical and sub-lexical routes (with no lexical advantage in the sub-lexical route), and some patients are tending to rely on one or other of these routes, then the patients repeating lexically should tend to make more errors on low frequency words. The patients repeating sub-lexically should be unaffected by word frequency. It is well-documented that anomic errors are more likely to occur on words of lower frequency. So this account would predict that while all patients' naming performance should be sensitive to frequency, only those who are repeating lexically will have a frequency effect in repetition. Taking ability to repeat non-words as an indicator of sublexical repetition for real words, there should thus be an interaction between word frequency, task (repetition or naming) and ability to repeat non-words.

A two-route model makes another kind of prediction. If there is more than one route available for repetition, then repetition performance will tend to be better than naming. If there is only one route, then except in the case of visual agnosic patients (CL and MH) who will have particular problems with picture naming, there should be no advantage for repetition over naming; and where there are input problems as well as the anomia (which is always the case with this set of patients), repetition should actually be worse.

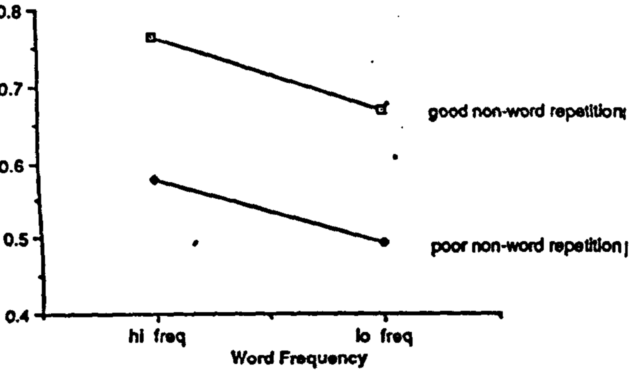
The RANT was divided into low (= less than the median for this set of words) and high frequency (greater than the median for this set of words) items. Patients were divided into "poor sub-lexical repeaters" and "good sub-lexical repeaters" by whether their non-word repetition was better or worse than the median for the group. A split-plot, 4 factor ANOVA was carried out with patients, good/bad sublexical repetition, task, and high/low frequency as factors, with the probability of correct response as the dependent variable. The results are shown in TABLE 5.3

RESULTS.

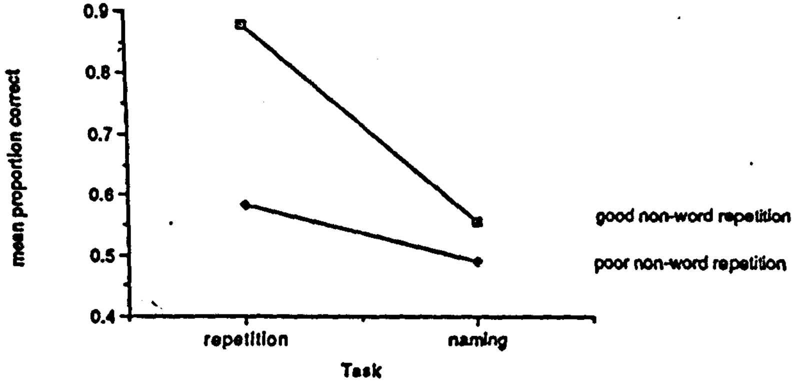
The first set of predictions is not supported: there is no interaction between word frequency, task and sub-lexical ability (F=0); neither is there any interaction between sublexical ability and frequency (F=.1) or frequency and task (F=.2). There is in fact a main effect of frequency (F=27, df 1,48 p<.001), which means that patients are more likely to repeat or name words if they are of higher frequency, which is consistent with a single route model.

However the second prediction is supported; there is a significant main effect of task (F=21 p<.001). Repetition is significantly better than naming which would not necessarily be predicted by a one route

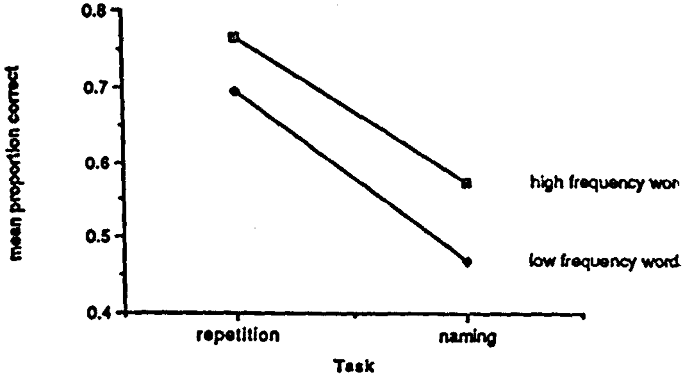
Non-word repetition x frequency



Non-word repetition x task

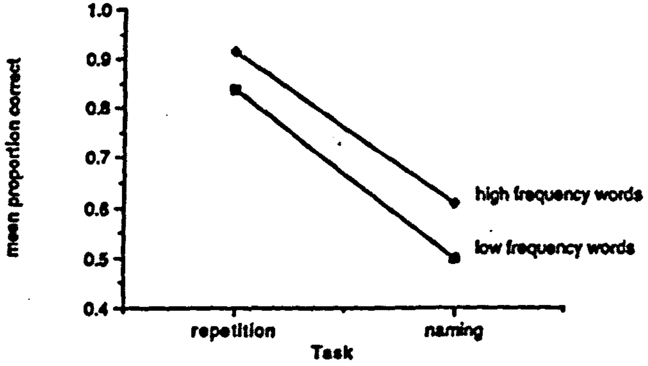


Frequency x task

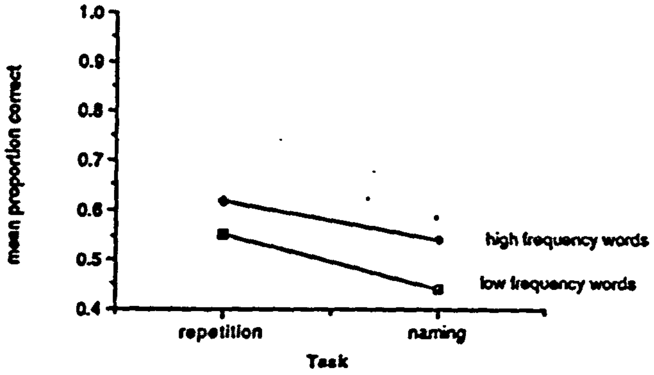


3-way interaction

good non-word repetition:



poor non-word repetition:



model. Furthermore there is a significant interaction between sub-lexical ability and task (F=6.2 p<.05), such that repetition is only better than naming in those patients with good sub-lexical ability; where sub-lexical ability is poor, repetition and naming do

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TABLE 5.3

ANOVA: Non-word repetition x task x frequency

Summary Table:

	df	SS	MS	F	p
Between Ss.	17	3.1086			
Groups	1	0.5868	0.5868	3.723	.072
Ss within groups	16	2.5218	0.1576		
Within Ss	54	2.18126			
Frequency	1	0.14222	0.14222	26.64	.0001
Freq x group	1	0.00055	0.00055	0.103	
Freq x Ss within groups	16	0.08542	0.00534		
Task	1	0.78125	0.78125	20.814	.0003
Task x group	1	0.23347	0.23347	6.220	.024
Task x Ss within groups	16	0.60056	0.03754		
Freq x task	1	0.00500	0.00500	0.24	
Freq xtask x group	1	0.00000	0.00000	0.00	
Freq x task x pts within groups	16	0.33279	0.02080		

---

not differ significantly. This result is not explicable in terms of the single-route model.

Effects of imageability in repetition.

In Chapter 3 it was demonstrated that 13 of these patients are significantly worse at comprehending words with a low imageability value. Many other patients' scores showed a trend in this direction, and no patient found it harder to comprehend high imageability words than low imageability words. A single repetition route must predict that the worse overall performance is in repetition, the larger the imageability effect will be. The size of the imageability effect in patients' repetition was correlated with performance in (a) repeating high imageability words, and (b) repeating non-words. The imageability x frequency list was used for this analysis. The proportion of low imageability words repeated correctly was subtracted from the proportion of high imageability words repeated correctly to obtain a measure of the imageability effect. These measures were correlated with a) the scores from repetition of the RANT list and b) the scores from non-word repetition.

RESULTS

There was no significant relationship between

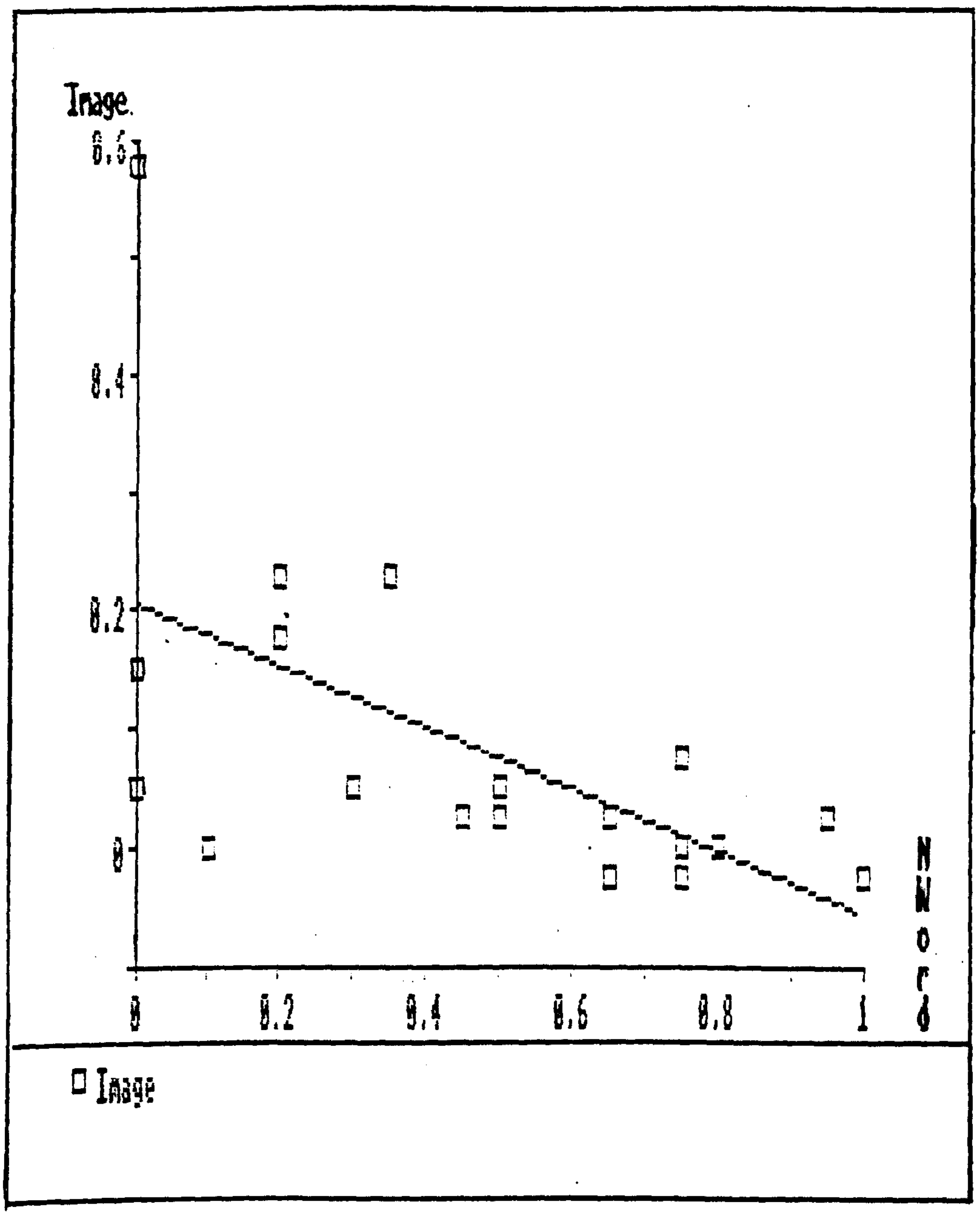


Figure 5.2: Imageability effects x non-word repetition.

imageability effect and repeating high imageability words ($r = -.255$), which is consistent with their being seperate routes for semantic and sub-lexical repetition. However there is a significant correlation between size of imageability effects and non-word repetition ($r = .61$, $F = 10.08$, df 1,18 $p<.01$). But when imageability effects are plotted against non-word repetition (Figure 5.2) it can be seen that all but five of the patients have imageability effects close to zero (that is, no effect of imageability), and these other five patients all have rather poor sub-lexical repetition. Little can be concluded from this since all patients who are able to repeat non-words will also be able to repeat all real words, which will obviously yield no imageability effect.

5.4 A direct lexical route?

The evidence so far has supported their being seperate lexical and sub-lexical routes. In order to examine the hypothesis of a direct lexical route for repetition, it is necessary to look at individual patients' repetition and contrast this with their naming (as tested by the RANT Test) and their comprehension as described in Chapter 3.

The patients' repetition performance can be grouped into 5 types:

1. good repetition
2. all repetition impaired because of word sound deafness
3. no non-word repetition
4. word repetition better than non-word repetition
5. repetition of words and non-words equally impaired

Patients with good repetition

Patients who scored more than 95% on word repetition and more than 75% on non-word repetition were put into this category. There are six such patients; D.I., M.H., C.J., V.W., E.W. and I.M. TABLE 5.3 shows their performance on auditory lexical decision and synonym matching, as well as repetition and naming.

Patients D.I. and M.H. were unimpaired on the non-word repetition task, so are able to repeat at least single syllabled words via the sub-lexical route. If they were repeating words via the semantic route then their repetition should reflect their comprehension and naming performance. D.I. has a significant effect of imageability in synonym matching (F.E. z=2.82 p<.01). For DI, repetition should therefore lead to errors on words of low imageability, which is not the case.

TABLE 5.3

Summary of Results for Patients with good repetition

	Patients					
	D.I.	M.H.	C.J.	V.W.	E.W.	I.M.
Word repetition	1.00	.96	1.00	1.00	.99	.99
Non-word repetition	1.00	.95	.80	.75	.75	.75
Auditory lexical decision	.98	.98	.96	.96	.92	1.00
Synonym matching:						
High imageability	1.00	.66	.84	.95	.97	--+
Low imageability	.76	--	.74	.84	.84	--+
Naming	1.00	3/60*	.73	.75	.45	.45

*Boston Picture Naming Test

+written synonym matching High imageability: .95

Low imageability: .79

For DI, repetition should therefore lead to errors on words of low imageability, which is not the case. M.H. has a major semantic deficit; she is severely impaired in synonym matching even with words of high imageability, so semantic repetition in her case would be severely impaired; yet she made 3/80 errors in word repetition and 1/20 errors in non-word repetition.

The remaining four patients made either one or no mistakes in the eighty item imageability x frequency list, but four or five errors in repeating the non-word list. Does this constitute a lexical advantage in repetition? One of the patients, E.W., appears to have a mild auditory input impairment (see Chapter 3). This would be expected to produce a slight problem in sub-lexical repetition but would perhaps have less of an effect on real word processing. Thus the discrepancy of .99 on real word repetition and .75 on non-word repetition could indicate a very mild impairment of sub-lexical processing. Clearly, as with the first two patients all these patients have impairments to the semantic route, both in terms of comprehension and naming. They cannot therefore be using the semantic route for repeating words. If four or five errors constitute a measureable impairment of sub-lexical processing, then their unimpaired performance on word repetition would be evidence for a third repetition route: the direct lexical route.

However, it is possible that there is some lexical advantage to sub-lexical route repetition (for example in terms of frequency of co-occurence of phonemes), so this slight discrepancy between word and non-word repetition could be considered to be a sub-lexical route operating sufficiently well to repeat real words correctly, but not maximally as in the case of D.I. and M.H. where even non-words are repeated correctly.

Patients who are unable to repeat non-words.

Three patients were unable to give any correct responses in non-word repetition. Their responses are summarized in TABLE 5.4, and they are patients E.S., M.K. and D.R.B. E.S. is the patient earlier described as "word-sound deaf", and therefore is impaired at identifying the acoustic representations at input. Since this level of processing is common to all repetition routes, an impairment here should affect real-word and non-word repetition and indeed this is the case; he is only able to repeat one item from the imageability x frequency list and no items from the non-word list.

TABLE 5.4

Summary of results for patients unable to repeat non-words

	Patients		
	E.S.	M.K.	D.R.B.
Repetition			
High Imageability	.03	.53	.75
Low Imageability	.00	.38	.13+
Non-word Repetition	.00	.00	.00
Auditory Lexical Decision	.68	.68	.98
Synonym Matching			
High Imageability	.79	.95	.95
Low Imageability	.63	.76*	.60+
Naming	.20	.90	1.00

+ DRB shows a significant effect of imageability in synonym matching (Fisher Exact Test, z=2.63, p<.01) and in repetition (Fisher Exact Test, z=4.97, p<.001)

* MK shows a significant effect of imageability in synonym matching (Fisher Exact Test, z=1.94, p<.05)

MK, DRB have a less severe repetition impairment; they are unable to repeat any non-words correctly, but are able to repeat some real words (MK 36/80 and DRB 35/80). They both make more errors in comprehending low imageability words than high imageability words (see synonym matching test). DRB is significantly better at repeating words with high imageability values than words with low imageability values. Although MK's imageability effect in repetition does not reach significance in this particular test, it does so in longer tests of repetition. Thus word repetition appears to be carried out by the semantic route. If they were repeating via an intact lexical route, DRB's word repetition would be unimpaired, since his auditory lexical decision is unimpaired as is his concrete word naming. Either there is no direct lexical route; or if there is such a route and it is impaired in DRB, it must be the access from the input to the output lexicon which is impaired in his case, since the lexicons are unimpaired. If there is such a route to be impaired, this requires there being two lexicons: an auditory input lexicon in some sense separable from the phonological output lexicon. Thus if there is a direct lexical route for repetition, there must be separate input and output lexicons.

Patients who are better at repeating words than non-words.

Eight of the patients, while having impaired repetition, are better at repeating words than non-words (See TABLE 5.5), although unlike the previous three patients they do have some ability to repeat non-words. Even if there is an advantage in the sub-lexical route for real-words, such that, roughly speaking, non-words are only repeated 75% as well as real words (as suggested by the first patient group reported), six of these patients (all except FC and ABa) have a more substantial lexical advantage. For these six patients the number of non-words repeated as a proportion of high imageability words repeated is as follows: Cl = .66, DM = .51, KJ = .48, FM = .32, NH = .26 and AD = .32.

If this lexical advantage cannot be explained in terms of a property of the sub-lexical route, then patients must be using either a semantic route or a direct lexical route. As I have previously argued, if they are using a semantic route, then their repetition should show the same properties and impairments as their comprehension and naming.

TABLE 5.5

Summary of results for patients who have a lexicality effect in repetition

	Patient							
	C.L.	F.C.	D.M.	A.Ba	K.J.	F.M.	N.H.	A.D.
Repetition								
High Image	.98	.88	.98	.73	.93	.93	.78	.63
Low Image	.98	.85	.95	.65	.90	.88	.55+	.40
Non-word Repetition	.65	.65	.50	.50	.45	.30	.20	.20
Lexical Decision	.80	.98	.94	.98	.96	.90	.92	.78
Synonym M.								
High Image	.95	.89	1.00	**	.97	.92	.74	**
Low Image	.82	.58	.82	**	.82	.76	.53	**
Naming	.30	.60	.58	.18	.48	.63	.50	.20

** unable to attempt this test;

on written triads version:

	High Imageability	Low Imageability
ABa	.79	.63
AD	.68	.68

+ significant effect of imageability in repetition

(Fisher Exact Test, z=1.85, p<.05)

Significant effect of imageability in synonym matching:

NH and KJ (p<.05)

DM and FC (p<.01)

CL repeats 98% of the imageability x frequency list correctly, but is able to name only 30% of the pictures in the RANT. However since CL has an impairment of visual semantics this could account for his poor performance on the naming test. His synonym matching score, although impaired, is not severely so; he could be using semantic route repetition.

FM has rather poorer repetition (High Imageability words .93, Low Imageability words .88) and again only a slight impairment in synonym matching (hi im .92 lo im .76), where there is no significant effect of imageability. His naming is also impaired (.63), but given that direct comparison of difficulty across tests cannot be meaningfully made, this could be compatible with his repeating via his impaired semantic route.

NH has a significant effect of imageability in both repetition and comprehension, so again could be using a semantic route; but she is also impaired in naming (.5), which could arguably make her repetition via the semantic route worse than her comprehension, since it will also have to utilize the impaired output route. Like FM, however this is difficult to quantify, so semantic route repetition could be a possible explanation for her advantage in repetition of real words.

DM repeats .97 of the image x frequency words correctly. He has a significant effect of imageability in synonym matching so repetition purely via the semantic route should produce errors on words of low imageability. He named only 58% of the pictures in the RANT, and since there is no evidence that he has any visual semantic impairment, this should mean that semantic route repetition would produce errors in repeating even high imageability words. This patient appears to be repeating at least some words by a direct lexical route.

KJ has a very similar profile to DM; he has a signficant effect of imageability in synonym matching but in repetition he repeats 93% of high imageability words correctly and 90% of low imageability words. His naming is impaired (.475) and again there is no evidence to suggest he has a visual agnosia.

AD repeats 63% of high imageability words correctly, despite being entirely unable to do the synonym matching test in a spoken form, being severely impaired in the spoken word to picture version of Pyramids and Palm Trees (34/52 correct) and only naming 20% of the RANT correctly. She is another patient who appears to be using a direct lexical route for repetition. She has, however, significant effects of both imageability and frequency in repetition, suggesting that she is sometimes using the semantic repetition route and sometimes the direct lexical route (the frequency effect being related to the naming problem)

Patients whose word and non-word repetition are equally impaired

AH is able to repeat 75% of non-words, but only 81% of real words (substantially less than the "good repeaters"). Furthermore, he is significantly better at repeating high frequency words then low frequency words. Since he was the only patient to show an effect of frequency in this repetiton test he was asked to repeat another list to replicate the effect. AH is not repeating via the semantic route, since he has a significant effect of imageability in synonym matching, but not in repetition. He has an impairment in lexical access, as indicated by his poor lexical decision score; it may be that he is able to repeat high-frequency words via the direct lexical route, but is forced to use the sub-lexical route for repeating low frequency words.

TABLE 5.6

Summary of results for patients whose word and non-word repetition is equally impaired

	Patients	
	A.H.	E.C.
Repetition		
High Imageability	.85	.50
Low Imageability	.78	.25
Non-word Repetition	.75	.35
Auditory Lexical Decision	.72	.84
Synonym matching		
High Imageability	.92	1.00
Low Imageability	.58	.89
Naming	.63	.25

A.H. shows a significant effect of frequency in repetition (Fisher Exact Test, $z= 2.28$, $p<.05$) and a significant effect of imageability in synonym matching (Fisher Exact Test, $z=3.16$, $p<.001$)

E.C. shows a significant effect of imageability in repetition, (Fisher Exact Test, $Z=1.85$, $p<.05$) but the disparity is not significant in synonym matching ($z=1.53$).

E.C. is severely impaired in non-word and real word repetition. E.C. repeats .38 of real words and .35 on the non-word list, despite having a significant effect of imageability in both repetition and in synonym matching. The fact that she performs equally well on real and non-words, despite the imageability effect, suggests that she is repeating at least some high imageability words by the semantic route, and is repeating other words by the sublexical route.

To test this hypothesis, she was asked to repeat the words from the imageability x frequency list again, this time with lip reading, which I shall argue in a later chapter supports sub-lexical route repetition. Without lip reading she repeated 50% of high imageability words correctly and 25% of low imageability words; with lip reading she repeated 33% of high imageability words and 30% of low imageability words. So when she was allowed to lip read, there was no longer any effect of imageability.

5.5 Do partially functioning routes combine?

An alternative explanation for the better perfomance of some patients in repeating real words over non-words is that two partially functioning routes, i.e. the sub-lexical and the semantic routes produce enough information between them to yield the correct result. Only three patients make semantic errors in repetition, MK, DRB, and ES; they are the only three patients who are entirely unable to repeat non-words. It may be that a partially functioning sub-lexical route is able to support the lexical route at the level of phonological output. If this were so, this phonological information would be incompatible with the activation produced by a semantic error, which would typically have no phonological relation to the target. This would entail the pattern of semantic errors only occurring with a non-functioning sub-lexical route (Howard 1985). However, the alternative account of some patients being able to use direct route repetition would also predict this pattern of results.

The patients who have some ability to repeat non-words and real words may be using a combination of the semantic and the sub-lexical repetition route, so their ability to repeat words should be predictable given knowledge of their comprehension, naming and non-word repetition impairments. To what extent is this true in these patients?

Figure 5.3 compares EC's performance with that of DM, KJ, and AD. Because AD found the synonym matching test

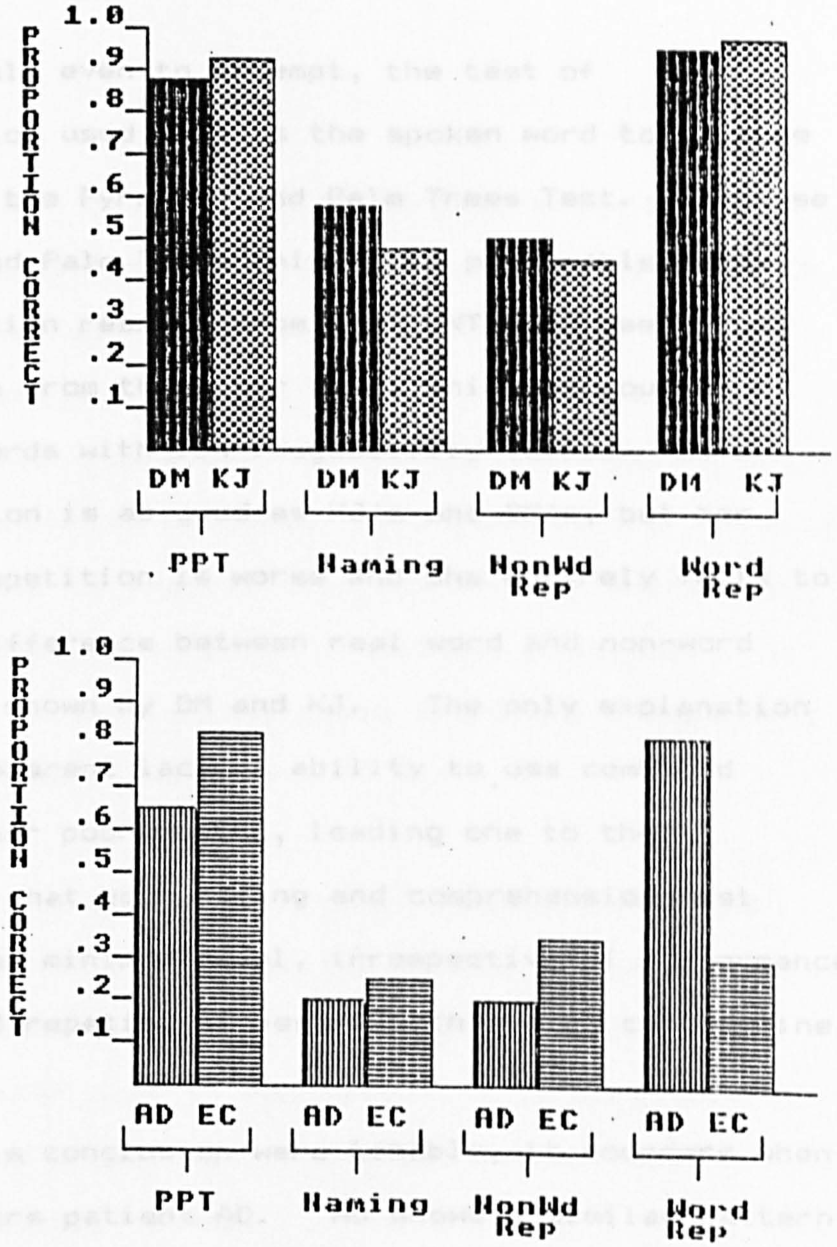


Figure 5.3: Summary of results for EC, AD, KJ & DM.

too difficult even to attempt, the test of comprehension used here is the spoken word to picture version of the Pyramids and Palm Trees Test. Because Pyramids and Palm Trees only tests picturable items, the repetition results from the RANT have been used, rather than from the other test, which of course includes words with low imageability values. EC's comprehension is as good as KJ's and DM's, but her non-word repetition is worse and she entirely fails to show the difference between real word and non-word repetition shown by DM and KJ. The only explanation for EC's apparent lack of ability to use combined routes is her poor naming, leading one to the conclusion that both naming and comprehension must achieve some minimum level, irrespective of performance on non-word repetition, before both routes can combine.

Even if this conclusion were tenable, it founders when one considers patient AD. AD shows a similar pattern of results to DM and KJ, but is more impaired at all tasks. She achieves a lower score than EC on naming, Pyramids and Palm Trees and non-word repetition, but is much better at repeating real words. If she is using a combination of routes, then there is no reason why EC should be unable to do so. That AD is (some of the time) using a direct lexical route to repeat, which is unavailable to EC, is a much better explanation of the data.

The particular patterns of impairment shown by these patients suggest that there are three routes by which words can be repeated; a sub-lexical route, a direct lexical route and a semantic route. Sub-lexical repetition is independent of sub-lexical reading until the point at which phonology is accessed, but there is some evidence to suggest that sub-lexical writing to dictation depends on prior phonological access. If there is a direct lexical route there are independent input and output lexicons.

There was no suggestion in these findings that the sub-lexical route is sensitive to the lexical property of word frequency. The next chapter considers the types of error made in repetition. It particularly explores the properties of the sub-lexical and lexical/semantic routes.

CHAPTER 6:

Assembled vs addressed phonology (and other errors)

In the previous chapter, the patients' performance on a number of tests of repetition, reading and naming was considered. This chapter presents analyses of the error data obtained from those tests. The first analysis addresses the issue of whether particular types of error are more likely to occur on more infrequent or more abstract words. The occurrence of neologisms is compared with the occurrence of phonologically related errors to determine whether they have a common origin.
By comparison with performance in other modalities, it is established that phonologically related errors cannot be attributed to an output phonological impairment. The rest of the chapter is devoted to distinguishing between errors of assembled and addressed phonology.

Errors are classified in the following ways:

1. no response.
2. phonologically related real words (where at least half the phonemes in the response occur in the target).
3. phonologically related non-word errors (where at least half the phonemes in the response occur

in the target).

4. neologisms (where the response is neither phonologically related, nor a real word).

5. unrelated real word errors.

6. semantically related errors.

7. circumlocutory errors, where the response is semantically related, but comprises more than one word.

8. derivational or inflectional errors (there were very few of these, they will not be discussed).

6.1 Possible loci of different error types.

The first category of error is 'no response'. Of course, this is a very difficult error to interpret; one cannot determine whether there is a failure to access at some level or whether errors are being edited out.

If phonologically related errors arise in the lexical/semantic system, they should tend to be phonologically related real word errors (addressed phonology in Patterson's 1981 terminology). These errors could be caused by (a) incorrect access to the auditory input lexicon, (b) an impairment of processing between the lexicons, or (c) an impairment in, or from, the phonological output lexicon. If phonological errors arise at the level of pre-lexical auditory analysis, in acoustic to phonological conversion or at the level of phonological assembly, then they should tend to be phonologically related <u>non-word</u> errors (assembled phonology according to Patterson 1981). However, many of these may by chance be real words (what Butterworth (1985) calls jargon homophones). Miller and Ellis (1987) suggested that phonologically related non-word errors in naming should show effects of decay across positions in the word if they are a result of a defective response buffer; but these authors in fact failed to find any significant position effects in their patient R.D.

Neologisms may arise in the same way as phonologically related non-word errors and may merely be severe errors of this form. An alternative theory is that neologisms are spontaneously generated at the level of phonological assembly when there is no usable information at all accessed at the level of phonological output and the patient is required to make a response.

Semantic errors are produced when the correct meaning is not suffiently specified or when information from the semantic system is not stable. Semantic errors indicate that the patient must have been able to access some part of the meaning. Circumlocutory errors presumably indicate the same thing: these are definitions "explaining" the meaning of the word that the patient is attempting to repeat.

TABLE 6.1

Repetition of Imageability x Frequency List: Number of Errors.

	No Response	PhonRW	PhonNW	Neol
E.W.			1	
E.S.	36	6	4	11
A.D.	17	11	8	2
A.By.		13	13	10
M.K.		14	2	
E.C.	11	18	9	5
A.H.		10	4	
C.L.		2		
A.Ba.	15	2	2	
F.M.	3	4		
N.H.	2	13	8	
M.H.		2	1	
K.J.		4	2	
D.M.		2		
F.C.		8	1	
D.R.B.	33	3	2	
I.M.		1		

TABLE 6.1 (cont.)

Repetition of Imageability x Frequency List: Number of Errors.

	Semantic	UnrelatedW	Der	Circum
E.W.				
E.S.	2	15	2	3
A.D.			1	
A.By.		7		
M.K.	4	24		
E.C.		4	3	
A.H.		1		
C.L.				
A.Ba.		6		
F.M.		1		
N.H.		3		
M.H.				
K.J.		1		
D.M.			1	
F.C.		2		
D.R.B.	4	3		
I.M.				

Unrelated real word errors generally have an obscure origin. There are many ways in which they could be generated. They could be "mixed" errors (e.g. auditory -> semantic -> phonological) which are so distant from the target as to evade detection. Some errors at least appear to be perseverations of whole or part previous responses. Other words could simply be randomly-generated probably high frequency words, a kind of lexical analogue to Butterworth's random phoneme generator.

The number of errors of each type for each of the 17 patients who make errors in real word repetition can be seen in TABLE 6.1.

The effect of word imageability and word frequency on error type.

To determine whether either word imageability or word frequency affected the types of errors made in repetition, a 3-factor ANOVA assessed the effects of patient, word frequency and word imageability on the proportions of total errors, no responses, semantic errors and phonologically related errors. There was a main effect of patients on all error types, but since there was also a large effect of patient on total proportion of errors (F=28 df 19, 57 p<.005), this is merely indicative of different levels of severity.

There were also main effects of both imageability (F=11.5 df 1,57 p<.005) and word frequency (F=7.1 df

1,57 $p<.005$) on the total number of errors. This is to be expected given the findings in the previous chapter (a) that patients tend to make errors on less frequent words and (b) that several patients are significantly better at repeating high than low imageability words, while no patient in this set is better at repeating low imageability words. The interaction of word imageability and word frequency was not significant (F=0.3 df 1,57 n.s.).

The only remaining significant main effect was of imageability on no response errors (F=11.7 df 1,57 $p<.005$). Patients were more likely to produce no response if the stimulus was a low imageability word. This suggests that on at least some occasions no response errors are attributable to a failure to access adequate information in the lexical/semantic system rather than to inadequate information further on in the production process or to monitoring out of incorrect responses.

6.2 Neologisms

If neologisms are severe instances of phonologically related errors, then neologisms should only occur in patients who make a large number of phonologically related errors. In other words, as phonologically related errors increase, the rate of neologisms should also increase. This should be particularly true for phonologically related non-words since both these errors and neologisms must be produced via an impairment of assembled phonology.

Data from the thirteen patients who made more than four phonologically related errors in repetition were used for this analysis. Phonologically related real words, phonologically related non-words and neologisms occurring in repetition and reading of the imageability x frequency list, in repetition and reading of the 20 item non-word list and in naming of the RANT were all expressed as proportions of total stimuli.
A series of correlations were carried out, each time with neologisms as one of the measures. The effects of phonologically related non-words and phonologically related real words were examined separately for each task in each modality. The results can be seen in TABLE 6.2.

There was a significant relationship between neologisms and phonologically related non-words in real word repetition, real word oral reading and in naming. No effects of phonologically related real words reached significance. Thus as predicted, the more phonologically related non-word errors are made, the more likely it is it that neologisms will be produced, supporting the theory that for these patients at least, neologisms are a severe form of phonologically related error.

TABLE 6.2

Correlations between neologisms and phonologically related errors

	Regression* neologisms and:	
TASK	PhonRW errors	PhonNW errors
Real word repetition	F=3.98 ns.	F=14.28 $p<.005$
Non-word repetition	F=0.34 ns.	F= 2.75 ns.
Naming	F=3.95 ns.	F=32.82 $p<.005$
Real word reading	F=4.89 $p<.05$	F=59.39 $p<.005$
Non-word reading	F=0.70 ns.	F= 0.02 ns.

*df 1,11 in all cases

The relationship between phonologically related errors and neologisms in reading and repeating non-words was not significant. This was rather surprising, given the real word test results; but for repetition at least, the lack of significance may have been due to the very small data set for neologisms in non-words, because the original stimulus set was so small.

Although this would seem to be evidence for neologisms being produced by the same mechanism as phonologically related errors,it is important to notice that none of the twenty subjects in this study corresponds to the classical description of a patient with neologistic jargon aphasia, such as R.D. (Ellis, Miller and Sinn 1983; Miller and Ellis 1987). It is likely that the neologisms produced by jargon aphasic patients are quite different in character and are produced by a mechanism such as a random phoneme generator.

6.3 Are phonological errors modality specific?

If phonologically related real word errors were jargon homophones, and all phonologically related errors were impairments in assembled phonology, then these errors could simply reflect an impairment at the level of phonological output ("response buffer" in the Morton 1970 or the Patterson and Shewell (1987) model) . If this were so then the same impairment should be found in all tasks which require spoken output, irrespective of modality, i.e. repetition, oral reading and naming.

TABLE 6.3

Phonologically related errors as a proportion of total errors

	Repetition		Naming	Reading	
	Non-word	Real-word		Non-word	Real-word
E.S.	.30	.13	.22	.15	.18
A.D.	.81	.49	.26	.61	.59
A.By.	.79	.60	.00	.67	.60
M.K.	.65	.36	.00	.00	.08
E.C.	.92	.54	.37	.00	.72
A.H.	1.00	.93	.08	.00	.04
A.Ba.	.43	.16	.03	.25	.10
F.M.	1.00	.50	.20	.71	1.00
N.H.	.88	.78	.09	.80	.41
K.J.	1.00	.86	.10	.00	.13
D.M.	1.00	.67	.05	.75	.50
F.C.	1.00	.82	.13	.67	.64
D.R.B.	.25	.11	.00	.15	.03

Regression real word repetition and:	df	F	
1) Naming	1,11	0.013	ns.
2) Real word reading	1,11	0.675	ns.
3) Non-word reading	1,11	0.636	ns.
4) Non-word repetition	1,11	47.588	p<.005

Thus there should be a significant correlation between the occurrence of phonologically related errors in both naming and oral reading with this error type in repetition. The imageability x frequency test was used for the repetition and oral reading data, the RANT for the naming data. The same thirteen patients were included who had been used for the previous analysis. The proportion of phonological errors was measured first as a proportion of total stimuli and then as a proportion of total errors.

TABLE 6.3 shows the number of phonologically related errors per patient as a proportion of all errors. The correlation between phonologically related errors in repetition and (1) naming and (2) reading does not reach significance. This does not support the notion that phonologically related errors are arising at the level of phonological assembly.

The same analysis was used to examine the relationship between the probability of phonologically related errors in non-word repetition and phonologically related errors in real word repetition, as a proportion of total errors. This was highly significant (F=47.59 df 1,11 p<.005). Figure 6.1 shows an extremely linear distribution when the proportion of phonologically related errors produced in response to real words is

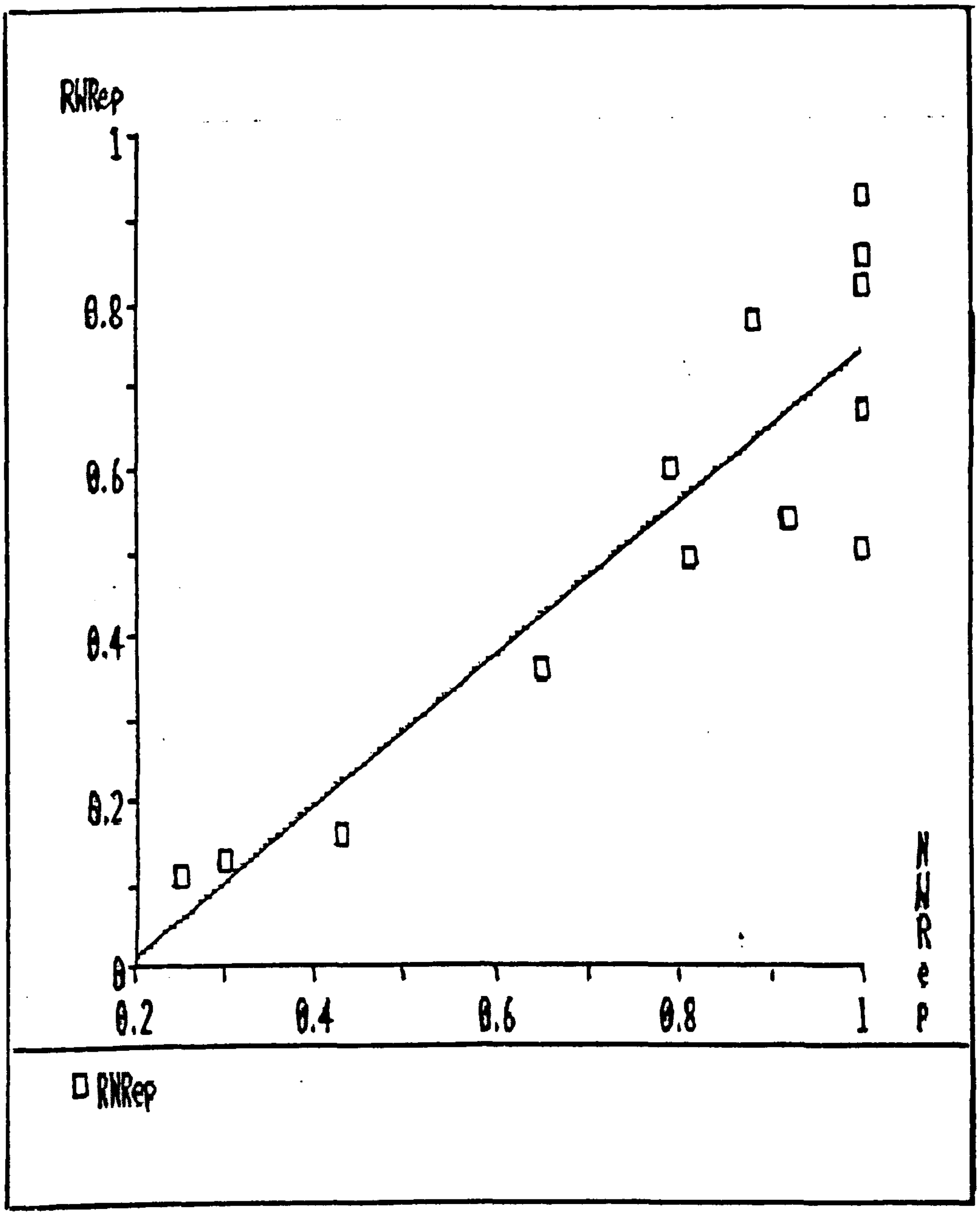


Figure 6.1: Word x non-word repetition;

proportion of phonologically related errors.

plotted against those produced in response to non-words. If errors are not a reflection of a phonological assembly problem, and given the evidence presented in the previous chapter for separate repetition routes, this is initially a surprising result. Neither can it be the result of a common input problem, since there is only one patient with a significant word sound deafness.

The significant correlation may simply be attributable to the fact that if patients have an intact sub-lexical system, they will not make errors in repetition at all. If the system is impaired, the only possible error types via the sub-lexical system are no responses or phonologically related errors; otherwise non-words will be repeated as (similar) real words. It is therefore very likely that patients producing phonologically related errors in real word repetition will also make them in non-word repetition. The other pattern of impairment would be phonologically related errors in non-word repetition co-existing with no such impairment in real word repetition. Patients with good real word repetition have not been used for this analysis, but in fact such a pattern exists (e.g. In non-word repetition VW and CJ make 5 and 4 such errors respectively, but make no errors in word repetition).

6.4 Word frequency of phonologically related errors

One notion of how phonologically related real word errors arise in the lexical/semantic system is that when the correct word is underspecified in some way, resulting in a failure of access, then a high frequency word of that general phonological form will be likely to be accessed instead. The phonologically related real word errors from both the imageability x frequency list and the RANT were taken, and the word frequency for each stimulus item was compared with the word frequency of the response. See TABLE 6.4

There is no pattern of response for the group as a whole. The majority of patients produce errors which are generally of higher frequency than the target words; but three patients, (E.C., A.D. and A.By.) all produced errors which were in the main lower in word frequency than the target items.

TABLE 6.4

Phonologically related real-word errors; word frequency

(for patients who make more than 4 phonologically related real word errors)

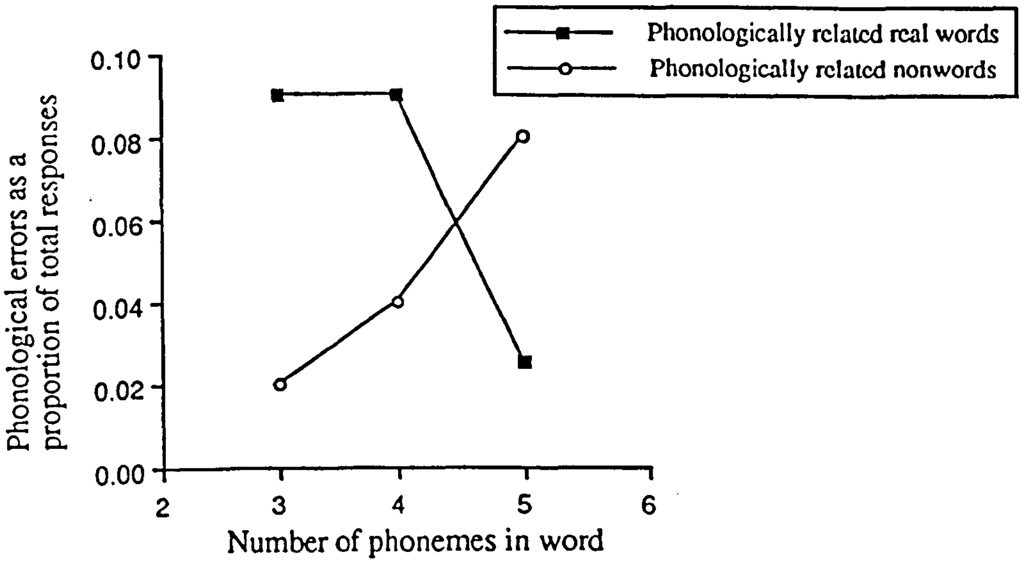
	No. of errors where response is of lower frequency than target	No. of errors where response is of higher frequency than target
E.C.	16	10
A.By.	12	7
A.D.	9	5
E.S.	6	8
K.J.	3	3
M.K.	6	13
F.M.	3	6
A.H.	3	6
F.C.	3	8
N.H.	5	9

6.5 Phonologically related errors; wordness vs length.

While phonologically related non-words will perforce be indicative of an impairment in assembled phonology (since these are all fluent patients who, by definition, have no dyspraxia or dysarthria), a proportion of phonologically related real words may be jargon homophones. Since assembled phonology is not sensitive to lexical factors, then jargon homophones will occur by chance, and will therefore tend to arise from stimuli which are phonologically similar to a large number of other words. The number of phonologically similar words a word has is closely related to its length; that is the shorter the word the more similar real words there will be. If jargon homophones are occurring in this way, then short words will tend to give rise to more phonologically related word errors, whereas longer words will tend to produce phonologically related non-word errors.

The phonologically related errors from the imageability x frequency list were used for this analysis. The majority of the words in this list were either 3, 4, or 5 phonemes in length, so stimuli with fewer than 3 or more than 5 phonemes were discarded. The errors were divided into phonologically related real words and phonological related non-words and were expressed as a proportion of the total number of stimuli of that phoneme length. (see Figure 6.2)

As predicted, there were a high number of real word



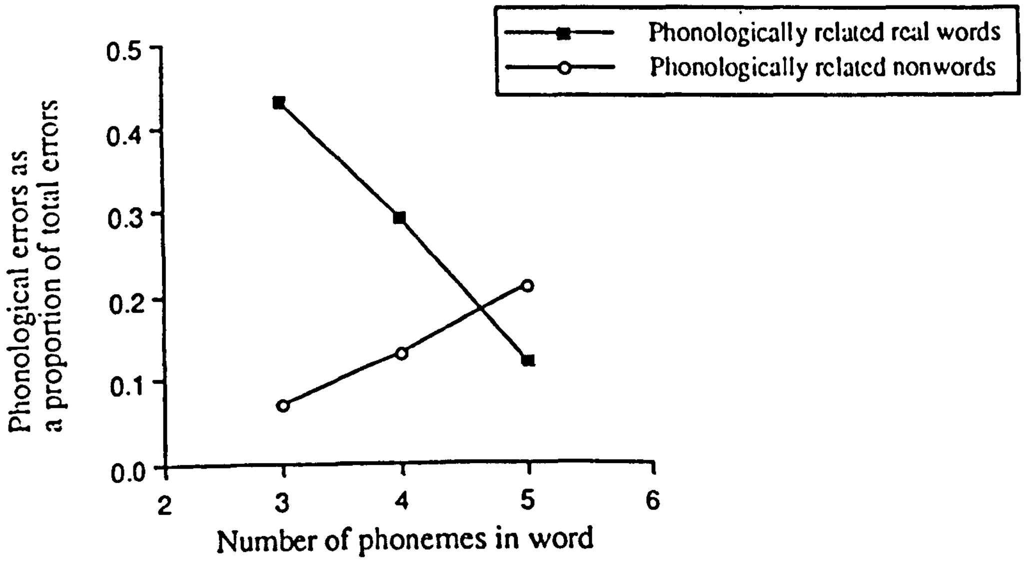


Figure 6.3: Phoneme length x phonologically related error type

errors for 3 and 4 phoneme words (.09 in both cases) which dropped to .025 for longer words. For phonologically related non-words there was a quite different pattern: the longer the word, the higher the proportion of non-word errors. A similar analysis was carried out on responses taken from the non-word list, but unfortunately, nearly all the items in this list are 3 and 4 phoneme; only one non-word was 5 phonemes, so it was impossible to look at the proportion of real to non-word errors at the critical length. For 3 and 4 phoneme strings, however, the non-word stimuli show a similar pattern to the real word stimuli, albeit with a higher over-all error rate.

Although these results fit the jargon homophone account very well, there is another possible account for these findings. It does not contradict this first account, but rather expands it. If a patient is using assembled phonology when producing errors, then how wordlike the string is should not influence performance; but the longer the string is, the more likely it is that errors will arise. If a patient is using addressed phonology, but has incomplete (auditory or semantic) information with which to address the word form, then s/he will access the word form that corresponds best to the available information. Here the number of neighbours the word has is critical; with a long word like crocodile, several of the phonemes could be incorrect or missing and it would still be the only possible candidate word, which would certainly not be true for the word cat. Thus not only are short words more likely to yield phonologically related real words by chance, but also because patients who have impairments in the system which produces addressed phonology (that is the patients who make real word errors) will make more errors with short words than long ones.

To test this hypothesis, two patients were selected, one who appeared to be using addressed phonology and one who appeared to be using assembled phonology. MK was entirely unable to repeat non-words and tended to produce phonologically related real word errors which were higher in frequency than the stimuli. EC was able to repeat some non-words, and moreover seemed equally impaired in repeating real words and non-words; unlike MK she tended to produce phonologically related real word errors which were lower in frequency than the stimuli. If MK is using an impaired lexical/semantic route to produce addressed phonology then he should have greater difficulty with short words than long ones; EC should show the opposite effect if she is using an impaired sub-lexical route to assemble phonology.

TABLE 6.5

Syllable length and repetition

(Proportion correctly repeated)

	Number of syllables		
	1	2	3
M.K.	.73	.63	.90
E.C.	.56	.13	.00

MK and EC were each asked to repeat a list of ninety words, thirty one syllable, thirty of two syllables and thirty of three syllables, matched for frequency and imageability. See TABLE 6.5

MK was significantly better on the three syllabled words than the other words (see Chapter 4); EC was best at one syllable words, worse at two syllable and was unable to repeat any of the three syllabled words correctly (Jonkheere Trend Test, z= 5.01, p<.001).

6.6 Do phonemes decay?

The phonologically related errors in the repetition corpus were analysed to see if phonemes at the ends of strings were more likely to be incorrectly repeated than those at the beginning. Phoneme positions were assigned according to the method devised by Wing and Baddeley (1980) for letter position; the first and last phonemes were assigned to the first and fifth positions respectively and other phonemes assigned symmetrically across the five positions (see Appendix 5). Errors taken from the imageability x frequency list, the RANT list and the non-word list were all analysed seperately. Phonologically related errors were also analysed from the naming version of the RANT. From the total number of stimuli per position and the total number of correct phonemes produced within the words, the expected distribution of the phonemes across the positions was calculated (as described by Miller and Ellis 1987). The results are shown in TABLE 6.6.

For all three repetition tasks the distribution of correct phonemes is significantly different from the predicted distribution. In all cases there were an excess of errors in the fifth position relative to predicted values. The distribution of correct phonemes in the naming task was not significantly different from the predicted distribution, but this may have been because there were far fewer errors in this corpus. (The same explanation holds for the small effect in the case of repetition of the RANT list.)

TABLE 6.6

Phonologically related errors in repetition and naming.

POSITION EFFECTS

1)Repetition of image x freq list:

	POSITION					
	1	2	3	4	5	TOTAL
Target Phonemes	166	95	108	95	166	630
Phonemes correct	104	69	79	72	83	407
Predicted distr.	112.0	64.1	72.9	64.1	112.0	

χ^2 (4) = 27.08, p< .001

2)Repetition of RANT list:

	POSITION					
	1	2	3	4	5	TOTAL
Target phonemes	86	39	65	39	86	315
Phonemes correct	47	25	49	25	41	187
Predicted distr.	51	23.1	38.6	23.1	51	

χ^2 (4) = 38.16, p< .001

TABLE 6.6 (cont.)

3)Repetition of non-words:

	POSITION					
	1	2	3	4	5	TOTAL
Target phonemes	158	66	98	66	158	546
Phonemes correct	110	53	67	53	72	355
Predicted distrib.	102.7	42.9	43.6	42.9	102.7	

χ^2 (4) = 41.79 p< .001

4)Naming RANT list:

	POSITION					
	1	2	3	4	5	TOTAL
A Target phonemes	38	16	30	16	38	138
B Phonemes correct	26	9	18	17	20	90
C Predicted distrib.	24.7	10.4	19.5	10.4	24.7	

χ^2 (4) = 2.37 NS.

Although there appeared to be an effect of decay when the data as a whole were analysed, a patient by patient comparison of number of position 1 phonemes produced correctly with the number of position 5 phonemes produced correctly indicates that three patients were responsible for this significant effect. (see TABLE 6.7)

These three patients were EC, ABy and AD, all of whom had impaired lexical decision, severe anomia and an impaired, but partially functioning, sub-lexical repetition route. They were also the three patients who produced responses which were less frequent than the stimuli. Decay appears to be a feature of an impairment in assembled phonology.

Because no individual patient yielded sufficient data to do the kind of analysis used above, it was carried out on the phonologically related errors made by EC when repeating the syllable length list. Because MK is using addressed phonology, he should not show any decay effect and so his errors on the syllable length list were also analysed for position effects. The results are shown in TABLE 6.8.

TABLE 6.7

Phonologically related errors: position analysis for each patient

(for patients making more than 4 errors)

	First position error	Final position error
M.K.	8	8
A.H.	7	4
F.C.	5	3
E.S.	3	4
N.H.	12	7
A.By.	8	16
E.C.	9	16
A.D.	5	9

As predicted E.C.'s errors by position differ significantly from those predicted; MK's do not. Figure 6.3 shows the proportion of phonemes correct for each position for both of these patients and it can be seen that EC shows a linear effect of decay.

Miller and Ellis (1987) considered that decay was a property of an impaired response buffer; if this is so then EC's naming should also show decay.

Unfortunately neither she nor any of the other patients produced sufficient phonologically related errors in naming to make a position analysis possible, but if it were a response buffer problem EC should show exactly the same effect in oral reading. She was asked to read the words from the syllable length list which had been used for the repetition analysis.

The results of a position analysis on these data can also be seen in TABLE 6.8. Her performance does not differ significantly from the predicted performance; Figure 6.4 contrasts this performance with her repetition of the same list. Unlike her performance in sub-lexical repetition she is entirely unable to read non-words, but still manages to read 22/80 words correctly; in oral reading she uses addressed phonology. For this patient at least decay does not appear to be a property of an impaired response buffer, but rather a property of an impaired acoustic to phonological conversion system.

TABLE 6.8

Phonologically related errors in repetition and reading of syllable length list: position effects.

1)Patient E.C.; Repetition:

	POSITION					
	1	2	3	4	5	TOTAL
Target Phonemes	57	54	57	54	57	275
Phonemes correct	43	36	21	21	16	137
Predicted distr.	28.4	26.9	26.4	26.9	28.4	

$\chi^2 (4) = 38.26,\ p < .001$

---

2)Patient M.K.; Repetition:

	POSITION					
	1	2	3	4	5	TOTAL
Target phonemes	26	22	17	22	26	113
Phonemes correct	14	13	7	13	17	64
Predicted distr.	14.7	12.5	9.6	12.5	14.7	

$\chi^2 (4) = 2.65$, ns.

3) Patient E.C.; Reading:

	POSITION					
	1	2	3	4	5	TOTAL
Target phonemes	45	37	44	37	45	208
Phonemes correct	21	23	29	21	24	118
Predicted distr.	25.5	21	24.9	21	25.5	

χ^2 (4) = 4.02, ns.

In this chapter it was found that the patients, as a group, made more errors on words of both low frequency and low imageability. No response errors were associated with low imageability words, suggesting a lack of semantic specificity for such words. Neologisms tended to co-occur with phonologically related non-word errors, suggesting that, for these patients at least, neologisms are a form of phonologically related error rather than being randomly generated strings. This may be because none of these patients are "jargon aphasics".

If all phonologically related errors were produced at a phonological output level, then they would occur in all tasks involving this component; in fact the occurrence of phonologically related errors in repetition does not

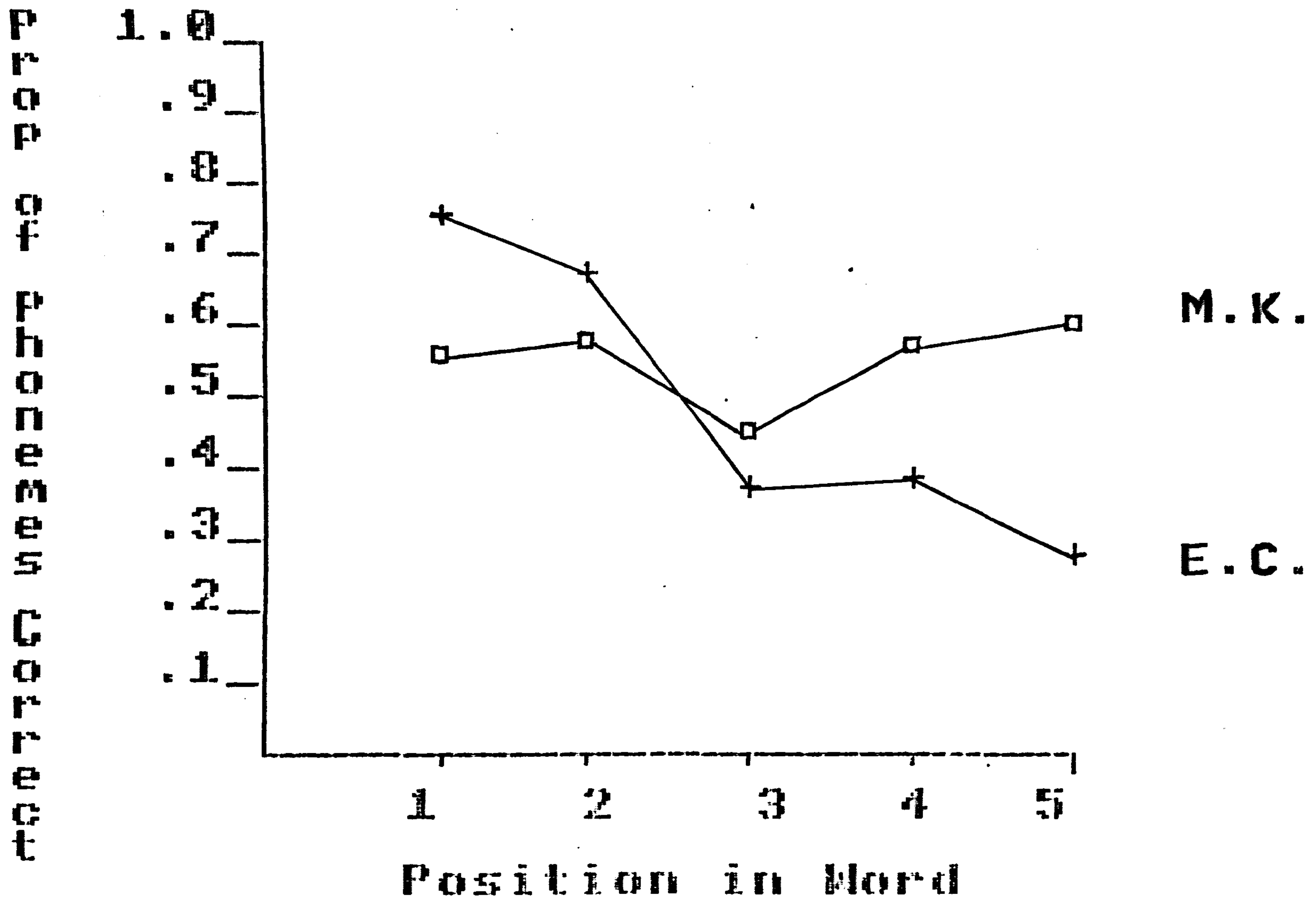


Figure 6.3: Position effects in repetition: EC and MK.

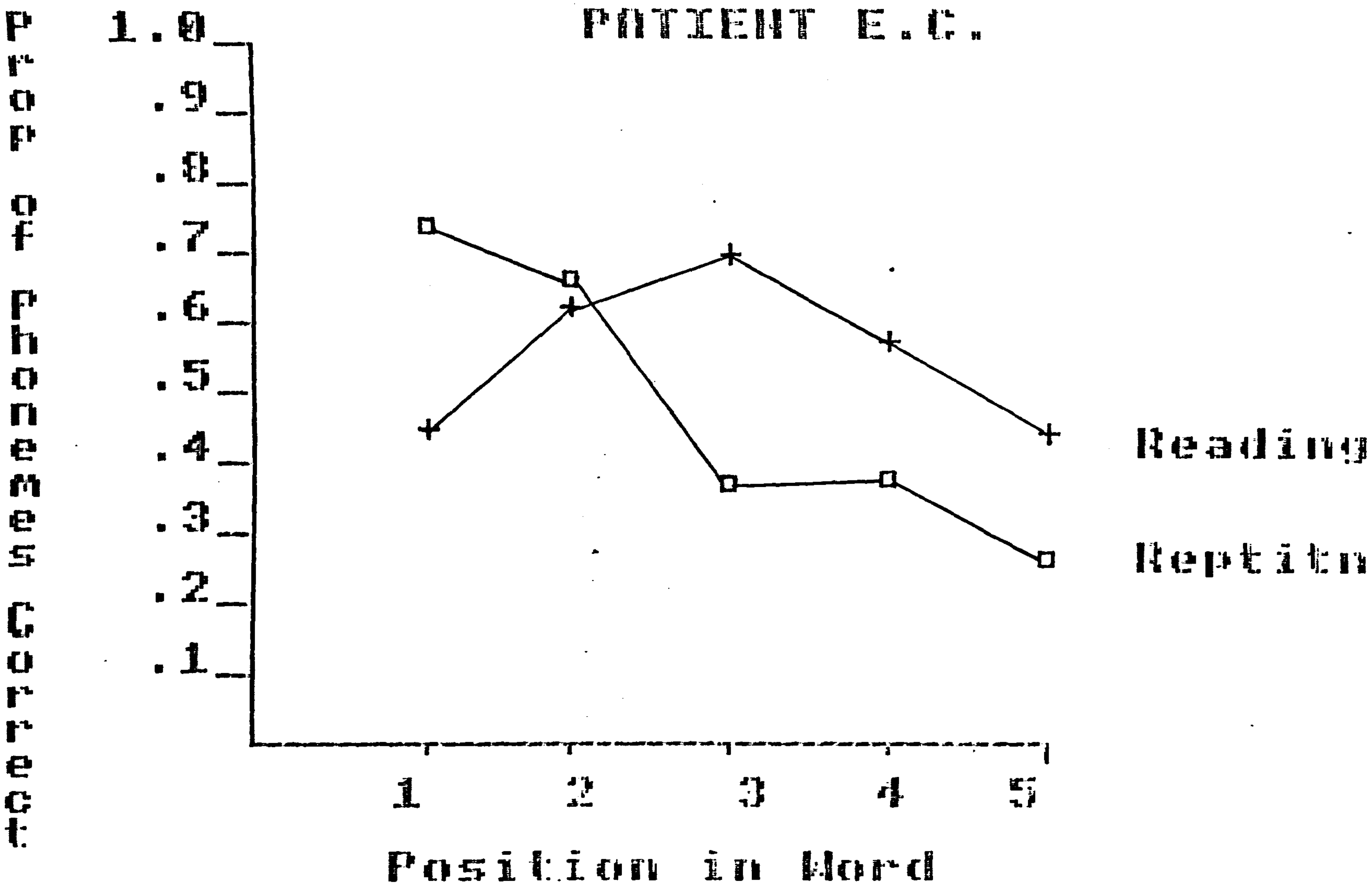


Figure 6.4: EC: position effects in reading and repetition.

significantly correlate with the occurrence of such errors in naming or reading. However, it is argued that phonologically related non-word errors reflect an impairment in phonological assembly, in the sense of being an impairment of the sub-lexical route. At least some phonologically related real word errors are due to an impairment in addressed phonology; that is, an impairment of the lexical/semantic route. Other phonologically related real word errors may be jargon homophones. An impairment in addressed phonology is associated with a preponderance of errors to shorter stimulus words and error-responses being of higher word frequency than the target items. An impairment in assembled phonology is associated with more errors to longer stimulus words, error responses of lower frequency than the target items, and errors affecting the end of words.

This "position" effect for errors of assembled phonology suggests that information being processed by the sub-lexical system is decaying fast. Does this suggest that the sub-lexical route has some association with short-term memory? The next chapter will address this issue.

CHAPTER 7: Short term memory, sub-lexical repetition and lip reading

Auditory short term memory tests obviously share peripheral processes with repetition, in that the information must be heard and articulated. Baddeley's articulatory rehearsal loop (Baddeley 1986) is otherwise not related to models of language processing, such as the logogen model (Morton 1979). There has been no reported case of a patient with impaired auditory short term memory having unimpaired sub-lexical repetition. In the previous chapter it was shown that patients' errors in assembled phonology in repetition were affected by length and the errors tended to occur at the end of the string. It would appear likely that sub-lexical repetition is in some way dependent on the auditory short term memory system. This chapter explores the relationship between sub-lexical repetition and auditory short term memory, in one patient, DRB.

It is well-known that lip reading can support auditory comprehension and immediate serial recall (Dodd and Campbell 1987); it is not clear at what point auditory and lip read information converge. Experiments with DRB will also address this issue.

7.1 Digit recall versus sub-lexical repetition

If sub-lexical repetition is dependent on auditory short term memory then performance on digit span recall should correlate highly with the ability to repeat non-words. Nineteen of the 20 patients (all except KJ) were given an immediate serial recall test, where they were given between 1 and 6 digits to repeat. There were 4 items at each length and the test was abandoned when there was 100% failure at one length. The non-word repetition test was the 20 item list already described. The fact that the two tasks share peripheral processes means that there will be a high correlation between them irrespective of whether there is a higher level relationship. However there will be the same correlation between digit span and real word repetition if it is merely attributable to peripheral factors.

Therefore the results of repetition of the 80 item imageability x frequency list were also used. The results of these three tests are shown in TABLE 7.1. (Span is calculated to the nearest number of items recalled to within .5 of an item; i.e 2/4 correct at that level.)

TABLE 7.1

REPETITION AND DIGIT SPAN (proportion correct)

PATIENT	Repetition		Digit
	Word	NonWord	Span
DI	1.00	1.00	4.5
MH	.96	.95	5.5
CJ	1.00	.80	4.0
VW	1.00	.75	4.5
EW	.99	.75	3.5
IM	.99	.75	3.0
AH	.83	.75	5.0
CL	.96	.65	5.5
FC	.86	.65	4.0
DM	.96	.50	1.5
ABa	.69	.50	2.0
EC	.37	.35	1.5
FM	.91	.30	0.5
NH	.71	.20	2.5
AD	.51	.20	0.5
ABy	.26	.10	2.0
MK	.45	0.00	0.5
DRB	.44	0.00	0.5
ES	.03	0.00	0.5

Word repetition and digit span, r = 0.673

Non-word repetition and digit span, r = 0.644

There are significant correlations between digit span and non-word repetition (r = .844) and digit span and real word repetition (r = .673); however, when the effects of real word repetition have been partialled out there is still a significant correlation between digit span and non-word repetition (F= 15.84, df 1,16 p<.005). This suggests that when one of these tasks is impaired, the other will be also, and that this cannot be wholly attributable to auditory discrimination or articulatory problems, since non-words correlate more highly than real words. This result again supports the idea that sub-lexical repetition is dependent on auditory short term memory.

7.2 DRB: Auditory Comprehension and Repetition

In the chapter on word imageability, it was demonstrated that DRB had no phonological impairment for direct auditory comprehension. (Table 7.2 gives a summary of data already presented) Although it was argued that he was impaired in comprehending abstract words, he performed at a normal level in tests of phoneme discrimination and auditory lexical decision. Unlike the word-form deaf patient, MK, he does not mistake words or non-words for other phonologically related real words, and he is no more likely to repeat

TABLE 7.2

DRB - summary of comprehension and repetition.

Phoneme discrimination tests

Same/different judgments:	40 item cv list:	.95
	cvc non-word:	.88
	cvc real word:	.94
Spoken word/picture matching:	cvc -> picture:	.90

Lexical decision

160 item list 156/160 (vis = no errors)

Synonym matching

	Spoken	Spoken->Written	Written
Hi Im	.95	1.0	1.0
Lo Im	.60	.95	.95

Repetition

Howard Image × Freq list:	Hi Im	.75
	Lo Im	.13
Syllable length list:	1 Syll	.70
	2 Syll	.67
	3 Syll	.70
Non-words:		.00

long words correctly than short ones. He is a surface dyslexic, able to read non-words, and he only makes (occasional) phonological output errors on long words, suggesting an extremely mild phonological output impairment. Despite this he is entirely unable to repeat non-words; he must therefore have an impairment between auditory analysis and phonological output. He is also unable to repeat even single digits reliably; what is the relationship between these two tasks?

7.3 Lip reading effects

DRB on many occasions stated that he was helped tremendously by lip reading (so much so that he eventually attended lip reading classes).
This seemed intriguing given that he did not appear to have any input phonological impairment, so it was decided to investigate the effects of lip reading on both repetition and comprehension. For the repetition test the 80 item imageability x frequency list from the PALPA battery was used. This is similar to the Howard list in that it comprises 20 high imageability high frequency words, 20 high imageability low frequency words, 20 low imageability low frequency words and 20 low imageability high frequency words, matched for letter length. The list was presented

three times on three subsequent days. On the first and third days DRB was not allowed to see the experimenter's face, but used lip reading on the second day. Thus it was hoped to distinguish lip reading effects from practise effects. The results are shown in TABLE 7.3. Although there <u>was</u> a practice effect, there was a much larger effect of lip reading. (McNemar Test, 2nd and 3rd presentations, $p<.001$). This was especially true for abstract words, presumably because they are more impaired to begin with.

<u>TABLE 7.3</u>

<u>Effects of lip reading</u>

1)Repetition of PALPA Image x Freq List:

	Day 1 0LR	Day 2 WLR	Day 3 0LR
Hi Im	.77	.95	.90
Lo Im	.07	.50	.17
Total	.43	.73	.53

TABLE 7.3 (cont.)

2) Comprehension of Syllable Length x Abstractness List:

	WLR	0LR
Hi Im	.94	.90
Lo Im	.30	.20

To test the effect of lip reading on auditory comprehension, DRB was asked to define (ie give a one-word association) to words he heard. The list comprised 90 high imageability and 90 low imageability words, of either one, two or three syllables. Since there was no effect of syllable length the results are collapsed across the length dimension. Half of the list was presented with lip reading, half without, and on another occasion the conditions were reversed, so presentation was controlled for practise effects. The results are shown in TABLE 7.3. Comprehension was significantly better overall in the lip read condition (McNemar Test, $p<.05$) Although lip reading helps both repetition and comprehension of low imageability words, the effect appears much greater for repetition than comprehension (.08 -> .50 versus .20 -> .30); this may to some extent be due to the fact that different tests were used. Other explanations will be considered later.

7.4 Phonological input and memory

If DRB's inability to repeat non-words relates to an inability to hold the sounds for phonological assembly, then other tasks which require phonemes to be held in real time should be impaired. For example tasks which require segmentation should be impaired, despite the fact that DRB is unimpaired in simple phoneme discrimination tests. Three tests were given which fulfilled this requirement. The first test was another taken from the PALPA battery. It comprised 2 lists each of 45 CVC strings (both words and non-words). DRB heard the string and then was shown 5 written letters immediately afterwards. With the first list he had to select the letter which corresponded to the initial sound of the string he heard; with the second list he had to select the letter corresponding to the final sound. Both lists were presented without lip reading; subsequently the second list was presented a second time and DRB was allowed to lip read. The results are shown in Table 7.4.

DRB performed fairly well on this task when he had to detect the initial phoneme, although he did make 7 mistakes. However he did make significantly more mistakes (24) when he had to select the final sound (Fisher Exact, $z=6.34$ $p<.001$). With lip reading he made fewer errors on this list but the difference was not significant.

The second test was a phonological equivalent of the "binary judgements test" described in the chapter on imageability. When DRB failed to repeat the word correctly, instead of being asked to select a synonym, he was asked to point either to the initial sound or the final sound (from a choice of two). He was impaired at selecting the initial sound (.74); when asked to select the final sound his performance fell to the level of chance (.48).

These two tests show that, despite the fact that DRB is able to do same/different judgments in phoneme discrimination tests, when he is required to segment phonemes he makes errors. This must be in some sense an impairment subsequent to auditory analysis since DRB is able to reject non-words in lexical decision even where the critical changed phoneme is at the end of the word.

The third task which requires phonological forms to be held and segmented is hearing two strings and judging whether or not they rhyme. DRB was given a 60 item

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TABLE 7.4

"Segmentation" tests.

1) Phoneme segmentation - PALPA TESTS:

Initial sound	.84
Final sound	.46
Final sound with LR	.58

2) Binary phonological judgements:

Initial sound	.74
Final sound	.48

3) Rhyme Judgments:	Spoken	Written
Correct	43/60	46/60
Errors (N=15 pairs/condition)		
Not orth. not phon.	3	4
Orth. not phon.	9	10
Phon. not orth.	2	0
Phon. and orth.	3	0

rhyme judgment test in both the spoken and written form. Of the thirty pairs which rhymed, 15 were orthographically similar (e.g. cream - team) while 15 were not (e.g. come - sum); of the thirty pairs which did not rhyme, 15 were orthographically similar (e.g. foot - boot) and 15 were not (e.g. wine - crane). The results are shown in TABLE 7.4. DRB was impaired, and with a similar pattern of performance, on both the written and spoken forms of the test.

7.5 Sub-lexical repetition and short-term memory: a model.

If DRB has no phonological impairment in direct comprehension, but is impaired in holding phoneme strings, is this the same impairment which makes it impossible for him to repeat non-words? A model of auditory short term memory (after Monsell 1987) is shown in Figure 7.1. If such a system, comprising a phonological input store (PSTS) and a phonological output store (or response buffer) and their connecting pathways, is also the system partially utilised by sub-lexical repetition, it would be possible to explain these results as well as the lip reading ones. Direct comprehension as well as lexical decision is carried out from auditory analysis (without any requirment to hold information at this level) via the auditory input lexicon to the semantic system. This is unimpaired for DRB until after lexical access; real word repetition may also use this system. Non-words will be repeated from acoustic analysis through the phonological short term memory store (where the input information may have to be held and "parsed" in order for output phonology to be available) to the response buffer via the connecting pathway (see Figure 7.1). Since DRB's impairment is not at the level of acoustic analysis or in the response buffer, it must be either in access to the PSTS, in the PSTS itself or in the rehearsal loop. The fact that he is impaired at segmenting even short strings would suggest that he is impaired at the level of the PSTS or the access to it.

According to this model lip reading information accesses the PSTS directly, so would improve performance substantially if the impairment were one of access, or if it was under-specification in the PSTS which was enriched by information coming from another source. Since DRB appears to have no problem with lexical access, then lip reading should not improve direct access to the semantic system, but should only improve sub-lexical processing. This would explain why there is a much smaller effect of lip reading for comprehension than for repetition.

In an attempt to provide further support for this model the effect of lip reading on short term memeory tasks and on non-word repetition was investigated.

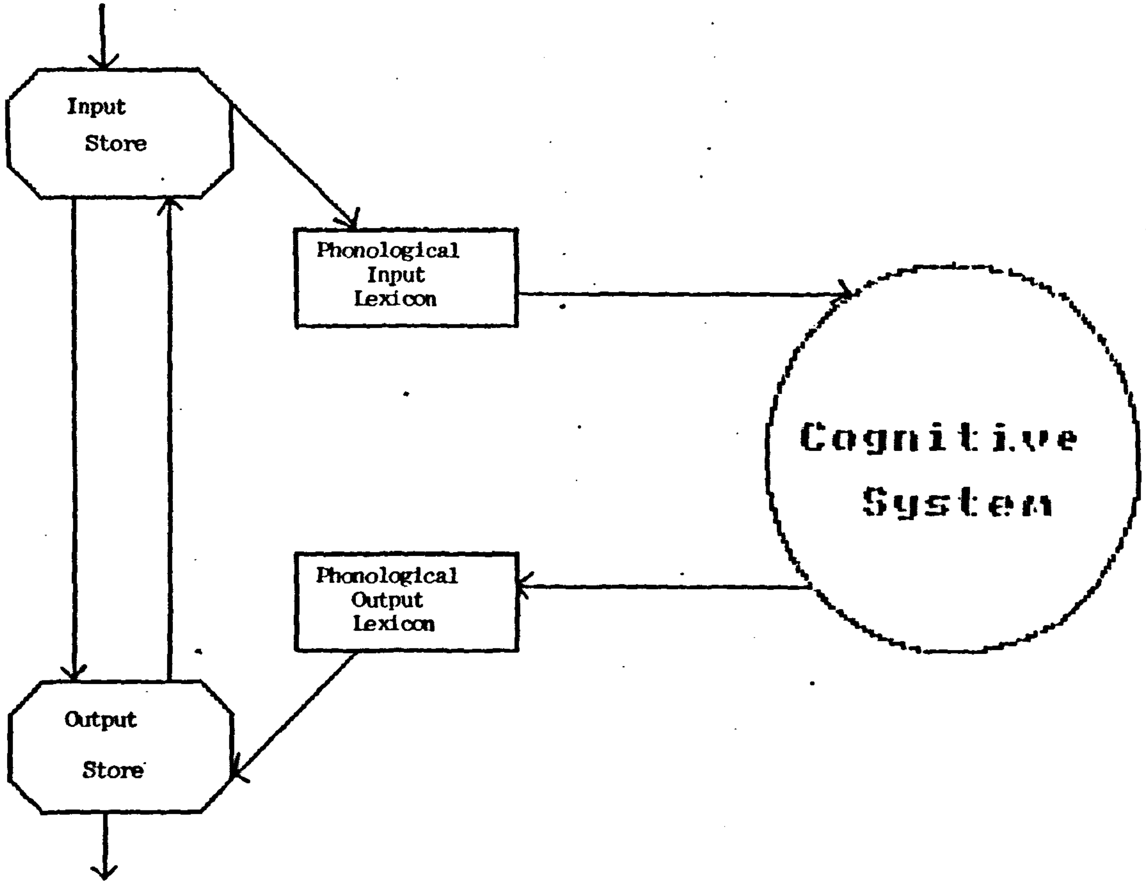


Figure 7.1: A model of short-term memory.

7.6 Lip reading, short-term memory and repetition.

Lip reading and digit repetition

DRB was asked to repeat strings of digits in three conditions; where he heard the digits but could not lipread, where he both heard and lip read them and where they were silently mouthed to him so that he was only getting lip read information. If lip reading is helping repetition via the assembled route, and if the assembled route is also the short term memory system, then it follows that lip reading should improve digit repetition.

The results are shown in TABLE 7.5. Digits were only considered correct if recalled in the correct order. Even on the heard only condition he repeated a high proportion of digits correctly, considering he cannot repeat one reliably. As predicted, the lip read conditions differed significantly from the heard only condition (χ^2 (2) = 6.00, $p<.05$), supporting the model and giving further weight to the argument that the impairment is pre-rehearsal loop.

Lip reading and matching span

If DRB's impairment is in the PSTS or the access to it,

TABLE 7.5

STM and Lip Reading

1) 3-Digit strings: digits correct 0LR = 96/180
only LR = 117/180
both = 114/180

2) Matching span for letter strings: prop. correct.
(N = 20)

	3 letter	4 letter
0LR	.65	.55
WLR	.85	.60

3) Phonological similarity effects: letters correct.

	Similar	Dissimilar
Auditory presentation		
(3 - letter)		
Without lip reading	25/150	30/150
With lip reading	40/150	71/150
Visual presentation		
3 - letter	30/30	30/30
4 - letter	31/40	33/40
5 - letter	34/50	34/50
6 - letter	34/60	28/60
TOTAL	129/180	125/180

then not only recall tasks but also matching span tasks will be impaired, and of course they should be helped by lip reading. He was given pairs of strings of 3 and 4 letters, half of which were identical while the other pairs differed, but only by order changes. The test was given both with and without lip reading.

The results are shown in TABLE 7.5. DRB is very impaired at this task: without lip reading only 65% correct for 3 letter strings and no better than chance for 4 letter strings. Performance improved when DRB was allowed to lip read, but mainly for three letter strings.

Phonological similarity effects

A property of the phonological input store is that phonologically simialr items interfere and are less well recalled (Baddeley 1986). This is even true for items presented in written form. If DRB's impairment is in access to the phonological input store, then his recall of auditorily presented letter strings will be severely impaired without lip reading. Performance should be better, with an effect of phonological similarity, for both auditory presentation with lip reading and for visual presentation. If the phonological input store itself is impaired, then there will be no phonological similarity effect for recall of visually presented strings.

DRB was given 80 3-letter strings for repetition, half of which comprised phonologically similar items; half were phonologically dissimilar. The strings were presented once with lip reading and once for audition only. Three, 4, 5 and 6 letter strings (10 phonologically similar and 10 phonologically dissimilar at each length) were presented visually, requiring a written response. The results are shown in TABLE 7.5.

There was no effect of phonological similarity for the heard only condition - but this is hardly surprising since his performance was so poor (.18 probability of individual letters being correct). With lip reading, there was an effect of phonological similarity (Fisher Exact Test, $z=3.58$, $p<.001$). He was better still at visual recall, but showed no effect of phonological similarity, suggesting he was not using phonological recoding to support recall. These findings suggest that there is some impairment both in access to the PSTS and in the PSTS itself.

Lip reading and non-word repetition

If lip reading improves word repetition because it improves assembled phonology then it should also improve non-word repetition. DRB was asked to repeat 50 non-words of between 3 and 5 phonemes in length, with and without lip reading. The results can be seen in TABLE 7.6 He repeated no items correctly without lip reading and just 4 with lip reading. When the number of phonemes correctly repeated is considered, there is a much greater difference; only 3% are correctly reproduced without lip reading, whereas about half are repeated correctly with lip reading.

TABLE 7.6

Non-word repetition; the effect of lip reading

	non-words correct	phonemes correct
0LR	.00	.00
WLR	.03	.49

While there is clearly a large effect of lip reading, non-word repetition is still extremely poor even with lip reading and considerably worse than real word repetition. This means that for real word repetition either the sub-lexical route itself has an advantage for real words over non-words, or that both routes are being utilised.

Lip reading and word length

MK, whose errors are ones of addressed phonology, is better at repeating longer words than shorter ones; EC, whose errors are of assembled phonology, is better at repeating shorter words than longer. Without lip reading DRB shows no length effect in repetition. What happens with lip reading? DRB was asked to repeat, both with and without lip reading, the list of 180 words of one, two, and three syllables that he had been asked to define earlier.

TABLE 7.7

Lip reading and syllable length:

	1 syllable	2 syllable	3 syllable
0Lip Reading	.70	.67	.70
WLip Reading	.93	.83	.73

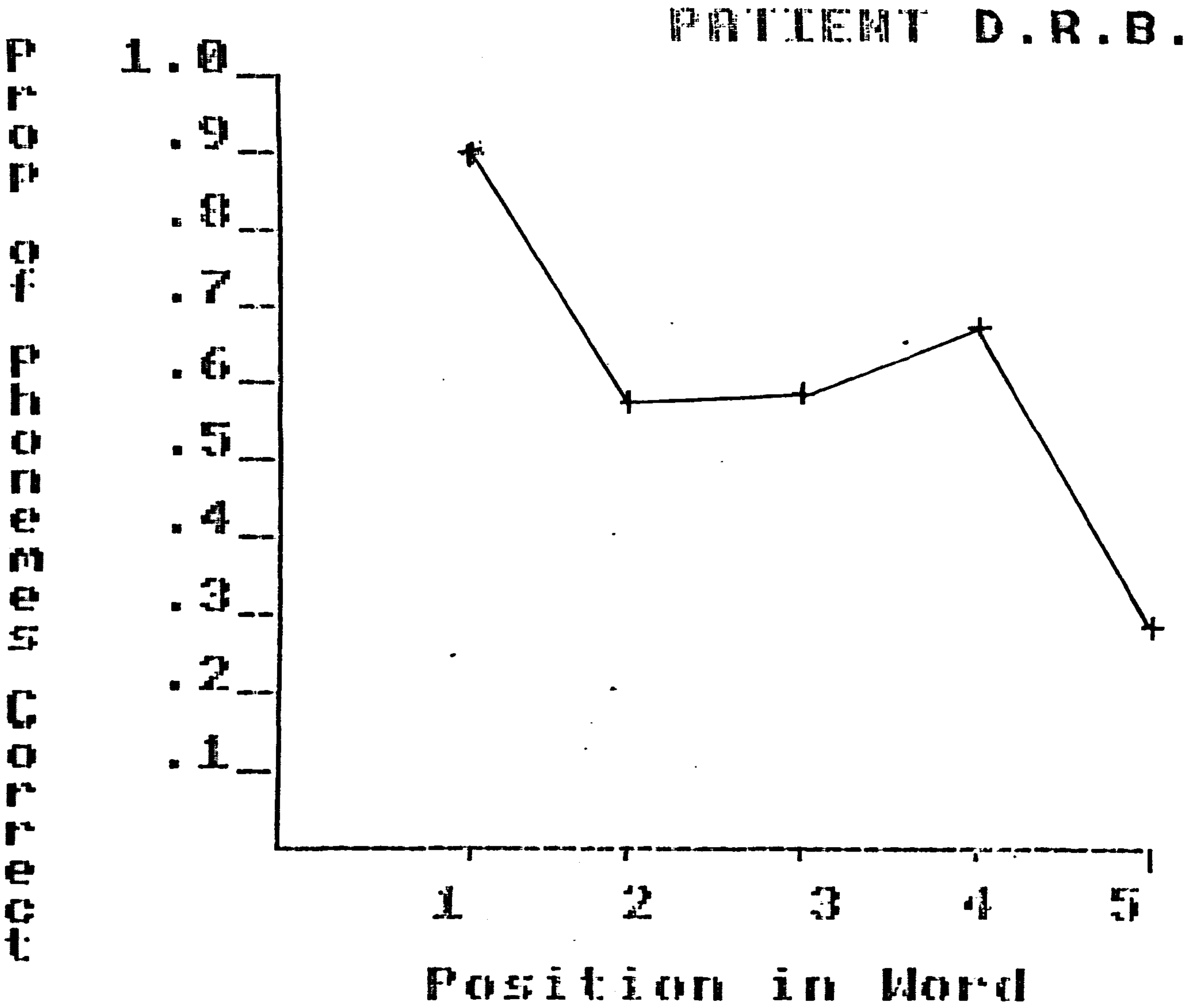


Figure 7.2: DRB: position effects in repetition. (Non-word repetition with lip reading.)

The results are shown in TABLE 7.7 There is again no effect of length without lip reading; with lip reading, 3 syllable words are repeated as poorly as all words without lip reading; however, the shorter the words, the more likely they are to be repeated correctly (Jonkheere Trend Test, z=1.89, p<.05). Thus with lip reading, DRB's performance shows an effect characteristic of EC, and of assembled phonology.

Position effects in non-word repetition

The other characteristic of EC's repetition was that phonemes at the ends of words were less likely to be repeated correctly than phonemes at the beginnings of words. DRB's errors on the fifty item non-word repetition test, where he had been allowed to lipread, were analysed for position effects. Serial position was assigned in the way described in the previous chapter. The results can be seen in figure 7.2. There was a significant effect of position (Jonkheere Trend Test, z=1.83, p<.05).

7.7 Lip reading, articulatory suppression, and writing to dictation.

DRB's writing to dictation appears, like his repetition, to rely on the semantic route, since he makes errors which are semantically related to the target and makes more errors writing words of low imageability than words of high imageability. As with repetition, DRB is entirely unable to write non-words to dictation; he scores 0/20 on the 20 item list.

TABLE 7.8

The effect of lip reading and articulatory suppression on writing to dictation.

TOTAL CORRECT (n=30 per cell)

		1 syl	2 syl	3 syl	Total
Neither	Hi Image	21	17	9	47
	Lo Image	3	1	1	5
	Total	*24*	*18*	*10*	*52*
A.S.only	Hi Image	17	16	7	40
	Lo Image	0	0	1	1
	Total	*17*	*16*	*8*	*41*
A.S.+L.R.	Hi Image	22	18	10	50
	Lo Image	4	2	3	9
	Total	*26*	*20*	*13*	*59*
L.R.only	Hi Image	26	21	12	59
	Lo Image	12	1	5	18
	Total	*38*	*22*	*17*	*77*

I have argued earlier that sub-lexical writing to dictation is dependent on prior access to a phonological output store. Assuming that DRB has an intact "phonological to orthographic conversion system", that is he is able to convert sub-lexical output phonological information to sub-lexical orthographic output, then his writing to dictation should also improve with lip reading. If this improvement is indeed attributable to an improvement in the sub-lexical routine then it will require processing space at the level of output phonology; therefore the improvement in performance with lip reading will be reduced if articulatory suppression is introduced.

To investigate the effects of lip reading and articulatory suppression on DRB's writing to dictation, the 180 item list of high and low imageability words of 1, 2, and 3 syllables was used. It was presented (in a Latin square design) under four conditions: with neither lip reading nor articulatory suppression, with articulatory suppression, with lip reading, and with both articulatory suppression and lip reading. For the conditions with articulatory suppression DRB continuously counted from 1-3, sub-vocally but with lip movements so that the experimenter could ensure that it was continuous. The results are shown in TABLE 7.8.

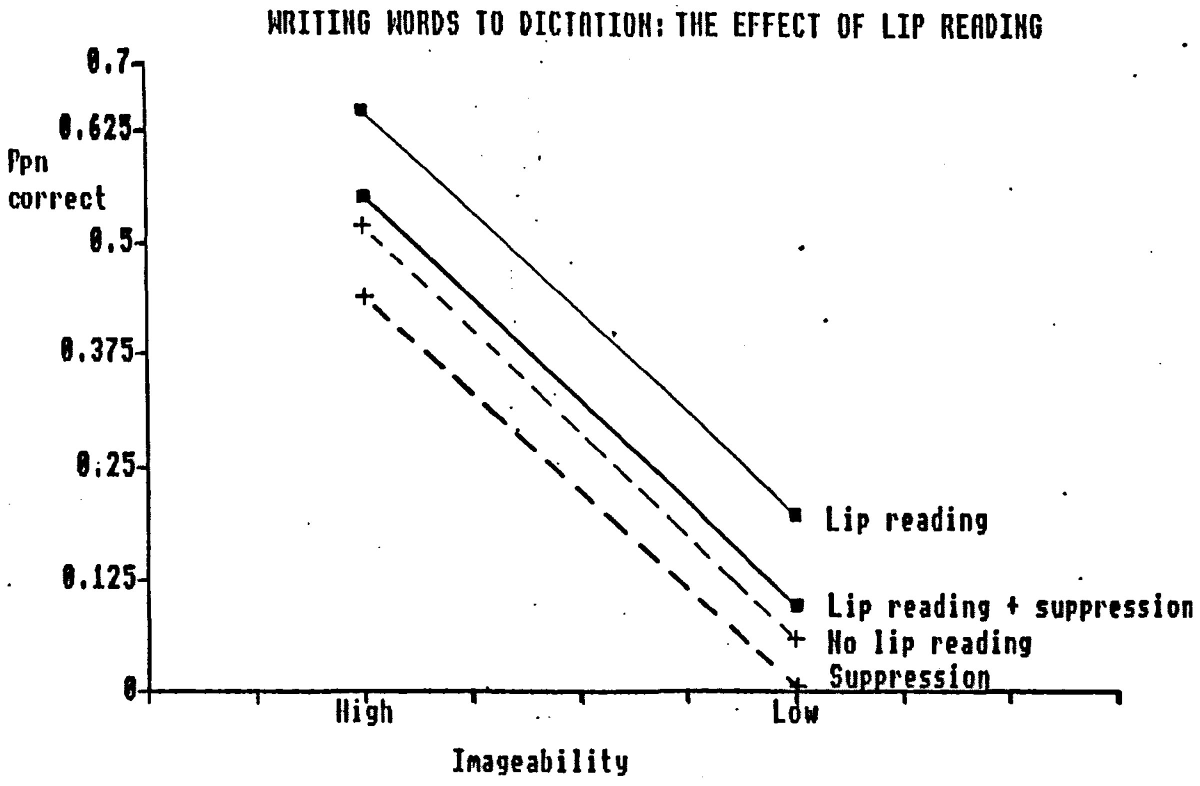


Figure 7.3: DRB: effects of articulatory suppression and lip reading on writing to dictation.

As predicted, DRB performs better in the lip reading conditions than the conditions where he is not allowed to lip read (137/320 vs 93/320, McNemar Test, z=4.11, p<.001). The fact that his writing does, to some extent, depend on assembled phonology is indicated by the overall superior performance without articulatory suppression (129/320 vs 100/320, McNemar Test, z=4.08, p<.001). The interaction between lip reading and articulatory suppression fails to reach significance (see Figure 7.3). For all conditions there is a clear effect of length; this can be entirely attributed to slight spelling errors. The fact that lip reading is not improving performance vis the semantic route is confirmed by the fact that the size of the imageability effect stays constant under all conditions. The proportion of semantic errors also stays constant, irrespective of lip reading (15/53 vs 24/87).

7.8 Lexicality effects in auditory short term memory.

To investigate whether DRB's performance in recall was better for words than non-words, he was given a probe task where he heard a string of words (or non-words), and then heard two of these words again; he had to judge whether the probe words were in the correct order. Two sets of list were given; one comprised three real words, where half the strings were highly imageable and half were low imageability words, matched for frequency and length. The other lists were of three non-words which were constructed to be the same length (phonemes and syllables) as the real words. If there is lexical support for his short-term memory (as one might expect in the light of his intact phonological lexicons) then he should be significantly better at the task with real words than with non-words. If this lexical support is occurring at an input phonological level, then performance for the real words will be constant irrespective of imageability. Since he is unable to produce any output for most low imageability words, if lexical support is occurring at an output level then there will be a significant difference in performance between the high and low imageability lists.

In fact, he was entirely unable to do the task with non-words and it had to be abandoned. With real words he scored 53/80, which was better than chance (binomial test, $z=2.79$, $p<.005$). Eleven of the errors were with high imageability words, 17 with low imageability words, which is a large but (possibly because of the small number of items) not significant difference (Fisher Exact Test, $z= 1.41$, ns.) but which contrasts with the extremely large imageability effects in other tasks. DRB was at chance on the items which required knowledge of the middle item in the list. It is therefore not possible to conclude definitely that he is using lexical information to support knowledge of order in the short term memory system.

DRB is unable to repeat non-words; this is not attributable to an impairment in auditory analysis or phonological output, but must rather be an impairment within the sub-lexical route. The findings in this chapter suggest that this is the same impairment which causes him to have severely impaired immediate serial recall. The fact that he performs poorly on tasks requiring segmentation, and that his immediate serial recall improves with lip reading, suggests that the impairment is at the level of the phonological input store. This is confirmed by the fact that there is no phonological similarity effect for visually presented letter strings, and with auditorily presented strings there is only a phonological similarity effect if DRB is able to lip read.

Lip reading also improves his single word repetition, but it is shown that the improvement is due to an improvement in the sub-lexical, rather than the lexical semantic route. Thus with lip reading, there is a phoneme length effect in word repetition, and a reduced number of semantic errors. Lip reading also improves DRB's non-word repetition, and his (real word) writing to dictation.

The final experiment reported suggests that the lexical system is able to interact with the auditory short term memory sytem, since there is an advantage for real words over non-words in probe span tasks. Further the lack of a significant effect of word imageability in these tasks suggests that this interaction must be at an input level. These findings will be discussed in more detail in chapter 9.

CHAPTER 8: Discussion.

8.1 Levels of impairment in comprehension

It was shown in chapter 3 how different patients' problems correspond to different levels of impairment. ES has a severe problem at the level of auditory analysis ("word sound deafness"), while 14 of the patients tested have no impairment at this level, and are able to discriminate phonemes as well as normal controls. Three of the patients who are not impaired at the level of auditory analysis (EC, AH and MK) are impaired at the level of word-form access ("word-form deafness"), while 10 patients show no impairment at this level.

These patients with no auditory input impairment themselves show different types of semantic impairments. For example, DRB is impaired in accessing meaning when words are presented auditorily, but has no such impairment for written words indicating he has a "word-meaning deafness". C.J. is equally impaired in accessing meaning in both modalities, which suggests he has a central semantic impairment. DI is impaired in both modalities, but only for low imageability words, suggesting a central abstract semantic impairment.

It is interesting to note that while patients may share the same symptom, there is no obvious way in which symptoms cluster into syndromes; what is striking is the very diversity of symptom complexes shown by these patients. Consider, for example, the three "word-form deaf" patients. E.C. has no severe semantic impairment, unlike AH and MK; MK is significantly worse at spoken than written synonym matching whereas AH is equally bad at both. EC is impaired in repetition, but her errors are closely related to the target items, her repetition of real words is as poor as her repetition of non-words and her poor repetition is most simply accounted for by an impairment in output phonology which also affects oral reading and naming. MK is completely unable to repeat non-words (because of an impairment in acoustic to phonological conversion), is better though still poor at repeating real words and is clearly using a semantically mediated route for real word repetition since he makes semantically related errors. AH is able to repeat a high proportion of both real words and non-words.

Different types of comprehension impairment are seen in different patients. Patterns of impairment are extremely diverse across the group. Clearly traditional theories such as those described by

Goodglass and Kaplan (1972), which only differentiate between comprehension impairments with or without repetition impairment, are woefully inadequate.

Performance on auditory lexical decision was not predictive of performance on written lexical decision. Of the nine patients who were impaired at the auditory version of this task, five were significantly better at written lexical decision, two were better at spoken and two were equally impaired in the two modalities. Auditory word-form access is independent of visual word-form access, and a patient with either word-sound deafness or word form deafness may or may not also have an impairment in visual word-form access.

By definition, a patient with word meaning deafness (such as DRB) will have better access to semantics from the visual word form, whereas a patient with a central semantic impairment (such as CJ) will be equally impaired in both modalities. The model predicts that there should be a visual analogue to word meaning deafness, where auditory comprehension is normal, access to the written word-form is also normal, but semantic access for written words is impaired. H.R.M., a deep dyslexic patient (Howard 1985), performed normally on visual lexical decision tasks but was impaired on word to picture matchng tasks such as the Peabody Picture Vocabulary Test (Dunn 1965), while performing normally on the spoken version of this test.

There are thus patients who are worse at word-form access or more peripheral processing for auditory input, and others for visual input. The same dissociation applies for tasks which access meaning, but there are also a proportion of patients whose semantic impairment affects both modalities.

Only ES had a severe word sound deafness. As predicted, he was extremely poor on the lexical decision and the synonym matching tasks. Real word repetition was as poor as non-word repetition. In the CV phoneme discrimination task ES was equally bad at discriminating phonemes which differed by three distinctive features and phonemes which differed by one distinctive feature. Equally, in the CVC phoneme discrimination test, his errors followed no pattern in terms of the site of contrast or the type of feature which was contrasted. This may be a reflection of the severity of the impairment; or it may be an artifact due to the extremely high rate of false positive errors he made on both phoneme discrimination tests. It is thus not possible to make any inference about the underlying mechanisms of his discrimination impairment.

8.2 Accessing lexical information

In Morton's "logogen model" (1979, 1970) logogens are transcoding devices to make possible the generation of an abstract code which can map onto semantics and output phonology. Logogens are information gathering devices which have to reach a threshold level of activation before any activation can occur at a subsequent level. However, Morton specifies that information can feed down from the cognitive system to the input logogens to account for context effects in recognition.

Other models allow partial activation to map onto higher levels of processing; some, such as TRACE, also allow for activation between levels which, as in the logogen model, results in top down processing (McClelland and Elman 1987). "Feed-forward cascade" models are purely bottom up models where context effects are explicable in terms of partial activation and within level interaction. (Norris, 1982)

In terms of impaired auditory comprehension clearly very interactive models will predict that an impairment at one level will result in multiple types of errors;

it is not clear whether this is also true of cascade models. In this section lexical access impairments will be reviewed to see whether there is a characteristic pattern of lexical access deficit, whether this is clearly dissociable from other auditory comprehension impairments, and which type of model, logogen, interactive activation or feed-forward cascade best fits the neuropsychological data. Since, traditionally, lexical access has been tested using a lexical decision task, it is appropriate also to ask exactly what levels of processing are required in this task.

8.3 Lexical decision - what is it testing?

Lexical decision minimally requires that information accesses word forms in the lexicon; but since normals' performance in lexical decision for low frequency words is affected by imageability, and since several deep dyslexics (Rickard 1986) as well as MK (Howard and Franklin 1988) are worse at lexical decision (with written and spoken words, respectively) if they are of low imageability, it seems at least worth considering the notion that lexical decision involves semantic as well as lexical access. It must be remembered that lexical decision is a metalinguistic task, where the subject is being asked to make a very conscious decision; this is presumably not a feature of normal speech processing, where the requirement for understanding has the effect of enhancing stimuli which do not quite correspond to known words to a point where they are actually perceived as real words. It may be that if lexical decision does literally require some sort of "conscious" decision this is only possible if some meaning has been accessed.

Superficially it would seem that lexical decision is possible without semantic access because there are cases of patients with either a central semantic impairment or a semantic access impairment who have unimpaired lexical decision ability. DRB (chapter 3) has entirely normal ability on lexical decision tasks. This is even true for low imageability words which he has difficulty comprehending. Further evidence that DRB is carrying out lexical decision entirely on the basis of lexical access might appear to come from the fact that, when trying to repeat words that he is able to judge as being real words, he makes a large number of "no response" errors. This perhaps suggests that he is obtaining no semantic information, a notion further confirmed by the fact that he judges low imageability words to be real words while reporting that he is not aware of having heard anything.

However, the binary semantic judgments test actually revealed that he did have some information about those low imageability words that he was completely unable to repeat; either this is partial information which is insufficient for output (this seems likely since the same task with a semantically related foil would be much more difficult for him), or it is a function of his abstract word anomia. If he is getting some information to the semantic system, this might enable accurate lexical decision on a semantic basis; he doesn't have to have accessed the complete correct meaning, just some meaning in order to judge that it is a word.

So despite the apparent dissociation, these patients do not show that a lexical decision impairment is independent of a semantic impairment. Such a conclusion is warranted however if patient MK is considered. I have argued in Chapter 4 that MK has a central semantic deficit (at least for abstract words). MK is impaired in lexical decision tests, despite the fact that in repetition, he does not make the large number of no response errors that DRB makes but rather makes a large number of real word errors of various types which show that some semantic information has been accessed. More significantly, despite his central semantic impairment, affecting written comprehension as well as auditory comprehension, MK performs entirely normally on written lexical decision. This means that his auditory lexical decision problem cannot be attributable to semantic impairment; and since I have argued that he has no impairment of phoneme discrimination, he must have a specific impairment in accessing lexical forms.

8.4 The properties of word-form deafness

As well as poor performance in auditory lexical decision, MK has several other symptoms indicative of word-form deafness. MK and DRB have similarly affected repetition in that they do not use a sublexical repetition route, make semantic errors in repetition and are worse at repeating low imageability words. MK, however, shows a number of additional features not present in DRB's pattern of performance. He is impaired at matching spoken words to pictures when phonologically related foils are present; he tends to define words with definitions appropriate to a word phonologically related to the stimulus word; he makes a large number of phonologically related real word errors in repetition; and he is better at repeating longer words than shorter ones. EC and AH are also word form deaf and they are also impaired at spoken word to picture matching when phonologically related foils are present. However they do not show the same types of repetition impairment; this is because they are both able to use the sublexical repetition route to some extent. If their impairment is similar to that of MK's one would predict that they would have a reverse word length effect for auditory comprehension, but this has not been tested.

8.5 Visual/phonolological errors in "deep" impairments

In deep dyslexia, as well as semantic errors, one of the cardinal features of oral reading is the presence of visual errors (e.g. OWN -> "now"). The obvious explanation for visual errors is an impairment in accessing the lexical form, as I have suggested is the case for MK in the auditory modality.

In Morton and Patterson's 1980 paper two deep dyslexics, PW and DE, are described. Like MK in the auditory modality, DE makes a substantial number of errors in visual lexical decision, so it is not surprising that he also makes a substantial number of visual errors in reading aloud. What is much more surprising is that PW, who was tested on a wide range of stimulus sets, performed normally on visual lexical decision tests, but still made "visual errors" in reading. Morton and Patterson suggested, within the framework of the logogen model, that when a word-form fails to access a meaning, then the subsequent lowering of thresholds at the level of visual input logogens would on some occasions lead to the meaning of a visually related word being accessed. This phenomenon could also be accounted for by the access being highly interactive, which would mean that an impairment at one level would tend to produce a multiplicity of error types.

If this were the case, then for semantic route repetition or reading, where a proportion of the errors are semantically related, one would predict the co-occurence of visually (in the case of reading) or phonologically (in the case of repetition) related errors.

However, DRB clearly does not show this pattern, as indicated by a comparison of his and MK's errors in repetition. They both have classic "deep" type problems in repetition: they both make more errors on low imageability/abstract words, make semantic errors and are unable to repeat non-words. Table 8.1 shows the number and types of errors they make on the Howard Imageability x Frequency list; this is typical of their performance in repetition. MK makes 44 errors, DRB makes 45, and they both make a small proportion of semantic errors. However by far the largest proportion of errors in DRB's case are errors where he fails to respond, whereas MK's errors are mostly

TABLE 8.1

Repetition of Imageability x Frequency List:

Error Types.

	D.R.B.	M.K.
No response	33	0
Phonologically related words	3	14
Phonologically related non-words	2	2
Semantically related words	4	4
Unrelated words	3	24

phonologically related real word errors and unrelated word errors; Howard and Franklin (1988) argue that his unrelated word errors are a mixture of perseverative errors and possible multiple phonological and semantic errors. DRB makes only 3 phonologically related real word errors; and since he also makes 2 phonologically related non-word errors, and since all these words are of short length , it is likely that the real word errors are actually "jargon homophones" and attributable to output problems. It was demonstrated in chapter 4 that he did have a slight phonological output impairment. Neither does he make many mixed errors; he only made 3 unrelated real word errors which were:

summer -> today
span -> saw
late -> liver

The second error is a possible phonological + semantic confusion (via "spanner"?).

There is thus no indication that DRB is making any phonological input errors. Phonologically related real word errors in repetition appear to reflect a problem in accessing the correct word-form; such errors do not entail threshold lowering or between level interaction. Is this reconcilable with the data on PW's reading errors? In the corpus of his reading errors given in the appendix to "Deep Dyslexia" (Coltheart et al 1980) there is no distinction made between visual (= input errors) and phonological output errors. Of the 44 errors given, only four are unambiguously visual errors:

WAS -> "wait"
MOMENT -> "money"
ORATE -> "over"
SAID -> "and"

Since the total number of visual/phonological errors is reported as 13% of the total number of errors (Patterson 1978), even if only a proportion of the ambiguous errors are actually output errors, then the number of visual errors he makes is very small (although there are also 7 examples of visual + semantic errors).

If the corpus of DE's reading errors is considered, then 17 of the 86 visual/phonological errors he makes are unambiguously visual rather than phonological errors, which is 20% of the published corpus, as opposed to PW's 9%.

While it is impossible to discount entirely the notion that some of PW's errors are visual ones, it certainly seems possible that their number has been much over-estimated. Over the deep dyslexia literature as a whole, there is a wide variation in the percentage of visual errors in reading (Shallice and Warrington 1980), and in so far as the relevant data are given, then it is only those patients who make errors in visual lexical decision who make a large number of visual errors in reading (eg GR: Marshall and Newcombe, 1966, and AR: Warrington and Shallice, 1979).

8.6 Evidence for between levels interaction?

In the spoken word to written word test of semantic judgments with phonological and semantic foils, the fact that EC and MK, two of the "word-form deaf" patients, did on some occasions choose the phonological foils suggests that the written words are biasing lexical selection. This is because one would not expect by chance that the word-form incorrectly accessed in the lexicon would happen to be related to the foil chosen in the test. (This is equally true for the spoken word to picture matching test with phonologically related foils, where the word-form deaf patients EC, MK, and AH all made substantial numbers of errors.)

In Chapter three I argued that if "top-down" processing were causing the biasing towards a particular "phonological" error, then more such errors should occur when the written information is presented first. A model with multiple outputs from the auditory input lexicon to the semantic system predicts that there will be an equal, and large number of "phonological" errors irrespective of order of presentation.

The fact that, for both MK and EC, the number of "phonological" errors remained constant, irrespective of whether the spoken or written word was presented first, indicates that the "top-down" processing explanation is not tenable, since it requires the first word to be presented to the better modality. In order for written information to help auditory comprehension, even after the spoken word has been presented, it must be possible for partial information to access information at a higher level.

8.7 Semantic Organisation

All patients who are deep dyslexic, i.e. make semantically related errors in reading, make more errors on words of low imageability than words that are rated as being highly imageable (Coltheart 1980a). This leads on to one of four possible conclusions:

1) That in a single semantic system, lower imageability words are more "difficult" and therefore more susceptible to damage.
2) As in 1), but the normal system does not work in a sufficiently specific way to distinguish between words of similar meaning in the absence of any disambiguating phonology.
3) There are two separate systems, one for concrete words and one for abstract words and the latter is damaged in deep dyslexia.

4) There are two semantic systems, one for visual information, one for verbal information; the verbal information system is damaged, but the visual system is directly accessible from the lexicons.

What is the evidence for each of these?

1) Imageability is an index of difficulty

Data from the 20 patients described in this study support the first proposition very well. Thirteen patients make significantly more errors on low than high imageability words in tests of auditory comprehension, and every patient makes numerically more errors on the low imageability words even when the difference is not significant. Three patients are significantly worse at repeating low imageability than high imageability words; none shows the reverse effect.

The notion that imageability is an index of difficulty in the normal system receives support from the study by James (1975) where he reports that normal subjects in a lexical decision task have slowed reaction times for abstract words of low frequency. This study has been criticised on the grounds that word-familiarity was not sufficiently balanced, but the study has been replicated in a better controlled experiment by Anne Edmundsen (personal communication), and precisely the same interaction was found.

The strongest support for the notion that low imageability words are more difficult is the modality specific effect shown by patient DRB, which is described in Chapter 4. DRB's performance in tests of auditory comprehension, repetition and writing to dictation all show an extremely robust effect of word imageability whereas his written comprehension is at a normal level. There are two possible explanations for this. One is that his ability to map lexical to semantic information is impaired in the auditory modality, but the semantic system itself is unimpaired. The other would be that the semantic system itself is impaired (especially in the case of words of low imageability) and the more temporary nature of the auditory trace (after all DRB does have an impairment of auditory short term memory) does not allow for extra activation, whereas the written form can be used for repeated attempts at access.

There are two problems for the latter explanation. One is that the patient MK, who like DRB has no deficit in written lexical decision, is impaired in comprehending written words of low imageability, and is therefore unable to benefit from repeated access. More importantly, DRB also has an impairment in naming abstract words. I have argued this on the bases (1) that he is unable to read abstract words via the semantic route despite being able to comprehend them; (2) that his repetition is worse than his auditory comprehension of the same words; and (3) that he is worse at category naming for abstract words than a matched control. An "abstract anomia" cannot be explained in terms of a fast-disappearing auditory trace, but must rather be an impairment of the mapping from the semantic system to the phonological output lexicon. That these are modality specific (rather than central semantic) impairments is further supported by the fact that there is no item consistency in repetition, once the relevant word properties have been taken into account.

How can a word imageability effect be modality specific? According to the "difficulty" theory, an access deficit will produce less specification in the semantic system, and because low imageability items require more activation/greater specification, they will tend to be more prone to error than high imageability items. Alternatively a modality specific imageability effect would be compatible with proposals 3 and 4 which will be considered shortly.

2) Abstract words require disambiguating phonological information.

In work on deep dyslexia, there has been a long running debate about whether semantic access from written input produces meanings insufficiently specified to produce the correct word, unless some output phonology is available (via a non-semantic route). This, it could be argued, is why semantic errors occur in deep dyslexics; they represent the non-specific information accessed when such additional output phonology is not available (Newcombe and Marshall, 1980). This has always been a rather unconvincing theory, since deep dyslexics' semantic errors tend not to be synonyms, which is what one would predict from this theory, and indeed some of the errors are quite distant from the target in meaning (Coltheart 1980b). The fact that DRB and MK are not anomic for concrete words, but do produce semantically related (non-synonymous) errors in repetition of concrete words indicates that such errors cannot always be attributed to an output anomia.

It seems more likely that, for semantic errors to occur, there needs to be an impairment to the semantic route <u>and</u> a severe impairment of the sub-lexical route. Partial phonological information will otherwise inhibit production of the semantic error which will be phonologically dissimilar from the target.

It is not only patients who make semantic errors in repetition who show an imageability effect. The three patients described earlier who make semantic errors in repetition (ES, MK and DRB) are all completely unable to repeat non-words, and indeed give no indication of being able to repeat by anything other than the semantic route; this suggests that they are unable to edit out semantic errors using phonological information. E.C., however, is worse at repeating low imageability words (as well as comprehending them) but never makes semantic errors in repetition, despite making semantic errors both in auditory comprehension and naming. Since she must know enough about the phonology of the target word to avoid making semantic errors, the fact that the imageability effect still remains suggests that it cannot be attributable to an undamaged semantic route which is merely suffering from a lack of disambiguating phonology.

3) Separate concrete/abstract systems.

The modality-specific imageability effect shown by DRB would be equally explicable with a model postulating separate systems for concrete and abstract words. In this case DRB would simply have an impairment between the phonological input/output lexicon(s) and the abstract semantic system. More importantly, this would provide an account which allowed for concrete words to be more impaired than abstract words. Warrington has reported three such cases (1975, 1981, Warrington and Shallice 1984).

Although there are methodological problems with all these reports (for example very small data sets, word lists which are not matched for all relevant properties and rather subjective criteria for acceptable definitions), the fact that three cases have been described with this symptom means that a unitary system, where complexity = imageability, is too simplistic. With separate concrete and abstract systems, these patients would simply have damage to the concrete system; the fact that these patients appear to be rare could simply be that the symptom is linked to less common lesion sites.

This model is, however, also problematic. If concrete and abstract semantic sytems are quite literally separate, then there should be for DRB an imageability value above which no words are impaired, and below which a constant proportion of words are impaired; in fact, as the imageability rating increases, his ability to repeat the words increases steadily. It is unlikely that this could be an effect of another variable interacting, since DRB's repetition is only affected by concreteness and age of acquisition, and imageability correlates highly with both of these ratings. Shallice (1987) advocates a more complex relationship between the representations of abstract and concrete words, which includes separable "subsystems" for sensory and functional attributes; but it is not entirely clear how this system would work. And unless they are literally separate systems, an account of the modality specific effect again becomes difficult to sustain.

4) Separate visual and verbal semantic systems

This hypothesis was motivated primarily by the phenomenon of "optic aphasia"; but as I argued in the introduction, the evidence for the existence of such a syndrome is not compelling. I also argued in chapter 3 that if there were separate visual and verbal systems, then the 20 patients described here should show a variety of patterns of semantic deficit, whereas in fact all those patients who have both severe auditory and written comprehension problems also have a visual semantic impairment. Although separate visual and verbal systems could explain DRB's imageability effect (assuming there was access to the visual system from verbal input), since concrete words would have dual representation, specific impairments for concrete words would be inexplicable.

A model of semantic representations

None of the accounts given above seems to fit the data adequately. An account is required wherein low imageability words are more prone to impairment than the high imageability words, but where it is also possible that concrete words can be specifically damaged in some cases. Since the three Warrington patients all have complex neurological impairments, and since a visual semantic deficit cannot be ruled out in these cases, it could be argued that these patients have a specific impairment of concrete representations. However, in at least one of these patients it was shown that there was not a specific effect of item consistency. Furthermore the notion that meaning can be encapsulated in item-specific storage systems seems highly unlikely.

If however there were two types of coding in semantic organisation, one to do with sensory information and the other to do with propositional information, then damage to the sensory coding mechanisms might produce a non-item-specific impairment which would affect more imageable items as well as severely affecting visual semantic processing. If the system was such that, irrespective of type of coding, more abstract items required more information to be uniquely specified, then any sort of verbal access impairment would result in a disadvantage for low imageability words. The fact that DRB has some semantic information about words he cannot repeat or define supports this.

This model predicts that all modality-specific access impairments for words will result in an abstractness effect. Warrington's (1981) patient is described as a concrete word dyslexic, but he clearly also has impaired auditory comprehension; and the fact that his written performance is worse can be attributed to impaired lexical access since his written lexical decision is extremely poor. There are therefore no reported cases of modality specific impairments where concrete words are more impaired than abstract words.

I have argued that, for auditory comprehension, DRB has degraded information accessing the semantic system, which results in an underspecification which is more likely to affect low imageability words. Such an explanation cannot account for an anomia for low imageability words; indeed it is simply unclear how an intact semantic system can give rise to such an impairment.

8.8 How many routines for repetition?

Semantic versus sub-lexical routes.

In Chapter 5 it was shown that for the group of patients as a whole, repetition was better than picture naming with an identical list of words; a single route model would predict that repetition would be worse than naming, since all the patients by definition have auditory comprehension impairments. Furthermore, repetition is only better than naming for those patients whose sub-lexical ability is above the median range (for the group as a whole) suggesting that the superiority is indeed explained by the availability of a sublexical route.

I have argued earlier that imageability is an index of difficulty for semantic route repetition. Therefore the larger the imageability effect, the worse repetition would be if there were only one available route. The fact that the correlation between the size of the imageability effect and the patients' ability to repeat concrete words is not significant is again compatible with the idea that there is more than one route for repeating real words. Further evidence for the availability of at least two routes can be found in chapter 6. There appear to be two characteristic patterns of repetition deficit. In one, associated with assembled phonology, longer words produce higher error rates, ends of words are more error prone than beginnings, a large number of the errors are phonologically releated non-words, and phonologically related real word errors are on average of lower frequency than the target. In the other pattern, associated with addressed phonology, long words produce lower error rates, ends of words are no more likely to be incorrect than beginnings, a large number of errors are phonologically related real words, and these errors are on average of higher frequency than the target.

The assembled phonology errors are associated with a partially functioning sub-lexical repetition route (with the lexical route being unavailable), whereas the addressed phonology errors are associated with a partially functioning lexical/semantic route (with the sub-lexical route being unavailable).

A direct lexical route?

The question of whether there is a direct lexical route is more controversial. It is clear that none of the twenty patients I have described have the auditory parallel of Funnell's (1983) case of phonological dyslexia, who made semantic errors in comprehension and naming, and whose oral reading was excellent for real words (with neither semantic paralexias nor regularisation errors) but zero for non-words. However, there are at least two patients whose real word repetition is only very mildly impaired, despite a severe anomia and poor non-word repetition (DM and KJ). These patients also show an effect of word imageability in auditory comprehension, but not in repetition. This suggests either that there is a "direct" lexical repetition route, or that these patients are able to use partial information from both semantic and sub-lexical routes.

The latter explanation cannot be true for AD, who is worse than EC on all related tasks, but considerably better at real word repetition. Since both the semantic route and the sub-lexical repetition route are less impaired for EC, a combination of them in real word repetition should yield superior performance to AD's. Thus unless a more complex relationship between the sub-lexical and semantic repetition routes can be specified (see next Chapter) this is evidence that AD is using a direct lexical repetition route which is unavailable to EC.

One or two phonological lexicons?

In the introduction it was concluded that the issue of whether there are separate input and output phonological lexicons is unresolved (and, if there can be no agreement on underlying assumptions, perhaps unresolvable). However the dual task experiment of Shallice, Mcleod and Lewis (1985) does weight the evidence against single lexicon models.

In Howard and Franklin (1988) it is argued that semantic errors in repetition are good evidence for separate input and output lexicons; not least because of Allport and Funnell's (1981) conclusion that semantic errors in reading constitute good evidence for separate orthographic and phonological lexicons. In order to sustain the notion of a single phonological lexicon, the lexicon must have separate outputs to the semantic system and to phonology and the former must be accessible on the same occasion that the latter is not. Since MK has a word-form impairment, it could perhaps be argued that he can access some semantic information, but cannot produce any phonological output from the phonological input, because this requires more precise information.

It is not clear how such a system would operate, particularly in MK's case where there is absolutely no evidence to suggest that he has a deficient phonological output lexicon. In the case of DRB, who has neither a word-form deficit, nor an impaired phonological output lexicon (for concrete words) yet still makes semantic errors in repetition, it becomes unsustainable. If DRB can access input word forms sufficiently well to produce an output to the semantic system, and can access output word forms sufficiently well (e.g. in object naming), then why is he unable to repeat without using the semantic system? This would have to be accounted for in one of two ways. Semantic access could be an obligatory part of lexical repetition, with phonological input information unable to activate phonological output; but this would mean that in some sense there must be separate input and output representations. Alternatively, direct lexical repetition could be possible for normal subjects, but in the case of DRB the input has somehow been "disconnected" from the output; how would this be possible in a single system? A 2-lexicon model explains DRB's repetition performance easily; he has intact input and output lexicons, and either there is no such thing as "direct lexical repetition" for even normal subjects, or for him the mapping from the input to the output lexicon is impaired.

The following chapter will consider the relationship between repetition and auditory short term memory and will have further implications for the issue of repetition routes.

CHAPTER 9: A model for repetition and auditory short term memory.

While there is general agreement that there is a short term memory system which is specific to auditory phonological processing, rather than a general working memory system, there are various models of the structure of this system. In 1969, Morton argued for a phonologically based output store (=response buffer); subsequently it became clear that there had to be some kind of input store because of the differential effects of phonological similarity with and without suppression on auditorily and visually presented lists (Baddeley et al 1984). Monsell (1987) proposed a system with separate input and output stores with a rehearsal loop connecting them . Unlike Baddeley's model of a phonological short term store and a rehearsal loop, both Morton and Monsell made explicit the relationship between auditory short term memory and lexical processing. Which of these theories are consistent with the neuropsychological data?

I will argue that dissociations between patients support a model which, like Monsell's, has three components; input and output stores which are both phonologically based, and a "rehearsal" loop connecting them. This is the system used for phonogical recoding and sub-lexical repetition, as well as for storing strings (see Figure 9.1). Initially data from three patients will be considered; DRB, MK (Howard and Franklin, in press) and the patient MV who is described by Bub et al (1987)

9.1 DRB: An impairment of the phonological input store.

There are several sources of evidence that DRB has an impairment of the phonological input store. He performs normally on tests of phoneme discrimination and of auditory lexical decision, indicating that he is able to analyse acoustic information to the phoneme level. (Phoneme discrimination tests require a same/different judgment to be made on two strings; at first sight this might seem to require at least the first string to be held in memory, but it appears that an identity match can be done at a pre-phonological level, unlike a rhyme judgment where the string has to be partially segmented.)

DRB is able to read non-words, is good at homophone matching and has fluent speech, indicating that there is no phonological output problem. Despite this he is unable to repeat non-words. Not only is repetition span impaired, but matching span is also severely impaired.

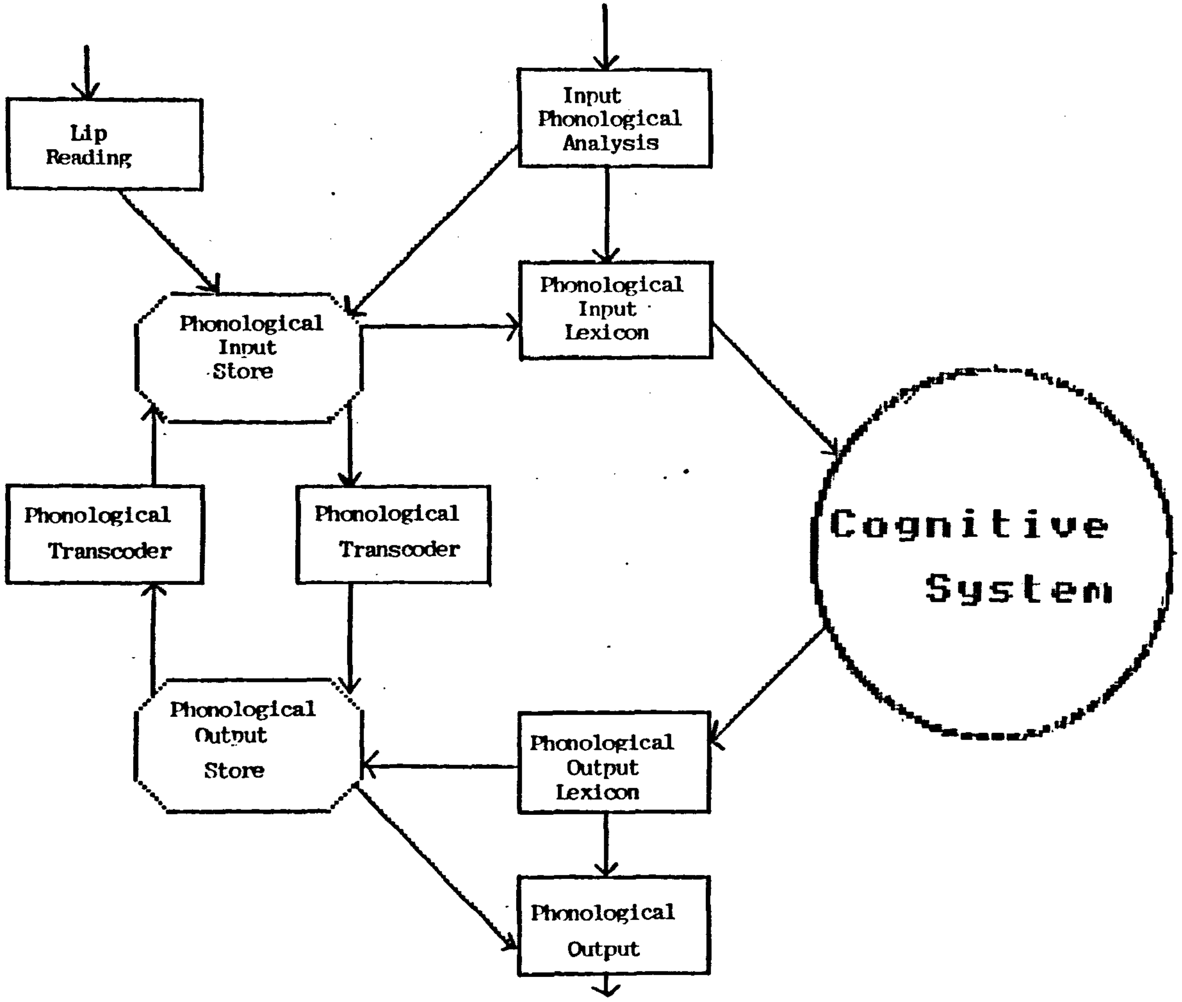


Figure 9.1: A model of short-term memory and repetition.

Lip reading effects.

Lip reading improves DRB's performance on repetition span tests and word repetition. Since his lexical decision is unimpaired it is unlikely that he needs lip reading to support the lexical/semantic route, suggesting that the effect on repetition here is due to lip reading improving processing via the sub-lexical pathway. This is confirmed by the significant improvement in non-word repetition with lip reading and by the fact that there is an effect of phoneme length for word repetition only when DRB is allowed to lip read.

There is no phonological similarity effect in DRB's repetition of letter strings without lip reading, but with lip reading phonologically dissimilar lists are better recalled.

Phoneme segmentation.

DRB is severely impaired at all tests which require phoneme segmentation, such as rhyme judgements. He is unable to identify the last phoneme in a CVC string, despite the fact that he can reliably reject, as non-words, strings which differ from a real word only in terms of the final phoneme. Errors in repetition of non-words (with lip reading) tend to occur at the end of the string, suggesting that the store is subject to fast decay.

Inner ear rehearsal.

Since DRB has an impairment in the phonological input store he should be unable to utilize "inner ear" rehearsal (Monsell, 1987 - that is, the route by which output phonology is converted to input phonology, Howard and Franklin, 1987). This is indeed the case; despite his visual letter span being significantly better than his auditory letter span, there is no effect of phonological similarity for visual span. He was at chance when asked to identify the pseudohomophone when shown a pseudohomophone and an ordinary non-word, despite being able to read both aloud.

9.2 MK: an impairment of the "rehearsal" loop.

Like DRB, MK has no impairment in phoneme discrimination (although he does have an impairment in auditory lexical decision), and no phonological output impairment in that he can read non-words, do homophone matching and has fluent speech. Also like DRB, he is entirely unable to repeat non-words.

* MK's impairment must be to <u>both</u> the input store -> output store <u>and</u> the output store -> input store pathways. He is severely impaired even at single item tasks requiring <u>either</u> of these routes; the input -> output deficit results in impaired non-word repetition; the output -> input deficit causes written pseudohomophone definition to be more impaired than definition of the equivalently auditorily presented words.

Phonological input store.

Unlike DRB, MK is better at matching span (reliable for four digits) than recall tasks. Neither non-word or real word repetition is improved by lip reading. MK is able to judge whether two spoken words rhyme and is significantly better at matching span tasks using phonologically dissimilar items than similar ones. These results indicate that MK does not have an impairment of the phonological input store. The only evidence to the contrary is that he shows no lexicality effect in matching span tasks; this can be attributed to his input lexical impairment.

Inner ear rehearsal.

Since MK has a severe impairment in repetition span and in non-word repetition despite unimpaired input and output stores, this must be attributable, as it were by default, to an impairment in the rehearsal loop, ie the processes linking the two stores.* This impairment should also result in an inability to feed back phonologically recoded written information for auditory comprehension. MK has no phonological similarity effect for letter strings presented in the written form despite showing such an effect when the strings are auditorily presented. He is at chance at judging which of two written non-words would sound like a real word and uses approximate visual access to define visually presented pseudohomophones. Howard and Franklin (in press) argue that MK behaves like a normal subject under suppression in these tasks.

Vallar and Baddeley (1984) describe a patient, PV, as having an impairment of the phonological input store. [illegible] There was no effect of word length in recall, and articulatory suppression did not affect visual immediate serial recall, a pattern suggesting impaired rehearsal. However Vallar and Baddeley's model of auditory short term memory comprised only an input store and a rehearsal loop; and since PV's fluent speech indicated intact output (and by implication an intact rehearsal loop), they were forced to the conclusion that PV had an input store impairment. The lack of an effect of articulatory suppression on visual recall, they attributed to a strategic decision by PV. Clearly, the 3-stage model of auditory short term memory is able to account for these findings much more satisfactorily; PV has an intact output buffer, compatible with fluent speech output, but, like MK, has an impairment of the rehearsal loop.

9.3 M.V.: an impairment of the phonological output store.

MV (Bub et al, 1987) was also unimpaired at phoneme discrimination and was reported to have good auditory comprehension. Matching span was not tested; but like MK, MV showed a phonological similarity effect in auditory presentation but not in visual presentation, suggesting that the impairment was not at the level of the phonological input store. MV was better than both MK and DRB at non-word repetition (50% correct for short strings) and at digit span repetition (span = 3). But MV was not only impaired at non-word repetition but also at non-word reading and Bub et al (1987) show that the impairments are both quantitatively and qualitatively similar. Further indication that this patient has an phonological output store impairment is that her speech, though not agrammatic, was non-fluent.

9.4 Summary of data on three patients

These three patients demonstrate that auditory short term memory comprises two stores and their interconnections. DRB and MK are able to use the output phonological store for assembled phonology from orthographic codes, and with the phonological output lexicon are able to use it for homophone judgments and perhaps for "buffering" speech production to maintain fluency (although presumably their monitoring will be impaired).

MV is unable to do any of these things, but it is interesting to note that there is no report of her making phonologically related errors in naming: the authors only report that she makes "verbal paraphasias". The dissociation between error type in naming on the one hand and (non-word) repetition and reading on the other could be explained by the information which is available from the semantic system. However, the model in Figure 9.2 allows for naming to be accomplished without requiring access to the phonological output store and therefore gives a simpler explanation for this dissociation.

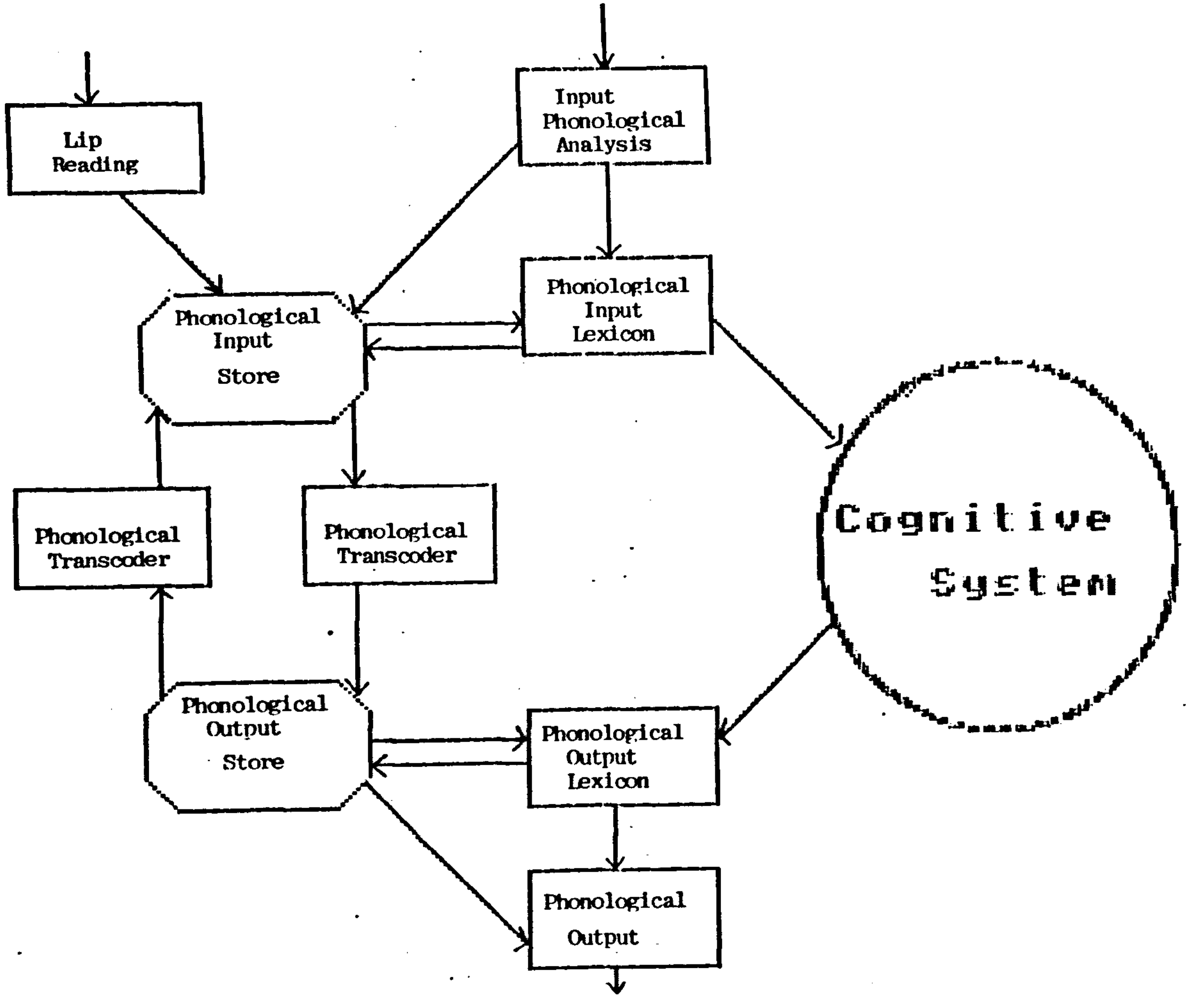


Figure 9.2: A revised model of auditory-short-term memory and repetition.

9.5 Properties of the auditory short-term memory system.

The phonological input store

Because immediate recall is worse for phonologically similar than dissimilar items, and because this effect is abolished by suppression when the items are visually presented but not when they are auditorily presented, the phonological similarity effect appears to be associated with the workings of the phonological input store (Baddeley 1986). Unfortunately, apart from the robust experimental phenomenon, it is not really clear what phonological similarity is, nor whether it is possible to make inferences from the phenomenon to the operation or organisation of the store. "Phonological similarity" clearly does not refer to phonemic distinctiveness of the letters: for the letters to be confusable they simply have to rhyme; syllables where the consonant stays constant and the vowel changes are not confusable in this way (Drewnowski 1980).

Interestingly, what seems to happen with confusable items is that they become misordered; Watkins, Watkins and Crowder (1974) showed that phonological similarity only impairs recall if scoring requires items to be correct in the correct position.

Use of the input store seems crucial for tasks involving segmentation. Visually presented rhyme judgments are affected by suppression (Besner, Davies and Daniels 1981) whereas homophone matching is not (Besner et al 1981; Baddeley and Lewis 1981), suggesting that there is sufficient space in the output store under suppression to hold two items, but that segmentation cannot be done there. MK and DRB are both impaired at visually presented rhyme judgments but not homophone judgments. MK, whom we have argued has an intact input store, is able to judge whether or not two auditorily presented words rhyme. DRB, who has an impaired matching span, is not only poor at auditory rhyme judgments but also has difficulty with segmentation tasks using only one word.

The fact that DRB is helped by lip reading for sub-lexical repetition and immediate memory tasks, despite having no impairment in phoneme discrimination or auditory lexical decision, suggests that lip reading can directly access the phonological input store. There has however been very little research on lip reading in aphasia, and it remains to be seen whether other patients will show this pattern.

RE, a university student with developmental memory and reading deficits studied by Butterworth et al (1986), actually found that she could do matching span better with her eyes closed; but this appeared to be because she was using visual information to hold the items and therefore lip reading interfered. The crucial difference between her and DRB in this respect is that she was reliably able to repeat single items.

Phonological output store.

Monsell (1987) suggests that the phonological output store, like the input store, is a possible locus for phonological similarity effects. Since MK and DRB both have unimpaired output stores, the fact that neither of them shows a phonological similarity effect for visually presented items (despite the fact that MK can be seen to be rehearsing visually presented items) suggests that phonological confusability is not in fact a property of the output store.

Besner et al (1981) conclude that since articulatory suppression affects rhyme judgments, then phonological segmentation must be carried out at an output level.
Because phonological recoding (tested by non-word

homophone judgments) is not affected by suppression, they argue that phonological recoding is entirely distinct from the auditory memory system. However, MK, who Howard and Franklin (in press) have argued cannot rehearse phonological information, is not impaired at auditory rhyme judgments. DRB, on the other hand, who has an intact phonological output store but an impaired phonological input store, is impaired at auditory rhyme judgments. This suggests that processing at the level of input is implicated in tasks requiring phonological segmentation of either auditory or visual input.

Word length does not appear to be a property of the input store, since suppression eliminates word length effects both for visual and auditory presentation. Is it then a property of the output store? If this were so then MK should show a word length effect for visually presented lists, since we have argued that his output store is intact. In fact MK shows no word length effect irrespective of mode of presentation (Howard and Franklin, in press).

The output store does seem to have some relevance to the production of fluent utterences. Dysphasic patients who, like MK and DRB, have poor repetition but are surface dyslexic (e.g. Goldblum 1985; Newcombe and Marshall 1984) are all fluent dysphasics (in the sense of a fluent rate of speech production, not as a syndrome classification). Patients such as Bub et al's MV (1987) and Funnell's WB (1983), on the other hand, who have the same impairment in assembled phonology for both reading and repetition, have "non-fluent" speech, suggesting a deficit in holding speech output in the store.

Connections between stores.

Since the word length effect does not seem to be attributable to either the input or the output store, it must, by default, be a function of transmitting information between the two stores. If the stores are holding devices operating on a single code (the most constrained definition of a store), and are sensitive to different properties (suggesting that they differ in their organisation), then the connections between the stores must be transcoding devices.

If the stores each deal in a single code, and since each interfaces with a pre- and post- lexical level of processing, the codes must correspond to some thing like individual phonemes (although held in the stores in chunks) and thus the transcode will reflect word length.

How does suppression affect the short-term memory loop?

Although suppression affects span, it is still possible to hold two-to-three visually presented non-words in memory while carrying out an articulatory suppression task (eg. Besner and Davelaar 1982). It is therefore unsurprising, as stated earlier, that homophone matching can still be carried out under articulatory suppression.

However, transcoding between stores will be completely abolished by suppression, since there is no storage at this level. Thus only one item can be transcoded at any one time and, assuming the suppression is at a fast enough rate, this will always be one of the suppression items. So despite the fact that more than one item can be held in the output store during suppression, any task that requires information (even regarding only one or two items) from the output store to be transcoded to the input store will be affected by suppression. Thus visually presented rhyme judgments (Besner, Davies and Daniels 1981) and even pseudohomophone detection tasks are affected by suppression. But if subjects are allowed to suppress at a slower rate, then their ability to detect pseudohomophones improves (Besner, Davies and Davelaar 1981), presumably because it is then possible to alternate transcoding between a suppression item and the pseudohomophone.

9.6 Lexical Effects in Immediate Recall.

Since immediate recall span is longer for real words than non-words (Baddeley 1986), then either the auditory short term memory system has an inbuilt lexical bias or it is able to interface with the lexical system. (These two possibilities are of course not mutually exclusive.)

A Unitary Phonological system

The single phonological processing system proposed by Allport (1984) is not tenable in the light of the dissociations of input and output short term memory problems shown by patients. There could still, however, be two systems, each dealing with both lexical and sub-lexical information, but with one system for input and one system for output. This would mean that, on input, both words and non-words would produce activation in the system: both would activate the output phonological system, but the words would also produce an output to the semantic system. This account is problematic [illegible]

[illegible]

A specific difficulty for this account concerns the input double dissociations shown by DRB and MK. Results reported here suggest that MK has impaired word-form access but an intact phonological input store, while DRB has intact word-form access but an impaired phonological input store. In a single system, words will always be less vulnerable to impairment than non-words, so DRB's pattern of impairment could be explained. However the opposite impairment shown by MK (the input store intact, the input lexicon impaired), would mean that items in the store could not be accessed, but could be maintained in the store (in a form sufficiently specified for MK to be able to judge whether items rhyme). It would also be difficult in such a system to explain why MK has a matching span of at least 4 items, and yet shows no effect of lexicality in this matching span task. MK's pattern of performance is much more easily explained in a system where the store and the lexicon are separable (but linked) systems.

Constraints on Transcoding Mechanisms

Given that the lexical superiority effect in span is not accounted for within the stores themselves, there must be activation between the phonological lexicons and the stores. There are at least two ways of modelling this relationship, depending on the constraints made on the transcoding procedure. Figure 9.1 showed the first such model, in which there are separate phonological input and output stores connected by transcoders as described earlier in the chapter. The constraint in transcoding implicit in this model is that for each level of transcoding there can be only one type of input code and one type of output code. As this would seem to be the most constrained form of the model, it is apposite to see whether this format is able to account for all experimental findings. The consequence of this constraint is that information from the phonological input store can activate input lexical information, but not vice versa, and information from the phonological output lexicon can activate the phonological output store, but not vice versa. Such a model provides for a flow of information for speech monitoring, but there is no mechanism for the input lexicon to provide additional activation for the input store; such support could only occur at the output level on this model. Conversely the output store is unable directly to activate lexical information without it being transcoded via the input store.

An alternative model can be seen in Figure 9.2. In this model the constraints are somewhat relaxed, in that while only one type of code can be accepted as input, the output can be in the same code as was used for the input or in one other, different code. For example in the case of the input lexicon, if the input phonology corresponds to a word, the lexical entry will produce two output codes, one exactly the same as the input code and one which will map onto the word's meaning. If the input phonology does not correspond to a word, the lexicon will produce no output. This model differs from the previous one in permitting information to flow between the appropriate lexicon and store in both directions.

There are few experimental results which will distinguish between these two models, but two lines of evidence suggest that the second model may provide the better account. The first is the finding by Besner and Davelaar that the pseudohomophone effect in recalling visually presented non-words is not abolished by articulatory suppression. The occurrence of a pseudohomophone effect implies that sub-lexical information must be accessing lexical forms. Since the pseudohomophone effect is actually quite small (rather less than one item) it can be explained by the extra item activating its lexical form. In the case of the first model this can only happen at the input level; I have argued that such transcoding is even abolished for one item under articulatory suppression. This model would therefore wrongly predict that articulatory suppression should abolish the pseudohomophone effect. The second model allows for the pseudohomophone to activate a lexical output form, which will still be possible under suppression.

In chapter 7 it was shown that DRB was impaired at probe span tasks where order was crucial. He was unable to do the task with non-words, but managed it, albeit not perfectly, with real words. This could be explained by access to one of the stores from a lexicon. In the first model it would have to be from the output lexicon to the output store. But DRB's performance was not drastically reduced for abstract words in the probe span task. Since he is severely impaired at producing any output for abstract words, this suggests he is accessing the phonological input store from the input lexicon, which again supports model 2.

9.7 Effects of Repetition Priming

Gipson (1986) showed that accessing the output phonological form of a word primes subsequent access to its input phonological form, but not as strongly as if the word is heard previously. If it were assumed that the strength of the prime related to the amount of activation the word-form originally received, then this could be accounted for by the model in Figure 9.2. When the output phonological form is accessed, the activation feeds back (via the short-term memory system) to the input lexicon, producing some priming effect. If the word is heard, on the other hand, then the input lexicon will be activated both directly and via the input store. It is possible that this dual-activation produces a stronger priming effect.

Monsell (1987) reports an experiment by Monsell and Banich where they compared the effects of hearing the word, deriving the phonology of the word and silently mouthing the word on auditory lexical decision. Silently mouthing the word is a more effective prime than just deriving the phonology; Monsell suggests that this is because silent mouthing is able to utilize a more peripheral feedback loop (the "inner voice").

The model in Monsell (1987) shows this feedback activating information from articulatory programmes to speech features. Since speech features are presumably at a phonetic level, then silent mouthing, like heard speech, should therefore produce dual activation in the input lexicon.

9.8 Impairments in repetition

Chapter 7 demonstrated a close relationship between repetition and auditory short term memory, and I suggested that the auditory short term memory loop was the system used for sub-lexical repetition (as well as for auditory feedback). The group of patients as a whole showed a high correlation between sub-lexical repetition ability and digit span repetition. Also it was shown in the previous chapter that patients who are using an impaired sub-lexical route for repeating real words are more impaired with words of longer length and are more likely to make errors on the ends of words. DRB has both an impaired auditory short term memory and very impaired sub-lexical repetition; where both of these functions have been tested they have invariably been found to co-exist (e.g. Caplan and Walters , unpublished manuscript). For DRB both sub-lexical repetition and immediate serial recall were improved by lip reading; his real word repetition showed decay and a word length effect when he was allowed to lip read.

Direct lexical repetition?

In chapter 5, I argued for separate lexical/semantic and sublexical routes in repetition. Furthermore, the fact that AD was more impaired than EC on all other relevant tasks while better at repeating real words seemed to be evidence for a third route where the output lexical form was directly accessed by the input lexical form. Is the direct lexical route still necessary? The repetition of these two patients showed that lexicality effects could not be accounted for simply by the combined use of the lexical/semantic and sublexical routes. However, the more interactive use of the two routes detailed in the model in Figure 9.2 can account for the discrepancy. Of course, this is conjecture until the relevant tests are done, but the difference in their word repetition could be explained by postulating that EC has an impairment of the processes between the input store and the input lexicon.

The large lexical advantage shown by patients such as KJ and DM could be explained as an impaired route from "input phonological analysis" to the input phonological store, with a retained ability to access the store via the lexicon. This would further support the idea of access from the phonological input lexicon to the input store, as discussed in a previous section.

9.9 Direct route reading ?

How does reading relate to this model of auditory short term memory and repetition? The sub-lexical reading route would access information in the phonological output store, as discussed above with reference to the Besner et al (1981) experiment on the pseudohomophone advantage in visual span. It is an impairment at this point which makes MV (Bub et al) equally impaired at reading and repetition, but able to name without producing phonologically related errors. It also contributes to her non-fluent speech production. MK and DRB on the other hand have different short term memory impairments and are able to read via the sub-lexical route.

R.E., described by Campbell and Butterworth (1985) and Butterworth, Campbell and Howard (1986) is a developmental phonological dyslexic, poor at reading non-words and with a short-term memory impairment. Testing of her auditory short term memory suggested that she had a phonological input store impairment. Why should this cause her to be a phonological dyslexic? One obvious possibility is that it is not a cause and she simply happens to have both impairments. More likely however is that the input store, while not necessary for non-word reading in an accomplished reader, could be a vital compononent for a learning reader, in terms of monitoring performance.

A possible model for reading, repetition and short term memory is shown in Figure 9.3. An orthographic input store has been added because many short term memory patients have been reported to have a visual span superior to their auditory span. (Shallice and Vallar, in press). There are two reading routes, the semantic route and the sublexical route. Whether there is also a direct lexical route is difficult to resolve. The same arguments can be applied as for direct lexical repetition, in that it is possible to use a combination of routes (see Howard, 1985), and in this model the lexicons support the sub-lexical route.

WB, the patient reported by Funnell (1983), is the most compelling case of a patient reading via a "direct route": he was unable to read aloud any non-words but read 90% of real words correctly. He was impaired in both naming and written comprehension, but his errors in comprehension occurred where fine semantic

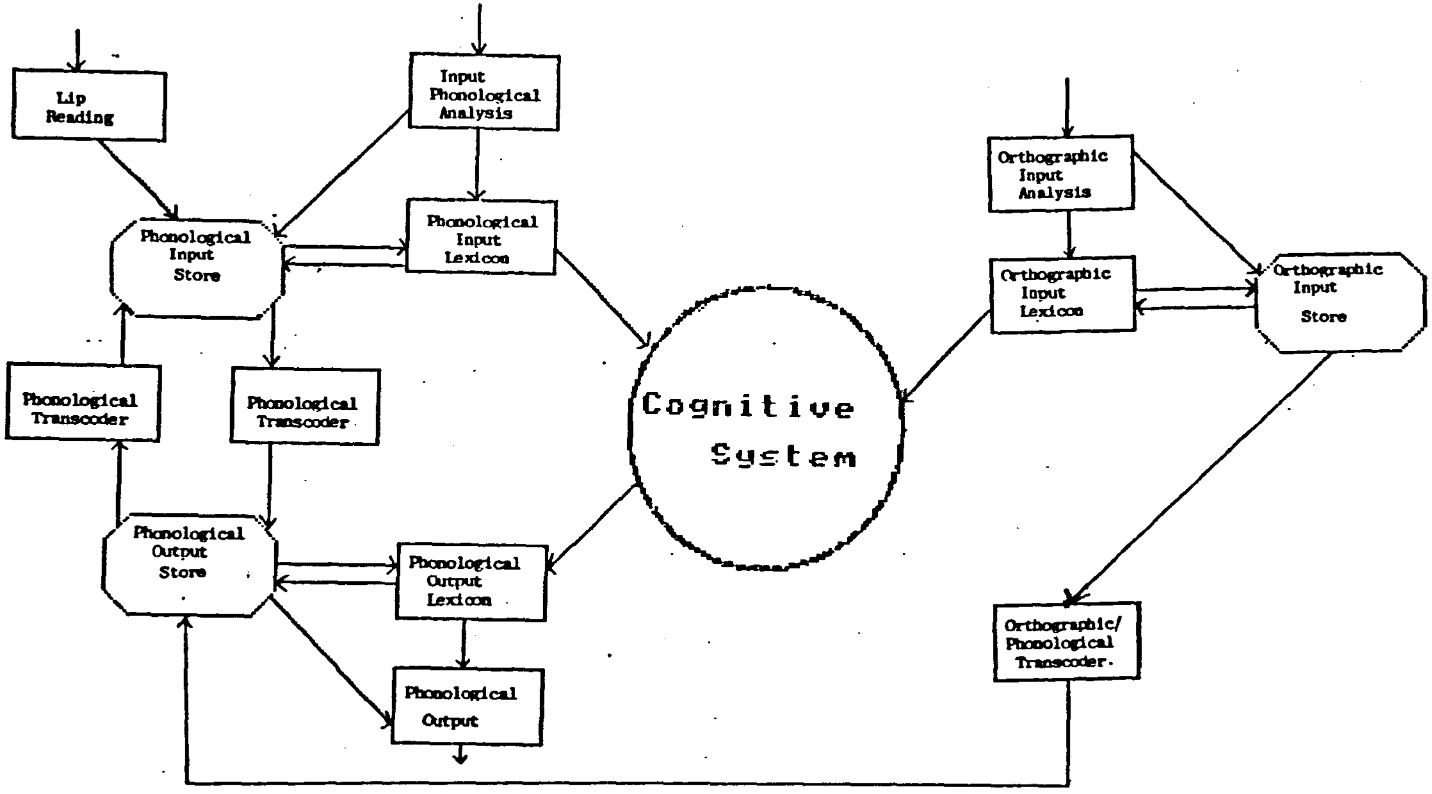


Figure 9.3: A model of short-term memory, repetition and reading.

judgments were required. If multiple outputs from the semantic system activate a number of semantically related words in the phonological output lexicon, then a small amount of information from the sub-lexical reading route, to the output lexicon, will serve to disambiguate lexical candidates. Since WB made very few phonologically related errors in naming, this suggests that the mapping between the output lexicon and phonological output was intact. However, an impairment in the output store, and possibly from the store to phonological output (non-word repetition was also somewhat impaired) mean that phonologically recoded information would not produce an output.

9.10 Conclusion

The data provided by these patients suggest that there are separate lexical and sub-lexical routes for auditory-verbal processing. There is no evidence to suggest any lexical advantage to the sub-lexical route *itself*. The sub-lexical route is used for repeating novel words, for immediate serial recall of auditorily presented material and for inner feedback. This model makes the prediction that impairments in auditory immediate serial recall and non-word repetition will invariably co-occur.

The fact that DRB's repetition and recall are enhanced by lip reading, despite his intact auditory comprehension, is support for Campbell's (1987b) conjecture, that lip read and auditory information interact at the level of the input buffer. It remains to be seen whether lip reading also interacts with auditory information at an earlier stage of processing.

The group of patients showed a considerable diversity of impairments in auditory comprehension. These impairments are compatible with an input lexicon which produces multiple outputs to an amodal semantic system. Experiments with DRB confirmed the vulnerability to impairment of abstract words. It is predicted that all impairments of access from the input lexicons to the semantic system will result in a greater impairment for abstract words.

APPENDIX

Appendix 1: Patient Summaries.

PATIENT: C.L.

Pyramids and Palm Trees

Picture version: 26/52

Spoken word -> Picture version: 31/52

Auditory Descrimination

CV list: NOT TESTED

Easy Lexical Decision

Spoken: 40/50

Written: 39/50

Synonym Matching

Auditory:	High Imageability	36/38
	Low Imageability	31/38
Written	High Imageability	NOT TESTED
	Low Imageability	NOT TESTED

Picture Naming

Spoken: 12/40

Written: NOT TESTED

Imageability x Frequency List

Repetition:	High Imageability	39/40
	Low Imageability	39/40
Reading:	High Imageability	13/40
	Low Imageability	18/40

Non-words

Repetition: 13/20

Reading: 2/20

Writing to dictation: NOT TESTED

Digit Span: 5.5

Appendix 1: Patient Summaries.

PATIENT: A.Ba.

Pyramids and Palm Trees

Picture version: 47/52

Spoken word -> Picture version: 46/52

Auditory Descrimination

CV list: 34/40

Easy Lexical Decision

Spoken: 49/50

Written: 45/50

Synonym Matching

Auditory:	High Imageability	0/38
	Low Imageability	0/38
Written	High Imageability	30/38
	Low Imageability	24/38

Picture Naming

Spoken: 7/40

Written: 0/40

Imageability x Frequency List

Repetition:	High Imageability	29/40
	Low Imageability	26/40
Reading:	High Imageability	12/40
	Low Imageability	6/40

Non-words

Repetition: 10/20

Reading: 0/20

Writing to dictation: 0/20

Digit Span: 2

Appendix 1: Patient Summaries.

PATIENT: A.By.

Pyramids and Palm Trees

Picture version: 32/52

Spoken word -> Picture version: 32/52

Auditory Descrimination

CV list: NOT TESTED

Easy Lexical Decision

Spoken: 32/50

Written: 26/50

Synonym Matching

Auditory:	High Imageability	33/38
	Low Imageability	26/38
Written	High Imageability	29/38
	Low Imageability	25/38

Picture Naming

Spoken: 15/40

Written: 0/40

Imageability x Frequency List

Repetition:	High Imageability	19/40
	Low Imageability	17/40
Reading:	High Imageability	22/40
	Low Imageability	10/40

Non-words

Repetition: 2/20

Reading: 2/20

Writing to dictation: 0/20

Digit Span: 2

Appendix 1: Patient Summaries.

PATIENT: M.H.

Pyramids and Palm Trees

Picture version: 26/52

Spoken word -> Picture version: 41/52

Auditory Descrimination

CV list: NOT TESTED

Easy Lexical Decision

Spoken: 49/50

Written: 42/50

Synonym Matching

Auditory:	High Imageability	25/38
	Low Imageability	NOT TESTED
Written	High Imageability	NOT TESTED
	Low Imageability	NOT TESTED

Picture Naming

Spoken: NOT TESTED

Written: NOT TESTED

Imageability x Frequency List

Repetition:	High Imageability	39/40
	Low Imageability	38/40
Reading:	High Imageability	NOT TESTED
	Low Imageability	NOT TESTED

Non-words

Repetition: 19/20

Reading: NOT TESTED

Writing to dictation: 14/20

Digit Span: 5.5

Appendix 1: Patient Summaries.

PATIENT: M.K.

Pyramids and Palm Trees

Picture version: 52/52

Spoken word -> Picture version: 45/52

Auditory Descrimination

CV list: 36/40

Easy Lexical Decision

Spoken: 34/50

Written: 49/50

Synonym Matching

Auditory:	High Imageability	36/38
	Low Imageability	29/38
Written	High Imageability	38/38
	Low Imageability	37/38

Picture Naming

Spoken: 36/40

Written: 34/40

Imageability x Frequency List

Repetition:	High Imageability	21/40
	Low Imageability	15/40
Reading:	High Imageability	38/40
	Low Imageability	36/40

Non-words

Repetition: 0/20

Reading: 20/20

Writing to dictation: 1/20

Digit Span: 0.5

Appendix 1: Patient Summaries.

PATIENT: F.M.

Pyramids and Palm Trees

Picture version: 49/52

Spoken word -> Picture version: 48/52

Auditory Descrimination

CV list: 33/40

Easy Lexical Decision

Spoken: 45/50

Written: 47/50

Synonym Matching

Auditory:	High Imageability	35/38
	Low Imageability	29/38
Written	High Imageability	33/38
	Low Imageability	27/38

Picture Naming

Spoken: 25/40

Written: 25/40

Imageability x Frequency List

Repetition:	High Imageability	37/40
	Low Imageability	35/40
Reading:	High Imageability	40/40
	Low Imageability	37/40

Non-words

Repetition: 6/20

Reading: 6/20

Writing to dictation: 0/20

Digit Span: 1

Appendix 1: Patient Summaries.

PATIENT: K.J.

Pyramids and Palm Trees

Picture version: 48/52

Spoken word -> Picture version: 48/52

Auditory Descrimination

CV list: 38/40

Easy Lexical Decision

Spoken: 48/50

Written: 45/50

Synonym Matching

Auditory:	High Imageability	37/38
	Low Imageability	31/38
Written	High Imageability	26/38
	Low Imageability	NOT TESTED

Picture Naming

Spoken: 19/40

Written: 6/40

Imageability x Frequency List

Repetition:	High Imageability	37/40
	Low Imageability	36/40
Reading:	High Imageability	17/40
	Low Imageability	2/40

Non-words

Repetition: 9/20

Reading: 0/20

Writing to dictation: 0/20

Digit Span: NOT TESTED

Appendix 1: Patient Summaries.

PATIENT: A.H.

Pyramids and Palm Trees

Picture version: 46/52

Spoken word -> Picture version: 37/52

Auditory Descrimination

CV list: 37/40

Easy Lexical Decision

Spoken: 36/50

Written: 47/50

Synonym Matching

Auditory:	High Imageability	35/38
	Low Imageability	22/38
Written	High Imageability	34/38
	Low Imageability	27/38

Picture Naming

Spoken: 25/40

Written: 24/40

Imageability x Frequency List

Repetition:	High Imageability	34/40
	Low Imageability	31/40
Reading:	High Imageability	40/40
	Low Imageability	37/40

Non-words

Repetition: 15/20

Reading: 19/20

Writing to dictation: 10/20

Digit Span: 5

Appendix 1: Patient Summaries.

PATIENT: D.M.

Pyramids and Palm Trees

Picture version: 46/52

Spoken word -> Picture version: 46/52

Auditory Descrimination

CV list: 37/40

Easy Lexical Decision

Spoken: 47/50

Written: 50/50

Synonym Matching

Auditory: High Imageability 38/38

Low Imageability 31/38

Written High Imageability 35/38

Low Imageability 34/38

Picture Naming

Spoken: 23/40

Written: 21/40

Imageability x Frequency List

Repetition: High Imageability 39/40

Low Imageability 38/40

Reading: High Imageability 40/40

Low Imageability 38/40

Non-words

Repetition: 10/20

Reading: 13/20

Writing to dictation: 2/20

Digit Span: 1.5

Appendix 1: Patient Summaries

PATIENT: F.C.

Pyramids and Palm Trees

Picture version: 36/52

Spoken word -> Picture version: 39/52

Auditory Descrimination

CV list: 36/40

Easy Lexical Decision

Spoken: 49/50

Written: 25/50

Synonym Matching

Auditory:	High Imageability	34/38
	Low Imageability	22/38
Written	High Imageability	NOT TESTED
	Low Imageability	NOT TESTED

Picture Naming

Spoken: 24/40

Written: 0/40

Imageability x Frequency List

Repetition:	High Imageability	35/40
	Low Imageability	34/40
Reading:	High Imageability	8/40
	Low Imageability	5/40

Non-words

Repetition: 13/20

Reading: 2/20

Writing to dictation: 0/20

Digit Span: 4

Appendix 1: Patient Summaries.

PATIENT: I.M.

Pyramids and Palm Trees

Picture version: 52/52

Spoken word -> Picture version: 48/52

Auditory Descrimination

CV list: 40/40

Easy Lexical Decision

Spoken: 50/50

Written: NOT TESTED

Synonym Matching

Auditory:	High Imageability	NOT TESTED
	Low Imageability	NOT TESTED
Written	High Imageability	36/38
	Low Imageability	30/38

Picture Naming

Spoken: 18/40

Written: 21/40

Imageability x Frequency List

Repetition:	High Imageability	39/40
	Low Imageability	40/40
Reading:	High Imageability	37/40
	Low Imageability	35/40

Non-words

Repetition: 15/20

Reading: 0/20

Writing to dictation: 17/20

Digit Span: 3

Appendix 1: Patient Summaries.

PATIENT: E.C.

Pyramids and Palm Trees

Picture version: 48/52

Spoken word -> Picture version: 46/52

Auditory Descrimination

CV list: 37/40

Easy Lexical Decision

Spoken: 42/50

Written: 50/50

Synonym Matching

Auditory:	High Imageability	38/38
	Low Imageability	34/38
Written	High Imageability	36/38
	Low Imageability	38/38

Picture Naming

Spoken: 5/20

Written: 2/10

Imageability x Frequency List

Repetition:	High Imageability	20/40
	Low Imageability	10/40
Reading:	High Imageability	13/40
	Low Imageability	9/40

Non-words

Repetition: 7/20

Reading: 0/20

Writing to dictation: 0/20

Digit Span: 1.5

Appendix 1: Patient Summaries.

PATIENT: N.H.

Pyramids and Palm Trees

Picture version: 23/52

Spoken word -> Picture version: 41/52

Auditory Descrimination

CV list: 34/40

Easy Lexical Decision

Spoken: 46/50

Written: 40/50

Synonym Matching

Auditory:	High Imageability	28/38
	Low Imageability	20/38
Written	High Imageability	27/38
	Low Imageability	21/38

Picture Naming

Spoken: 20/40

Written: 0/40

Imageability x Frequency List

Repetition:	High Imageability	33/40
	Low Imageability	22/40
Reading:	High Imageability	28/40
	Low Imageability	7/40

Non-words

Repetition: 4/20

Reading: 0/20

Writing to dictation: 0/20

Digit Span: 2.5

Appendix 1: Patient Summaries.

PATIENT: E.S.

Pyramids and Palm Trees

Picture version: 51/52

Spoken word -> Picture version: 35/52

Auditory Descrimination

CV list: 28/40

Easy Lexical Decision

Spoken: 34/50

Written: 46/50

Synonym Matching

Auditory:	High Imageability	30/38
	Low Imageability	24/38
Written	High Imageability	35/38
	Low Imageability	29/38

Picture Naming

Spoken: 8/40

Written: 0/40

Imageability x Frequency List

Repetition:	High Imageability	1/40
	Low Imageability	0/40
Reading:	High Imageability	37/40
	Low Imageability	29/40

Non-words

Repetition: 0/20

Reading: 17/20

Writing to dictation: 0/20

Digit Span: 0.5

Appendix 1: Patient Summaries.

PATIENT: V.W.

Pyramids and Palm Trees

Picture version: 48/52

Spoken word -> Picture version: 43/52

Auditory Descrimination

CV list: 40/40

Easy Lexical Decision

Spoken: 48/50

Written: 50/50

Synonym Matching

Auditory:	High Imageability	36/38
	Low Imageability	32/38
Written	High Imageability	37/38
	Low Imageability	35/38

Picture Naming

Spoken: 30/40

Written: 31/40

Imageability x Frequency List

Repetition:	High Imageability	40/40
	Low Imageability	40/40
Reading:	High Imageability	40/40
	Low Imageability	37/40

Non-words

Repetition: 15/20

Reading: 20/20

Writing to dictation: 14/20

Digit Span: 4.5

Appendix 1: Patient Summaries.

PATIENT: E.W.

Pyramids and Palm Trees

Picture version: 48/52

Spoken word -> Picture version: 50/52

Auditory Descrimination

CV list: 28/40

Easy Lexical Decision

Spoken: 46/50

Written: 48/50

Synonym Matching

Auditory:	High Imageability	37/38
	Low Imageability	32/38
Written	High Imageability	36/38
	Low Imageability	26/38

Picture Naming

Spoken: 18/40

Written: 12/40

Imageability x Frequency List

Repetition:	High Imageability	40/40
	Low Imageability	40/40
Reading:	High Imageability	40/40
	Low Imageability	38/40

Non-words

Repetition: 15/20

Reading: 5/20

Writing to dictation: 8/20

Digit Span: 3.5

Appendix 1: Patient Summaries.

PATIENT: D.I.

Pyramids and Palm Trees

Picture version: 51/52

Spoken word -> Picture version: 51/52

Auditory Descrimination

CV list: 40/40

Easy Lexical Decision

Spoken: 49/50

Written: 50/50

Synonym Matching

Auditory:	High Imageability	38/38
	Low Imageability	29/38
Written	High Imageability	36/38
	Low Imageability	34/38

Picture Naming

Spoken: 40/40

Written: 31/40

Imageability x Frequency List

Repetition:	High Imageability	39/40
	Low Imageability	40/40
Reading:	High Imageability	40/40
	Low Imageability	39/40

Non-words

Repetition: 20/20

Reading: 19/20

Writing to dictation: 18/20

Digit Span: 4.5

Appendix 1: Patient Summaries.

PATIENT: C.J.

Pyramids and Palm Trees

Picture version: 41/52

Spoken word -> Picture version: 38/52

Auditory Descrimination

CV list: 34/40

Easy Lexical Decision

Spoken: 48/50

Written: 46/50

Synonym Matching

Auditory:	High Imageability	32/38
	Low Imageability	28/38
Written	High Imageability	36/38
	Low Imageability	24/38

Picture Naming

Spoken: 29/40

Written: 29/40

Imageability x Frequency List

Repetition:	High Imageability	40/40
	Low Imageability	40/40
Reading:	High Imageability	38/40
	Low Imageability	35/40

Non-words

Repetition: 16/20

Reading: 15/20

Writing to dictation: 7/20

Digit Span: 4

Appendix 1: Patient Summaries.

PATIENT: A.D.

Pyramids and Palm Trees

Picture version: 36/52

Spoken word -> Picture version: 34/52

Auditory Descrimination

CV list: 29/40

Easy Lexical Decision

Spoken: 39/50

Written: 49/50

Synonym Matching

Auditory:	High Imageability	NOT TESTED
	Low Imageability	NOT TESTED
Written	High Imageability	26/38
	Low Imageability	26/38

Picture Naming

Spoken: 8/40

Written: 12/40

Imageability x Frequency List

Repetition:	High Imageability	25/40
	Low Imageability	16/40
Reading:	High Imageability	15/40
	Low Imageability	7/40

Non-words

Repetition: 4/20

Reading: 2/20

Writing to dictation: 0/20

Digit Span: 0.5

Appendix 1: Patient Summaries.

PATIENT: D.R.B.

Pyramids and Palm Trees

Picture version: 50/52

Spoken word -> Picture version: 48/52

Auditory Descrimination

CV list: 38/40

Easy Lexical Decision

Spoken: 49/50

Written: 49/50

Synonym Matching

Auditory:	High Imageability	36/38
	Low Imageability	23/38
Written	High Imageability	38/38
	Low Imageability	36/38

Picture Naming

Spoken: 40/40

Written: 39/40

Imageability x Frequency List

Repetition:	High Imageability	30/40
	Low Imageability	5/40
Reading:	High Imageability	40/40
	Low Imageability	38/40

Non-words

Repetition: 0/20

Reading: 17/20

Writing to dictation: 0/20

Digit Span: 0.5

Appendix 2: d' for lexical decision tests.

	Easy Lexical Decision		320 Item Auditory Lexical Decision
Patient	Auditory	Visual	
E.W.	2.93	4.08	
E.S.	1.04	3.32	0.64
A.D.	2.00	4.08	
A.By.	1.74	0.12	
M.K.	0.94	4.65	2.18
E.C.	2.93	4.65	1.22
A.H.	2.91	3.50	1.60
C.L.	2.10	2.00	
A.Ba.	4.08	3.36	
F.M.	3.17	3.50	2.73
C.J.	3.73	3.32	2.67
N.H.	2.93	1.87	
M.H.	4.08	2.33	
K.J.	3.50	2.75	
D.M.	3.50	4.65	
F.C.	4.08	0.00	
V.W.	3.73	4.65	
D.I.	4.08	4.65	
D.R.B.	4.08	4.08	4.38
I.M.	4.08	--	

Appendix 3: Semantic tests: details of testing.

SYNONYM MATCHING TEST

(Note: Synonym matching test: IM was not given the spoken version of this test, MH was not given the written version. CL and FC were both unable to attempt the written version of the test. ABa and AD were unable to attempt either version, but were both given the written test in a triad form. KJ was given only the high imageability items in the written version.)

Patients with a significant effect of imageability in synonym matching (Fisher Exact Test):

Spoken only	Spoken + Written
AH $z = 2.28$, $p<.05$	ES $z = 2.13$, $p<.05$
MK $z = 1.94$, $p<.05$	ABy $z = 1.85$, $p<.05$
FC $z = 2.85$, $p<.005$	FM $z = 2.29$, $p<.05$
NH $z = 1.65$, $p<.05$	EW $z = 3.28$, $p<.001$
KJ $z = 1.86$, $p<.05$	CJ $z = 2.97$, $p<.005$
DM $z = 2.36$, $p<.005$	
DI $z = 2.82$, $p<.01$	
DRB $z = 2.63$, $p<.01$	

Patient who is significantly worse at written than spoken synonym matching (McNemar Test):
(High imageability items only)

KJ $z = 3.05$, $p<.005$

Patients who are significantly worse at spoken than written synonym matching (McNemar Test):

DI $z = 2.11$, $p<.05$
DRB $z = 3.87$, $p<.001$

PYRAMIDS AND PALM TREES TEST

Patients who are significantly worse at three picture version (McNemar Test):

MH $z = 2.89$, $p<.005$
NH $z = 3.67$, $p<.001$

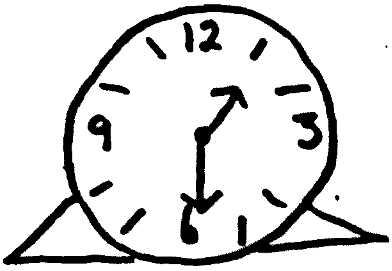
Patients who are significantly worse at spoken word to picture version (McNemar Test):

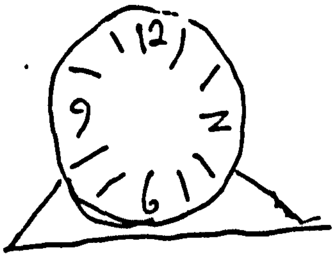
ES $z = 4.00$, $p<.001$
AH $z = 2.32$, $p<.01$
MK $z = 2.65$, $p<.005$

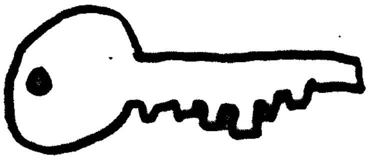
Appendix 4: Examples of drawing by MH.

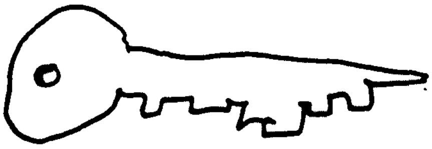
A. Copying the experimenter's (bad) drawings:

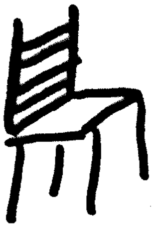
EXPERIMENTER MH

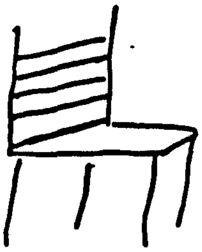












(All drawing examples carried out within a short period of time.)

Appendix 4 (continued)

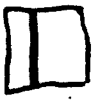
B. Drawing to dictation.

apple

comb

watch → Ø

book

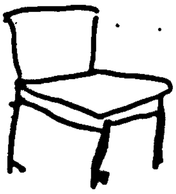


glasses

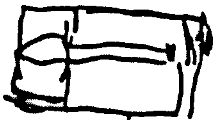
purse

key

chair



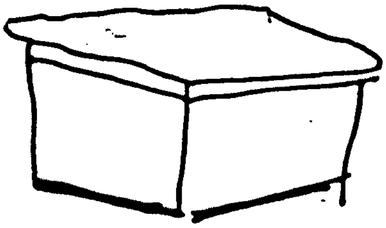
bus



pipe

spoon

table



umbrella

spade

Appendix 4 (continued)

C. Drawing from life (unfinished portrait).

Appendix 5: Method of assigning elements to Five serial positions. (Wing and Baddeley, 1980).

Total no. of elements in string	*Serial position in string*				
	1	*2*	*3*	*4*	*5*
1	—	—	1	—	—
2	1	—	—	—	2
3	1	—	2	—	3
4	1	2	—	3	4
5	1	2	3	4	5
6	1	2	3,4	5	6
7	1,2	3	4	5	6,7
8	1,2	3	4,5	6	7,8
9	1,2	3,4	5	6,7	8,9
10	1,2	3,4	5,6	7,8	9,10
11	1,2	3,4	5,6,7	8,9	10,11
etc.					

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