PHONOLOGICAL AWARENESS: INFLUENCES AND ASSOCIATES IN THE CONTEXT OF THE DEVELOPMENT OF WORD READING IN YOUNG CHILDREN

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ABSTRACT

This thesis sets out to investigate aspects of the development of phonological awareness in relation to word reading in children aged between 5- and 7-years. The principal aim has been to establish how, for these children, phonological awareness relates to other cognitive factors that might jointly support the development of early reading skills. Data derives from children in their first three years of formal education (aged 5- to 7-years) and a group of partially-hearing children aged 7-years.

The children's performance in a measure of categorical speech have been compared with their levels of implicit phonological awareness. The results do not indicate that phonological awareness is significantly associated with children's ability to categorise speech sounds.

Following this investigations have been conducted to determine the extent to which implicit phonological awareness is affected by working memory and lexical knowledge. It emerges that memory is implicated in the phonological awareness tasks, but is not a developmental antecedent. The phonological similarity effect is also studied and not found to relate to age or reading ability in hearing or partially-hearing children. Aspects of the working memory model are discussed in relation to children's performance in tests of word recognition and phonological awareness.

In the penultimate chapter children's lexical knowledge (vocabulary) is found to interact with their performance in the measure of memory span. It appears that the development of the awareness of initial phonemes may be facilitated by having limited memory processing space. Overall it was found that lexical knowledge was predictive of phonological awareness. This conclusion was supported by a finding that the partially-hearing children had poorer lexical knowledge than younger hearing children with levels of phonological awareness similar to the partially-hearing children.

The findings in that chapter also indicate that phonological awareness and lexical knowledge may make separable contributions to word reading. In the final chapter structural equation modelling of 'Reading' is undertaken in order to establish how phonological awareness, memory span and lexical knowledge together relate to word reading. The findings there confirm the covariance of phonological awareness, memory

span and lexical knowledge, but also suggest that, in contrast to other research findings, these factors may not always be clearly related to word reading.

The study has also elicited some information about the likely difficulties of partially-hearing children who were here not found to have good levels of phonological awareness or lexical knowledge. In the final chapter it is suggested that further work should be undertaken to study partially-hearing children to establish how reading develops in the absence of age-appropriate levels of phonological awareness and lexical knowledge.

Chapter One

Introduction and Aims

It is widely acknowledged that 'phonological awareness' is a central component in children's reading (see Share, 1995, for a recent overview). Without adequate phonological awareness children's reading develops slowly, or falteringly (Liberman & Shankweiler, 1985). It has also been shown (Bradley & Bryant, 1983; Hatcher, Hulme & Ellis, 1994; Tunmer & Hoover, 1993) that specific training in phonological awareness causes improvements in reading performance. Frith (1995) locates phonological difficulties as a central cognitive problem for children with dyslexia, and Stanovitch (1994) concludes that most cases of 'reading disability' arise because of difficulties in word recognition processes. It should be noted in passing that there is evidence from case studies of clinical disorders (eg Saffran & Masrin, 1977) and of early readers (Seymour & Elder, 1986) that word recognition is not wholly dependent on phonological processing. Bryant & Bradley (1987) also emphasise that in their researches while phonological processes consistently account for a significant proportion of the variance in reading, there is still a substantial amount of variance in reading that is not accounted for by phonological processes. It is however now recognised that fluent word recognition is clearly inhibited if children have difficulty learning the coding relationship between alphabetic letter patterns and phonological segments (Bryant, MacLean, Bradley & Crossland, 1990; Goswami & Bryant, 1990; Tunmer & Nesdale, 1985; Wagner & Torgesen, 1987). It should however also be recognised (as pointed out by Fries, 1963) that there is not a one-to-one relationship between letters and sounds.

Much of the work that has been undertaken has been devoted to researching the influence and development of phonological awareness during the development of reading. Arising out of this work evidence has emerged which indicates that children's phonological skills are not stable cognitive competencies, but form part of a relationship which is reciprocal with reading and other competencies. Cataldo & Ellis (1988) and Ellis & Large (1987), for instance, found that reading and 'implicit' phonological awareness (that is a level of awareness that precedes the explicit and conscious ability to manipulate segments of sounds) have reciprocal influences on each other.

Ellis (1990) extended the picture by including short-term memory as a variable and showed that at an early stage phonological processes interact with an aspect of short-term memory in the development of reading. But once reading acquisition was underway it was, in Ellis' (1990) account, reading itself that promoted phonological skills and short-term memory. If, therefore, as Wagner, Torgesen, Laughon, Simmons & Rashotte (1993) conclude, there are causal influences on phonological processes *during* the acquisition of reading, it would seem interesting to attempt to clarify some earlier influences that might be available to children during the earliest stages of education *before* they begin to acquire skills in literacy. By studying children who, at the start and during their first year of formal education make little progress in reading, it was hoped in this present research project to gain some further understanding of how phonological awareness might develop independently of reading.

The development of implicit phonological awareness, that is the awareness of the sound structure of language (Wagner and Torgesen, 1987), as assessed by two measures, and its relationship to the development of word reading between the ages of 5- and 7-years is described in Chapter 4 of this thesis. A simple question that is then asked is whether the development of phonological awareness is at all dependent on children's perception of speech sounds. The evidence in answer to that question is explored in Chapter 5 where the relationship between phonological awareness and children's categorical perception of speech is assessed in children with and without hearing difficulties.

The relationship between memory and phonological processes has variously been assumed and explored. In the methodology for assessing phonological awareness that was developed by Bryant and colleagues (Bradley & Bryant, 1978, 1983; MacLean, Bryant & Bradley, 1987) it was acknowledged that children's memory could be a factor in limiting their performance in the phonological awareness tasks. As part of the work that is described in Chapter 6 an assumption made by MacLean *et al* (1987), that phonological awareness tasks impose a memory load, is tested. Further, work by Gathercole & Baddeley (1989, 1993a, 1993b) and colleagues (Gathercole, Willis & Baddeley, 1991; Gathercole, Willis, Emslie & Baddeley, 1992) has explored commonalities between aspects of phonological awareness and 'phonological memory', and has shown causal relationships (that changed in direction with age) between 'phonological memory' and vocabulary knowledge. Although some aspects of this work have been challenged (Snowling, Chiat & Hulme, 1991) because within 'phonological memory' input and output phonological processes may be confounded, Gathercole *et al*'s work has highlighted the possibility, at least, of interactions between memory, vocabulary and phonology amongst the influences on children's early attempts at reading words. In Chapters 6 and 7 of this thesis aspects of the relationship between children's phonological awareness, short-term working verbal memory and vocabulary knowledge, and the development of word reading skills are further explored.

The overall aim and methodology adopted for the research that is described in this thesis has also been developed in order to arrive at a model of the inter-relationships of a number of possible sources of influence on phonological awareness. The rationale underlying the particular methodology used is discussed in greater detail in Chapter 2. Essentially the approach adopted is one in which performance in tasks assessing phonological awareness, speech perception, memory and vocabulary knowledge by a group of children is investigated in detail and compared to the performance in the same measures of a group of partially hearing children. The group of partially-hearing children have been included because they might provide critical tests of certain hypotheses relating primarily to children's perception of speech and language, and because children with 'mild' or 'moderate' permanent loss of hearing are a group who, in comparison to children with severe or profound hearing-impairment, have been significantly underinvestigated.

A further reason for wanting to include a group of partially-hearing children was because of the wide-spread prevalence of conductive loss of hearing due to otitis media, and some unquantified evidence that a substantial proportion of children referred by schools with reading difficulties were, retrospectively, found to have suffered some intermittent hearing difficulties. In reviewing reported prevalence rates Bamford & Saunders (1991) indicate that otitis media is indeed a very common disorder, particularly in preschool and early school-age children. In summary Bamford & Saunders (1991, p79) state that 'It appears therefore that most children suffer an attack of otitis media at least once before the age of 10 [years].' There is however (Bamford & Saunders *op cit* report) a lack of consensus about a working definition for otitis media, and diagnosis rates vary as a consequence. The lack of clear diagnostic factors and the potential for fluctuations in hearing levels were, with regret, thought to present operational difficulties in terms of defining and selecting a distinct group of children for this study. It was however possible to produce a precise working definition for children with a partial sensori-neural loss of hearing. The criteria for inclusion in this group were defined as a prelingual diagnosis of sensori-neural loss in the range 40 to 80 dB in both ears. To some extent therefore this clinically definable group must suffice as a proxy for the clinically less distinctive group of children with intermittent or fluctuating conductive loss of hearing, although the consequences of the two types of hearing loss are clearly not equivalent.

Children who have, or who have had, otitis media deserve more thorough studies in their own right (see Bamford & Saunders, *op cit*, for reviews of work in this field), but it was thought that such a study was beyond the scope of this research project. However typical hearing levels in children suffering bouts of otitis media are reported to be of the order of 25dB and to affect all frequencies (in contrast to sensori-neural losses in which there may be substantially poorer hearing thresholds, and differential effects across the frequency range are very likely). This might suggest that the conductive loss should be considered the less serious of the two sources of hearing difficulties. Bamford & Saunders *op cit* however take a more negative view. This arises because children at risk of otitis media may also incur a significant risk of language delay. Problems in language development for the child with otitis media may occur because, as the condition fluctuates, the processes of organising and categorising auditory information is likely to be impaired. As indicated by Bamford & Saunders (*op cit* pp 176) the unpredictable and fluctuating hearing impairment caused by otitis media may have 'a surprisingly adverse effect on speech and language development, in comparison with a sensori-neural loss of the same, or even greater, degree.' This slight digression is intended to point out that although effects of the two types of hearing difficulties are different, it is possible that a study of children with mild/moderate sensori-neural losses might provide an estimate of the potential effects of recurrent otitis media.

As Davis, Elfenbein, Schum & Bentler (1986) and Webster & Wood (1989) have noted, there is, in any event, a scarcity of evidence relating to the development and needs of children with partial (mild or moderate) loss of hearing. It is hoped that some parts of this present study will help to add to the small body of knowledge about such children. Children with mild or moderate sensori-neural losses seem in fact to be more prevalent than children with severe or profound loss. Upfold & Isepy (1982) reported that children with mild or moderate losses were found in 1.5 children per 1000 live births (and formed 58.5% of the hearing impaired children), whereas severe losses were found in 0.6 per 1000 live births (23.7% of the hearing-impaired) and profound losses in 0.5 per 1000 (17.5% of hearing-impaired children); and Parving (1983) found that in a sample of 117 children (median age 8 years) there were approximately twice as many children with moderate sensori-neural losses as there were severe or profound losses of hearing. There appear however to be very few studies which include data on children with mild or moderate sensori-neural losses.

In one of the few studies of partially-hearing children, Hardy, Pauls & Haskins (1958) found a non-significant difference between reading levels, but a significant difference in vocabulary knowledge between the hearing and partially-hearing children. The partially-hearing children had pure-tone hearing thresholds which averaged 42dB (SD=9.3). A very high correlation (r=0.91) was found between the partially-hearing children's reading and vocabulary scores, whereas for the normally hearing children the correlation was rather smaller (r=0.75). Hardy *et al* (1958) do not evaluate the significance of the difference between these coefficients but interpret the finding as suggesting that '...reading is probably a more important resource of language for the hearing-impaired than for the normal-hearing child.' (*ibid*, p8). In fact using the procedure for testing the significance of the difference between two correlation coefficients described by Cohen & Cohen (1983, p 54) these two correlations are not significantly different (z=1.63, one-tailed p=0.0516). On the basis of the data collected by Hardy *et al* (1958) it is also not possible to infer any causal connection, let alone a direction of causality. However the evidence of association between reading and vocabulary is of interest, and has since been substantiated in both partially- and normally-hearing children (Davis, Elfenbein, Schum & Bentler, 1986; Owrid, 1970; Tunmer & Nesdale, 1985).

Vocabulary knowledge also appears to be depressed in the hearing-impaired. Davis *et al* (1986) found that children with hearing losses in the range 15 - 80 dB obtained scores in a standardised test of vocabulary (PPVT, Dunn & Dunn, 1981) that were significantly below those that would normally be expected. King & Quigley (1985) state that deaf students show a typical profile of performance in subtests of educational achievement with the lowest scores being found consistently in vocabulary. Jensema (1975) and Rogers, Leslie, Clarke, Booth & Horvath (1978) also found a relationship between vocabulary and degree of hearing-impairment such that greater loss of hearing was associated with poorer vocabulary.

The literature that does exist on partially-hearing children's reading also suggests that even moderate losses of hearing may be associated with significantly worse performance in tests of reading (Conrad, 1979; Cooper & Arnold, 1981; Davis *et al*, 1986; Kyle, 1980). In this thesis the data obtained from the group of partially-hearing children (mean age 7-years) will be analysed and compared with the hearing children who are grouped as 5-, 6-, and 7-years-old, in order to evaluate the effects of the hearing difficulties on reading and contributory factors.

As has been outlined above separate chapters of the thesis are devoted to selected aspects of children's abilities and how each of these abilities relates to their phonological awareness and reading. Each chapter also provides a detailed review of literature relevant to the topic of that chapter. In the final chapter (Chapter 8) the inter-relationship of the separate variables is assessed by means of confirmatory factor analysis using LISREL (Jöreskog & Sörebom, 1984).

This last aspect of the research reflects recent work on both theoretical and empirical models of the inter-relation of variables which might affect reading, (Barron, 1986; Cataldo & Ellis, 1988; Ellis & Large, 1988; Hulme, Snowling & Quinlan, 1991; Rack, Hulme & Snowling, 1993; Seymour, 1987; Wagner, Torgesen, Laughon, Simmons & Rashotte, 1993).

There is now sufficient understanding of the role played by various factors (including phonology, memory and vocabulary) in the development of reading which is substantiated in theoretical and experimental work (see for example Adams, 1990; Adams & Bruck, 1993; Rack, Hulme & Snowling, 1993; Siegel, 1993; Stanovitch, 1993) to warrant modelling of the inter-play between variables. Developments in statistical methodology now provide experimenters with the tools with which to investigate such models. The research reported in this thesis is a small scale attempt to trial such an approach in the context of natural experiments carried out within a case study of a small group of children. As such, therefore, the conclusions of the investigations carried out here can only be regarded as tentative, requiring replication in large scale studies involving children drawn from a range of settings to substantiate or refute the claims that will be made below. The following chapter outlines in greater detail the rationale underlying the investigative approach adopted.

Chapter Two

Investigative Rationale

2.0 Overview

This chapter is intended simply to provide a description of the approach adopted to investigate the role and inter-relationship of variables of interest. Subsequent chapters will provide reviews of previous work in the field that is relevant to the topic of each chapter and the development of this thesis.

2.1 Background

Traditional paradigms for scientific research involve the testing of hypotheses to establish or confirm general laws or theory. This approach as it applies within psychological research has been described for example by Kerlinger (1969). In this type of approach the scientist would, on the basis of experience and previous researchers' work in the area of interest, formulate a problem and a testable hypothesis. The hypothesis could then be tested by experiment and observation. As Kerlinger (*op. cit.*, p 17) noted:

> 'What is important is the over-all fundamental idea of scientific research as a controlled rational process of reflective inquiry, the interdependent nature of the parts of the process, and the paramount importance of the problem and its statement.'

In discussing the development of the scientific approach Popper (1969, p 36) asserted the need for theories which are incompatible with certain possible results of observation. This view arose from Popper's critique of interpretations in the light of theories (such as Freud's psycho-analytic theory) and the need to avoid the 'Oedipus Effect' (*ibid* p38). Popper (1969) used this term to describe the influence that a theory or prediction might have on the events predicted by the theory, and the associated risks to theory (and scientific progress) of merely seeking evidence that confirms a speculation.

2.2 The development of the paradigm for this research

Simon (1981), however, described psychology as an example of a 'Science of the Artificial'. By this he meant that psychological research was concerned with exploring phenomena that arise when the functioning of one system is determined by, or is an *artifice* of, its interaction with another system. In the context of the research described in this thesis, this can be seen as the phenomenon of phonological awareness arising from the interaction between children's cognitive abilities and the demands of learning to read.

2.2.1 '*Problem Solving Without a Goal*'

An approach that was considered for the research to be undertaken here was that entitled 'Microgenetic' (Siegler & Crowley, 1991). In that paper ways of studying change were described. A problem that is addressed by the microgenetic method was identified by Vygotsky (1978, p68) as being one in which (previously) "investigators have studied reactions in psychological experiments only after they have become fossilised." The microgenetic approach requires knowledge and theories about a particular domain, and is well suited to investigating how children's problem solving strategies change. An advantage of the approach is that it is not restricted to testing whether a predetermined outcome has, or has not, been achieved. A major disadvantage, critical for this researcher, is the need in applying the microgenetic approach for dense sampling of behaviours and the consequent cost to the researcher in terms of time. It was not felt that it would be possible in this research project to be able to reliably and intensively gather sufficient data to use the microgenetic method.

An alternative approach, though less detailed, is a process described by Simon (1981) as 'Problem Solving Without a Goal'. Whilst mindful of Popper's (1969) caution against conforming to an 'Oedipus Effect' the methodological aim in the present research was to undertake research within a given domain without the constraint, or foreknowledge, of what outcomes might be expected in terms of the detailed inter-relationship between variables.

Simon's (1981) process has as its objective the discovery of concepts and conjectures about them within a specific domain. The system consists of three basic protocols. These define firstly criteria for 'interest', secondly heuristics for searching in the problem space, and finally some rudimentary knowledge about the domain to be searched. One of the important strategies in the process, to reduce the size of the solution space, is to deliberately set out to find contradictions that would follow from a postulated solution. This is an element in the process which has similarities with Popper's (1969) requirement for refutable conjectures as necessary to qualify as having the status of a scientific methodology. Consequently problem solving may become an iterative process since, if a conjecture is found to be false, or evidence contradicting a possible solution is found, the original hypothesis must be reformulated and retested. Thus the main purpose of the process is at each stage to redefine the problem and the problem solving process, without simply seeking confirmatory evidence.

In terms of criteria for 'interest' with respect to concepts or conjectures that might be discovered, Simon (1981, p124) suggested that possible criteria of interest would be that a concept can be used to formulate 'strong' conjectures, or if an example of the concept is 'borderline' - that is it barely satisfies the definition of the concept. Simon (1981) does not define what a 'strong' conjecture might be; Popper (1969), however, described 'interesting' questions as ones which will sharpen the focus of attention (within the iterative process of enquiry) to show that there are circumstances, or examples, when a given conjecture or hypothesis does not hold.

There are, for the statistical tests of hypotheses that are used in psychological research, conventional probabilities for accepting or rejecting alternative hypotheses. Recently Dracup (1995) has provided a reminder of the logic underlying such decisions. This entails some acceptance of conditional probabilities. Thus, as Dracup (*ibid*, p359) says with respect to the probability of making Type 1 errors:

> "The correct interpretation is that if the null hypothesis were true, then the probability that our experiment would produce a significant result (and the null hypothesis [that there is no effect] be rejected as a consequence) would be equal to the significance level at which the test was conducted."

Thus if, for example, the significance level is set at 0.05 and a null hypothesis is rejected at that level, then it is wrong to infer that the probability that the null hypothesis *is true* is also 0.05. The valid line of reasoning given by Dracup *op. cit.* leads to the probability, $p(H_\varnothing)$, that the null hypothesis is true given a significant result being given as

$$p(H_\varnothing) = [\alpha \times p(H_0)] \div [\alpha \times p(H_0) + (1 - \beta) \times (1 - p(H_0))]$$

where $(1 - \beta)$ represents the power of the test, and $p(H_0)$ represents the probability of the null hypothesis being true before the investigation is carried out.

The values of $(1 - \beta)$ and $p(H_0)$ are however indeterminate for any real experiment. The strategies that are available to minimise the value of $p(H_\varnothing)$ are to attempt to reduce the size of $p(H_0)$ and to increase the power of the investigation, $(1 - \beta)$. The power of an investigation is the probability of failing to reject the null hypothesis, given that it is false, ie of making a Type 2 error (Cohen & Cohen, 1983; Dracup, 1995)

$p(H_0)$ can be reduced by selecting for investigation hypotheses that on the basis of previous theoretical and experimental work are more plausible in that domain. The power of the investigation is greater when the sample size is large; when the experimental effect size is large; and when the reliabilities of the measures used is high thus reducing the standard deviation.

On the basis of the above line of argument the investigations to be carried out in this present study may be thought to have low power (due to small sample size). It may also be the case that the work is vulnerable to a high risk of making Type 1 errors since the approach adopted is one in which repeated examination of the same sample will be made, in the iterative approach that follows from Simon (1981) and Popper (1969), with an increased probability of detecting a 'significant' result by chance. It is as well therefore to regard this work as a pilot study, and as was indicated on Chapter 1, to stress that any results of interest should be subjected to further replication in both experimental work and surveys of children in a wider range of settings.

2.3 A brief overview of the approach adopted

Within Chapters 4 to 7 the data obtained from both normally hearing and partially-hearing children will be used to test hypotheses which derive firstly from extant research carried out by others. In the light of the results of these tests, where appropriate, and within the limits of the data that is available, alternative conjectures will be examined. With respect to the model of investigation that has been outlined above the guiding principles for the formulation of conjectures are

1) Concurrence with preexisting theory;

2) Susceptible to refutation or confirmation by two-tailed statistical tests with $p<0.05$, or greater;

3) Of interest in terms of illuminating or challenging existing knowledge;

Within each chapter, where possible, the data are examined both cross-sectionally, ie for relationships between data from measures applied at the same age, with contrasts between ages, and between the groups of normally-hearing children and the group of partially-hearing children being highlighted, and also longitudinally to establish if over the 12 month period between measures there were developmental changes.

In the process of the repeated analysis of the data, as was suggested above there is an increased risk of spuriously significant results being detected. However if, as is intended the process is likened to the use of an archeologist's sieve, then the aim of the process is to eliminate spurious matter and to be left with the most salient and consistent set of conjectures. In the final chapter (Chapter 8) therefore the resultant model of the inter-relationship between variables that can be derived from the findings of the preceding chapters will be subjected to analysis by means of LISREL (Jöreskog & Sörbom, 1984). In this however Mulaik, James, Van Alstine, Bennett, Lind & Stilwell (1989) cite Popper (1961) and stress the need for an awareness of the issue of scientific parsimony and 'disconfirmability'. Thus although it is hoped that the final conclusions may be held to have some statistical and psychological validity, it should be recognised that the final models should only be regarded as conjectures for which it may be easy to find refutations.

Chapter Three

Methodology

3.0 Overview

This chapter will set out and describe the overall design of the study, the groups of children who were studied and the measures used.

3.1 The overall design

The purpose of the study has been to investigate the relationships between variables which, on the basis of an examination of existing literature, might be thought to inter-relate and have some bearing on the development of phonological awareness and word reading. The approach adopted, to establish whether or not there are interconnections between variables, has been to study cognitive functions in two discrete groups of children.

Since the study was intended to explore factors relating to the first stages of word reading, the children were selected from the first three years of formal education (ie aged approximately 5-, 6- and 7-years), with the youngest having only just begun full-time school. Since an hypothesis to be investigated was that phonological awareness might depend on children's hearing of speech, the second group of children were selected with a partial, but permanent, loss of hearing in both ears. These children were selected to be aged 7-years in order to achieve some comparability with the normally hearing children, but, in expectation that the partially-hearing children might not, in some respects, be functioning as well as their chronological age peers, it would be possible to compare the partially-hearing children with hearing children aged one or two years younger.

From the first group, children who had no diagnosis of hearing difficulties, data was obtained from a range of measures (outlined below) on two occasions separated by twelve months. Testing was carried out during September and October on both occasions so that the youngest children had only just begun formal education, and that a full school year elapsed between the two test sessions.

In this way it was intended to gather both concurrent, cross-sectional, data relating to children's performance at any one age, and longitudinal, developmental, data. Comparisons between ages might therefore be achieved from both unrelated and related groups.

The second group of children, those with partial loss of hearing, were also administered the same set of tests as the children with no hearing difficulties. Due to constraints of access and time however these children were only studied on one occasion. Their performance in the same set of tests has been compared with the performance of the children without hearing difficulties.

3.2 The children studied

The children with no hearing difficulties were drawn from the full population of a mainstream primary school in a community of low socioeconomic status (over 60% of children having free school meals). A group from each age was drawn in two successive years (1992 & 1993) and was selected from those who were thought by their teachers not to show any indication of sensory, learning, or reading difficulties.

Children who might participate in the research were all screened using a Goodenough analysis of their drawings of a person. One child was eliminated from the study on the basis of failing to achieve a developmental level in the Goodenough test that was within one year of his chronological age. All remaining children were checked against audiological records for hearing difficulties, and none found. All children had English as their home language. From the remaining suitable children 15 at each age (5-, 6- & 7-years) were randomly selected with roughly equal numbers of boys and girls in each group.

The battery of tests that were administered included tests of non-verbal ability (Ravens Coloured Matrices), receptive vocabulary (BPVS) and tests of Word Recognition (Carver) and Word Reading (British Ability Scales). Raw scores for all children are reported in Appendix 1. All children scored within normally acceptable limits on the non-verbal screening measure (Ravens matrices). No child in the R-groups (aged 5-years approximately) was able to demonstrate any raw-score on the BAS test of word reading, and all children in these groups performed at levels that might have occurred by chance on the test of word recognition. All 5-year old children in the study may therefore be considered non-readers.

Unfortunately some children who were seen in the first round of tests were not available for the second round of testing, so the longitudinal data consists of 13 children tested at 5- and again at 6-years, and 11 tested at 6- and a year later at age 7-years of age.

In order to investigate the possible effects of impaired perception of speech, data from 15 seven-year old children with prelingually diagnosed moderate-severe hearing loss (in the range 40-80dB bilateral sensori-neural loss) were gathered. These children were identified by teachers of hearing impaired children and were drawn from a number of LEAs in the North of England. The audiological thresholds for the partially-hearing children are presented in Appendix 3. The overall mean loss for this group was found to be 62.3dB. The profile of mean thresholds across the frequency range suggests that as a group these children would be more likely to have difficulty perceiving higher frequencies, such as that which typically cues consonantal information. The test battery was administered to the partially-hearing children while they were wearing their hearing-aids, the fit and functioning of the aids having been checked by the child's teacher immediately before tests were administered.

For the purpose of a more formal experimental investigation of an aspect of memory and phonology that was undertaken, and is reported in Chapter 6, a random selection of children aged 5- to 7-years was made from the population of two other primary schools in the same area of the North-East of England. Details of the methodology, the children and their schools are reported in §6.1.3.

All children were tested individually in a quiet room in their school. Tests were administered in the order: Speech Perception; Phonological awareness; Memory; Vocabulary; Non-verbal ability; Word recognition; Word reading. Most children were able to complete this battery of tests within 30 minutes. However a few who were thought to be having some difficulty were seen on two separate occasions.

The overall plan of comparisons and investigations is shown below in Figure 3.1.

Fig 3.1: Outline of planned comparisons and investigations

	Speech Perception	Memory	Vocabulary	Phonological Awareness
Changes with Age ?	Cross-sectional and longitudinal comparisons: Non-parametric tests. See Chapter 5.	Cross-sectional and longitudinal comparisons: F-ratio. See Chapter 6.	Cross-sectional and longitudinal comparisons: F-ratio. See Chapter 7.	Cross-sectional and longitudinal comparisons: F-ratio. See Chapter 4.
Associated with Phon'l Awareness ?	Correlational and regressional analysis. See Chapter 5.	Correlational and regressional analysis, and experimental manipulation. See Chapter 6.	Correlational and regressional analysis. See Chapter 7.	Chapter 4
Associated with other Variables ?	Correlational and regressional analysis in Chapter 5	Correlational and regressional analysis in Chapters 6 and 7.	Correlational and regressional analysis in Chapters 6 and 7.	Correlational and regressional analysis in Chapters 5, 6 and 7; experimental investigations in Chapter 6
Associated with Reading ?	Not to be tested	Correlational and regressional analysis in Chapters 6. LISREL analysis in Chapter 8.	Correlational and regressional analysis in Chapters 7. LISREL analysis in Chapter 8.	Correlational and regressional analysis in Chapters 4. LISREL analysis in Chapter 8.
Affected by Hearing Impairment ?	Performance of partially-hearing and hearing children compared in Chapter 5.	Performance of partially-hearing and hearing children compared in Chapter 6.	Performance of partially-hearing and hearing children compared in Chapter 7	Performance of partially-hearing and hearing children compared in Chapter 4.

3.3 The measures

3.3.1 Speech Perception

Voice Onset Time, defined as the time between the initial opening of the vocal tract and the onset of the voiced vowel, was chosen as the variable to assess perceptual ability. This parameter was chosen since there is an extensive literature on its use in experimental work with children, and voicing is a feature in Chomsky & Halle's (1968) taxonomy which can be experimentally manipulated. The use of Voice Onset Time perception in relation to the phonemic system of the listener and the development of phonology is reviewed in Zlatin & Koenigsknecht (1975). Further, there is reference data (for example Simon & Fourcin, 1978) and the available measure has been used with children with hearing impairments (Hazan, Fourcin & Abberton, 1990, 1991). An identification task, rather than a discrimination task, was chosen because the former could be thought to be linguistically more demanding (Burnham, 1986). In pilot testing of the measure used here (a test of categorical speech labelling that has been developed by Fourcin and colleagues at UCL (see Hazan & Fourcin, 1985, for details)) it also appeared that the stimuli ('goat' 'coat') had greater familiarity and appeal for children in the present study than did another option (a place of articulation contrast using 'date' & gate' as stimuli). The 'date'-'gate' continuum appears to be more accessible to slightly older children (Elliott, Longinotti, Meyer, Raz and Zucker ,1981; Hazan and Fourcin, 1983; Snowling, Hulme, Smith and Thomas, 1994).

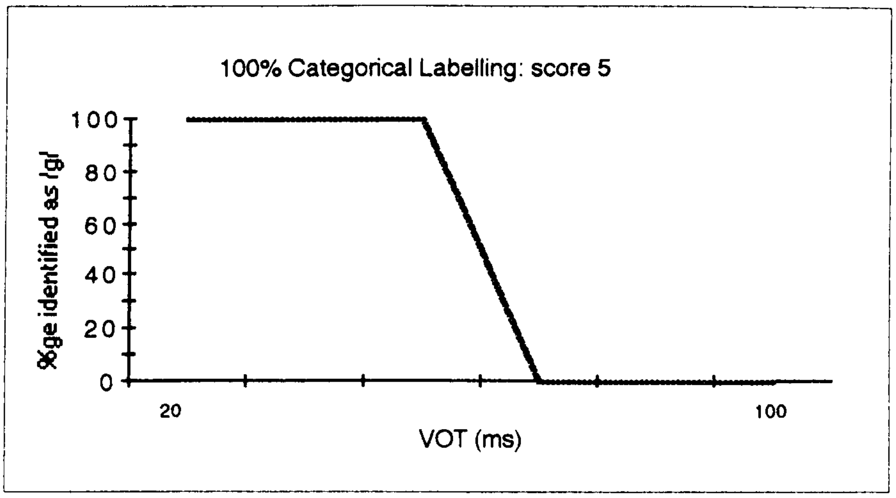
The procedure adopted was therefore a forced-choice task in which children were presented with synthesised stimuli drawn from the Voice Onset Time continuum varying in 6 steps from 20ms for /goat/ to 100ms for /coat/. Stimuli were presented from audio cassette in a fixed random order. Free field presentation was used (with the cassette player (a Coomber Model 2060-1) placed 1 metre in front of the child) and the child was required to indicate, by pointing to either of two pictures placed in front of the child, whether it was [goat] or [coat] that had been perceived.

Each child was first given 6 practice items using only the endpoints of the continuum with, if necessary, prompted identification of the pictures as 'goat' and 'coat'. Test stimuli were then presented in 10 blocks of 6 stimuli, with a token at every point on the continuum occurring once in each block. The order of stimuli is different between blocks, but fixed for all children. The test stimuli were given without any feedback or help.

Following the lead of Hazan, Fourcin & Abberton (1991) children's responses were coded depending on the accuracy and consistency with which stimuli were categorised with respect to the idealised adult pattern of labelling (see Figure 3.1, below). If steps 1,2,5,6 and either 3 or 4 were labelled with 100% consistency and accuracy a score of 5 was given. An idealised representation of this is given in Figure

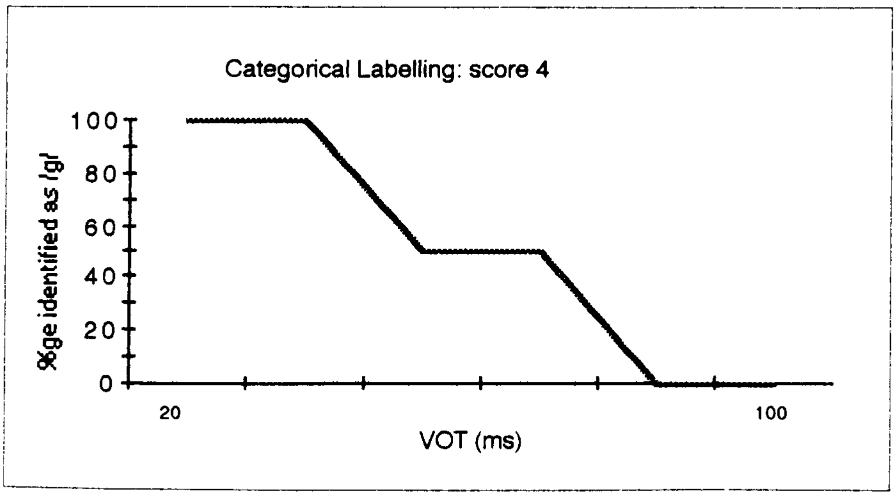
3.1a. In these figures the vertical axis indicates the percentage of stimuli categorised as /g/

Fig 3.1a: Idealised pattern of responses which are 100% consistently categorical as either 'goat' (steps 1 - 3) or 'coat' (steps 4 - 6)



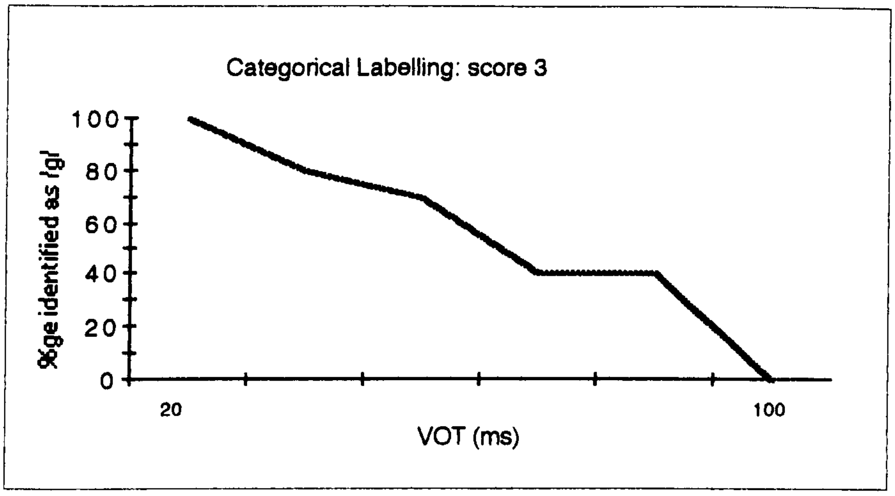
If steps 1,2,5 & 6 were always labelled accurately a score of 4 was given, and an example of the pattern of responses (the labelling function) for this score is shown in Figure 3.1b:

Fig 3.1b: An example of the labelling function scored as 4



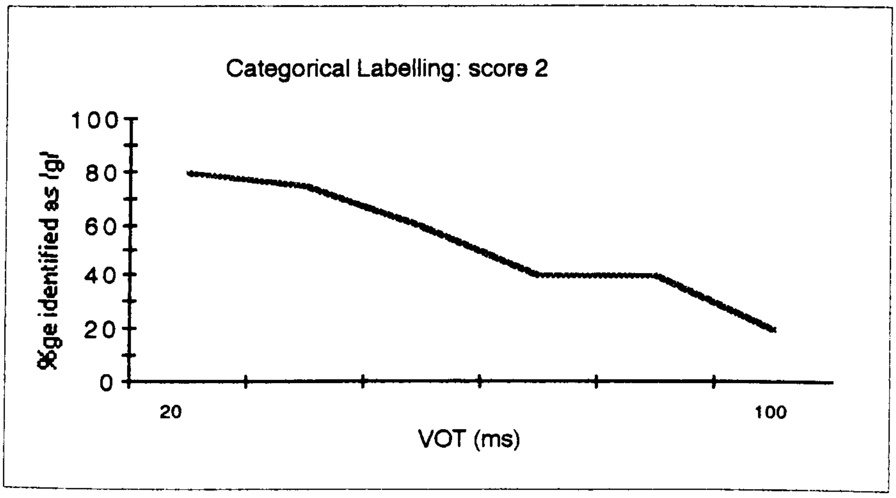
When only steps 1 & 6 were labelled 100% accurately, the child scored 3, with responses being somewhat as in Figure 3.1c.

Fig 3.1c: <u>An example of a labelling function scored as 3</u>



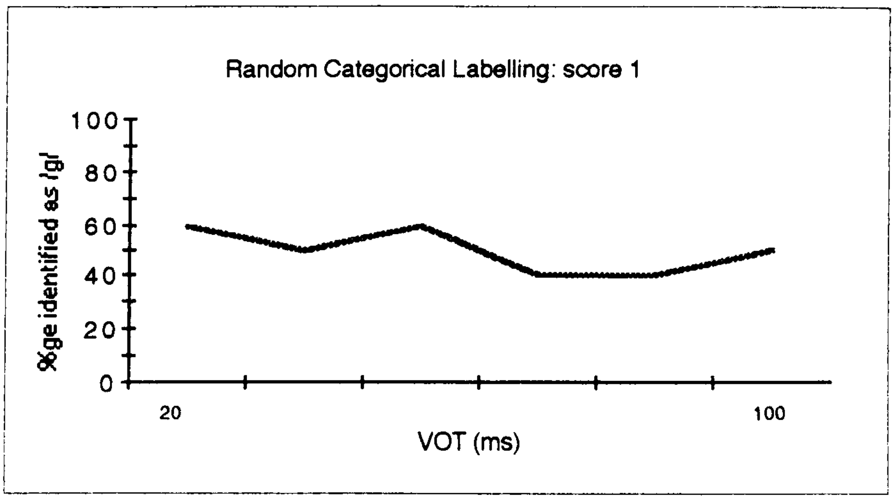
A score of 2 (as shown in Figure 3.1d) was given when steps 1 & 6 were only labelled with 80% accuracy.

Fig 3.1d: <u>An example of a labelling function scored as 2</u>



A child was given a score of 1 if none of the above criteria were fulfilled and the child appeared to be labelling on a random basis. Figure 3.1e provides an example of how this type of response might be represented.

Fig 3.1e: An example of a random labelling function scored as 1



3.3.2 Phonological Awareness

Tests of two aspects of phonological awareness have been developed for this study. Both involve *implicit* awareness (Cataldo & Ellis, 1988), in that in these tasks children are not required to perform conscious segmentation and manipulation of phonological segments. (This will be discussed in more detail in Chapter 4.)

Since the measures were to be administered to both young hearing and partially-hearing children, it was thought that pictures might help the children to attend to the tasks. (The assumption that the memory load is relieved by the use of pictures has been tested, and the results of that investigation are reported in Chapter 6.) Words to be used as stimuli had therefore to be chosen so that they could be represented in the form of a simple black and white line drawing. The use of pictures to support children in this type of task was first reported by MacLean, Bryant & Bradley (1987). Lenel & Cantor (1981) had earlier used pictures to represent words in a test of children's ability to identify the word which rhymed with a word (and picture) presented by the experimenter.

Two other modifications were made to the 'odd-one-out' approach (as developed by Bradley & Bryant, 1978, 1983) that formed the basis for the tasks employed here. The first of the modifications was to present just three words for comparison. Bradley & Bryant (1978, 1983) used trials containing 4 items of which three had a phonological feature in common. In the measures developed here it was thought that three words per trial would be adequate, and would permit the second modification to further simplify the administration of the test, and reduce the overall cognitive load of the test. The second modification was to require the child to identify the two words which contained the same phonological feature. Thus in the rhyme test the child would be asked to point to, or to say, which two words shared the same rhyme sound. Similarly in the test of awareness of initial phonemes, the child would be asked to identify which two words began with the same sound.

The tests were developed consisting of three practice trials, in which help and encouragement might be given, followed by 9 test trials in which no feedback was given. The position of the word which was intended to be phonologically distinct (the 'odd-one-out') was randomly varied to be, with equal likelihood, in each of the three possible positions within each three word trial.

Two pilot versions of the tests were administered to 18 children aged 5- to 7-years (6 in each year group) and reliability coefficients (Kuder-Richardson, r_{II} , see Anastasi, 1968) were computed for these children's scores. For the Rhyme and Initial Phoneme tests values of 0.52 and 0.09 were found. On examining the pattern of children's responses and the test items, and following further discussion and correspondence (Peter Bryant, personal communication, 1992) some possible flaws in the pilot versions of the test were identified.

Firstly, although some care had been given to minimise any possible semantic association between items, it seemed possible that for some children there was a non-phonological association between some words. Secondly, it was realised that the 'odd-one-out' sometimes shared sounds with other words in the same trial. Thus 'sun' and 'duck' were thought to share a similar vowel sound, and 'dog' and 'goat' both contained the phoneme /g/. The unevenness of these non-target similarities could, it was concluded, create confusion for some children. The tests were accordingly modified, and the resulting measures are shown in Appendices 4 and 5. The reliability of the final versions of these tests is discussed in Chapter 4.

3.3.3 Memory

3.3.3.1 *Memory Span*

Memory Span has been assessed using a test analogous to the familiar digit-span tests (such as those in the Weschler batteries and the British Ability Scales) which are widely used by professionals as measures of short-term memory. The test used here however involves auditorily presented letter names as stimuli. This test was also developed to provide a measure of span that would serve as a guide to the level of task difficulty that individual children could manage in an investigation of phonological similarity effects (see Chapter 6). Letter-names were chosen as the stimuli for this reason. Auditory presentation for both tasks (memory span and phonological similarity effect) was chosen for two reasons. Firstly, in terms of the discussion underlying this present research and with regard to the current model of working memory (Baddeley and Hitch, 1974; Gathercole & Baddeley, 1993b), auditory presentation should ensure that verbal information automatically enters the phonological store. Secondly, the use of auditory presentation would allow direct assessment of the impact of speech perception or hearing difficulties.

Memory span stimuli are strings of non-rhyming letter names drawn from the set {H,K,L,Q,R,S,W}. Stimuli are constructed by random selection (without replacement at any one string length) of letters from this set to form strings of increasing length. Stimuli are recorded by an adult English speaking male on audio tape at the rate of one letter a second. Twice the string-length time was allowed between items. Two strings of each length are presented, starting with two units {S, Q}. The full set of stimuli are shown in Appendix 6.

During individual testing (in a quiet room) each child sat facing the tape-recorder (a Coomber 2060-1) which was placed approximately 1 metre away with the experimenter sitting at the child's right-hand side at right-angles to the axis between the child and tape-recorder. Visual contact with the child could therefore be established and maintained, and the tape-recorder controls operated with ease. Following an introduction to the task during which individual letters were played and the child was asked to repeat each individual letter name (to allow for familiarisation and setting the volume at a comfortable level), children were then presented with strings of letter names of increasing length, beginning with strings of two letter names. The child was asked to repeat the letter names that they heard. Strings were increased by one unit if both strings of a given length were correctly repeated. Testing was discontinued when both strings of a particular length (N) were failed. Scores are the total number of strings passed.

The reliability and validity of the measure is discussed in Chapter 6.

3.3.3.2 *Phonological Similarity Effect*

Following the determination of memory span and the length of the string at which the child is first unable to repeat both strings of the same length, children were then presented with alternating rhyming and non-rhyming strings of letters. The rationale for this investigation is given in Chapter 6, but briefly follows from work by Conrad (1964, and *passim*), Johnston, Rugg & Scott (1987) and others, who have shown that the recall of phonologically similar items is less accurate than recall of phonologically distinct material.

The stimuli (see Appendix 7) were again prerecorded letter names, spoken at the rate of 1 letter per second. Twice the string length time was allowed between presentations for the child to respond, but the tape could be stopped if necessary to allow a child any additional time. This was in fact necessary on only a very few occasions. The scores were the total number of strings of either variety which were recalled correctly in serial order.

3.3.4 <u>Vocabulary</u>

The British Picture Vocabulary Scale (BPVS) - Short Form (Dunn & Dunn, 1982) was used to assess children's lexical knowledge. The BPVS is a commercially available standardised test of receptive vocabulary. This measure has been widely used in research (eg Gathercole, Willis, Emslie & Baddeley, 1991; 1992; Michas & Henry, 1994).

In the test children are required to choose (by pointing) which picture (from four on display) corresponds to the word spoken by the test administrator. Following four practice items when help and encouragement are allowed, the test is given without any further help. In this study testing began with the first item in the scale, although the test manual offers guidance for a higher starting point for children aged 7 to 9 years. In accordance with standardised procedures testing was discontinued when 4 errors had been made in 6 consecutive responses. Raw scores (ie total number of correct responses up to the point at which testing was discontinued) have been recorded.

The information given in the test manual includes split-half reliability coefficients. For children aged 4 to 8 years these range from 0.78 to 0.84 with a mean average of 0.81. In the results section (Chapter 7) reliability (Kuder-Richardson) coefficients are given for the data obtained here which compare favourably with the standardisation data.

3.3.5 Non-verbal ability

In order to be able to have some data relating to children's relative non-verbal cognitive abilities the Coloured Progressive Matrices, Sets A, A_B, B (Book Form, Raven, 1962; restandardised 1982) were administered to all children. Each item in this test consists of a coloured, non-representational picture with a choice of six inserts to complete the main picture. The child is scored as passing an item if the correct insert is chosen. With the three sets chosen the maximum possible score is 36.

3.3.6 Reading

3.3.6.1 *Word Recognition*

Word Recognition was assessed using a modification of the Carver test (Carver, 1970). In this test single words are spoken to the child, and repeated again in the context of an appropriate sentence. Children are tested individually and are required to select from a printed line of 5 or 6 single words the word that matches the word spoken by the test administrator. In the investigations reported here children were only given the first 10 test items from the full test. Reliability coefficients (Kuder-Richardson) have been computed for the data gathered from this test and are reported in Chapter 4 (Table 4.7). With the exception of the data from the youngest children the test as used in this study shows acceptable reliability.

3.3.6.2 *Word Reading*

Immediately following the Carver test each child was given the British Ability Word Reading Test A (Elliot, Murray & Pearson, 1983). In this test children are required to read aloud single words. The stimuli are lower case words printed in 18 lines of 5 words on one side of a sheet of A4 size card. There is no semantic context to aid recognition.

An objection to this test, that it is more likely to assess sight-word knowledge and not exercise children's phonological skills, has been raised by Gathercole and Baddeley (1993a). Although this point may have some validity, for the purpose of this study the measure provides a standardised indicator of children's word-reading development, and has, in comparison to many other measures of reading, been relatively recently standardised for children aged upwards of 5-years old. Thus although the test will not reveal the nature of the reading strategy that children might be using, it may be relied on to provide valid data on the children's relative development within the domain of word reading.

Chapter Four

Phonological Awareness and Reading

4.0 Overview

In this chapter the development of two aspects of phonological awareness (rhymes and initial phonemes) will be discussed first (§4.1). Findings from children aged 5- to 7-years will be reported which demonstrate age-related trends in both aspects.

In the second part of the chapter the concurrent and developmental relationships between phonological awareness and word reading are examined. In §4.2 the hypotheses to be tested are, broadly, that either phonological awareness is an antecedent of reading, or that the acquisition of reading facilitates the development of phonological awareness.

The last section of the chapter (§4.3) will contrast the findings derived from the work with children who have no hearing difficulties with results obtained from the group of 7-year-old children who have a moderate and permanent sensori-neural loss of hearing.

The focus of this chapter is on the developmental changes in phonological awareness in the children studied. It is necessary to establish how these children's phonological awareness might relate to their emerging skills in word reading before proceeding to the investigations into the effects of other factors on phonological awareness and reading that will be reported in later chapters.

4.1 The development of phonological awareness

4.1.1 Introduction

Children's ability to be aware of phonological segments within the speech stream has been of considerable interest to researchers over at least the past 30 years. In relation to reading, phonological awareness has been thoroughly investigated using a variety of tasks. The outcomes of this research consistently substantiate a high correlation between phonological awareness and reading skills. (For reviews of this see Adams, 1990; Ball, 1993; Goswami & Bryant, 1990; Share, 1995; Snowling & Hulme, 1994; Wagner & Torgesen, 1987).

One of the issues to be addressed in this chapter is the nature and development of children's awareness of phonological units. As will be made clear in this section and in §4.2, the stage at which children become aware of different units relates both to age and proficiency in literacy. It will be seen that awareness of rhyme and word-initial phonemes develops differentially.

One of the first contributors to the field, Bruce (1964), showed that it was not possible to take for granted children's ability to analyse sounds within words, and that young children (aged about 5- and 6-years) had extreme difficulty with tasks requiring an explicit awareness of phonemes.

The nature of the phonological segment to be identified was studied by Liberman, Shankweiler, Fischer and Carter (1974), and children aged 5- to 7-years were found to be able to detect syllables at an earlier age than phonemes. A similar developmental progression was found in a study of children aged 3- to 7-years by Fox & Routh (1975). They found an age-related progression in children's increasing ability to analyse sentences into words, syllables and finally phonemes. This suggested that for young children, at around the time they were learning to read, phonemes were not as easily identified, or manipulated, as syllables.

Mann (1986) proposed that awareness of syllables might be regarded as a simpler task than awareness of phonemes since syllables might be perceived to be isolable acoustic elements which are less 'encoded' within the speech stream than phonemes. (The nature of 'encoding' within the speech stream has been discussed and investigated by Liberman, Cooper, Shankweiler & Studdert-Kennedy (1967) who demonstrated that a 'phoneme' was not a distinctive element within the acoustic signal. It was found that there was no invariant acoustic cue for a given 'phoneme', but rather that the acoustic signal for that 'phoneme' varied according to the phonemic environment.)

The effect of the position within a word of the phoneme to be identified was investigated by Content, Kolinsky, Morais & Bertleson (1986), who found that although 4- and 5-year-old 'preliterate' children could delete both word-final and -initial phonemes, they were more likely to make mistakes with the initial phonemes. The results of Bradley & Bryant (1978, 1983) further suggested that children with some experience of reading (with reading ages equivalent to those which might be found in children aged up to 9-years 4-months) found tasks involving a discrimination of words' initial (phonemic) sounds harder than comparable tasks requiring awareness of medial or final sounds. The final and medial sounds in Bradley & Bryant's (1978) report were manipulated as 'phonemes', but in essence the changes also produced different rhymes.

Concentrating on sounds at the end of words, Lenel & Cantor (1981) had assessed the ability of children to recognise rhymes. Children in the study were aged 4-, 5- and 6- years. It was found that children at age 4-years could discriminate between rhyming and non-rhyming words. There was however also a significant effect of age showing that children's ability in the task improved with age. The methodology used by Lenel & Cantor *op cit* also enabled them to establish that children could show some understanding that the rhyming words (that were used in that particular experiment) differed only in their initial consonant. An interpretation of this offered by Lenel & Cantor *op cit* was that children as young as 4-years, and perhaps younger, could discriminate phonemes. The work carried out by Lenel & Cantor *op cit* also established that awareness of rhyme and phonemes could exist before the children had acquired any knowledge of reading. This study thus helped to show that while young children might not be able to manipulate phonemes, as required for example in Bruce's (1964) study in which children had been asked to remove the initial sound from a word to form another word (eg nice-ice), they might, according to the findings of Lenel & Cantor *op cit*, none-the-less be able to identify what sound a word began with.

This type of finding prompted some discussion about the demands of different phonological awareness tasks. On the basis of work undertaken with children aged approximately 6-years Stanovitch, Cunningham and Cramer (1984) concluded that there existed considerable comparability and interchangeability among the tasks assessing phonological awareness. However they found that some tasks (most notably those requiring a rhyming response) were significantly easier than others. However a task requiring the removal of the initial consonant was found to be extremely difficult, indicating once again how difficult the explicit manipulation of word-initial phonemes was for some children. At an intermediate level of difficulty were tasks employed by Stanovitch *et al, op cit* which assessed children's ability to identify if words shared a consonant sound in either initial or final positions. Some commentators (eg Cataldo & Ellis, 1988; Treiman & Zukowski, 1991; Valtin, 1984) have discussed the progression of cognitive demands made by phonological assessment tasks in terms of *implicit* and *explicit* phonological awareness. At the stage of making *implicit* judgments about phonology, it was suggested by Cataldo & Ellis (1988), children might be able to make some decision about whether or not words rhyme, but not yet be able to segment an individual phoneme or rime. Tasks requiring *explicit* awareness are ones in which there is a demand for conscious identification and manipulation of a phonological feature, as is required by a tasks such as those used by Bruce (1964).

The distinction between levels of segmentation has also been developed by Treiman (1985) and others who have clarified the evidence for a distinction between *Onset* and *Rime* in the structure of syllables. The onset is the initial consonantal sound (if any), and the rime consists of the vowel and final consonants. Thus 'train' segments into the onset /tr/ with the rime being /-ain/.

Morais, Alegria & Content (1987) had suggested that awareness of rhymes was not related to reading, and that awareness of phonemes was a consequence of learning to read. Kirtley, Bryant, MacLean & Bradley (1989) however showed, contrary to the views of Morais *et al* (1987), that children could show awareness of phonemes before learning to read, provided the phoneme to be identified coincided with the onset of the word. Kirtley *et al* (1989) demonstrated intermediate steps in the development of children's phonological awareness, finding that between the ages of 5- and 7-years children showed awareness of the intrasyllabic speech units of onset and rime, and that awareness of rhyme (which could be syllabic) might be due to awareness of rime (which will be intrasyllabic).

In the context of reading, phonological awareness, it seems, cannot therefore be considered to be a unitary concept. Within the general developmental view it is evident that awareness of various types and positions of phonological segments is differentiable, and that 'levels' of awareness may emerge in response to the needs of different developmental stages. Specifically it appears that the ability to distinguish rhyming from non-rhyming words seems to precede abilities to segment phonemes (Fox & Routh, 1975; Lieberman *et al*, 1974; Stanovitch *et al* 1984). Kirtley, Bryant, MacLean, & Bradley (1989) have since shown that at an intrasyllabic level of phonological awareness children who are non-readers can distinguish between words on the basis of a difference between single phonemes provided that the phoneme coincides with the word's onset.

The main prediction that is tested in the following section is that there were increments in children's phonological awareness as they learned to read. These analyses form a necessary preliminary to investigations that are reported in subsequent chapters. The choice of the tasks (Initial Phoneme and Rhyme awareness) was determined by theoretical considerations as outlined above, and a pragmatic need to use tasks that could be administered to both young hearing and partially-hearing children. It had been shown by MacLean, Bryant & Bradley (1987) using 'odd-one-out' tasks, that some children aged aged less than 4-years (mean ages 3 years 8 months) could detect rhyme and alliteration. MacLean *et al* (1987) had also thought it would be helpful (to remove the memory load from the tasks) to use pictures that represented the words in the task. Interestingly a substantial proportion of the children (at age under 4 years) in MacLean *et al*'s study scored at levels that could have occurred by chance. MacLean *et al* also found that there was a significant social class difference in scores in the alliteration task, with children from higher socioeconomic groups achieving better scores. On the basis of these results the measures to be used here were designed with accompanying pictures (as in MacLean *et al* s (1987) study), with the further modification of requiring children to identify the two words, out of three, which sounded alike. In Chapter 6 the validity of the assumption that the memory load is reduced by the presence of pictures will be examined. The phonological tasks employed here are thought to require only 'implicit' awareness since no conscious manipulation of segments is necessary.

A secondary prediction that will be examined is that children become aware of rhyme and initial phoneme at different times in their development. It seemed likely that the children would show awareness of rhymes before they became proficient at reading, but that awareness of the initial phonemes (which coincide with the onsets of the words) would emerge more slowly and not be clearly evident until reading was established.

4.1.2 Changes in Phonological Awareness over time

4.1.2.1 *Methodology*

The measures used and details of the children who participated in the study have been described in detail in Chapter 3.

Children's phonological awareness was assessed using the Rhyme awareness and Initial Phoneme awareness tests. The main study consists of data obtained from children aged 5-, 6-, and 7-years, in other words in the first three years of formal education. These groups will hereafter be labelled R (Reception class), Y1 (Y1 class) and Y2 (Y2 class) in accord with current policy in schools in England and Wales. Children at these ages were tested on two occasions separated by twelve months (in 1992 and 1993). Some of the children seen on the first occasion were available for testing on the second occasion and therefore form the basis of a longitudinal survey.

All tests were administered to children individually. All 5-year-old children were found to have no score in a the standardised test (BAS) of word reading. A high proportion (73%) of the 6-year-old children were also found to be unable to achieve a score in the same test. These children are therefore considered to be non-readers.

4.1.2.2 *Results*

The means and standard deviations of scores in the tests of phonological awareness and word reading at T1 and T2 are shown in Table 4.1 (below) together with Ravens matrices (non-verbal ability) scores and ages. Scores in both the tests of phonological awareness could range from 0 to 9. The BAS scores could range from 0 to 90. The highest score obtained was 71.

Table 4.1: Means (sd) in Rhyme and Initial Phoneme awareness, BAS test of word reading, non-verbal ability (Ravens matrices) and Age in months. n=15 for each group.

	'92			'93		
	R	Y 1	Y 2	R	Y 1	Y 2
Rhyme	4.87 (2.4)	7.0 (1.7)	6.93 (2.1)	4.47 (2.2)	6.0 (2.4)	7.6 (1.6)
Initial Phoneme	3.93 (1.7)	5.93 (2.0)	6.93 (2.3)	3.67 (1.4)	5.27 (3.1)	7.47 (2.1)
BAS	0	1.53 (3.5)	17.4 (17)	0	5.73 (14)	17.4 (19)
Ravens	15.5 (2.7)	18.2 (4.2)	19 (4.4)	12.3 (3.1)	15.9 (3.5)	18.7 (5.3)
Age	58 (1.2)	69.8 (1.6)	81.9 (1.2)	56.5 (1.9)	69.8 (1.6)	81.2 (1.7)

4.1.2.2.1 *Data screening and treatment*

Reliability coefficients (r_{II}) for the phonological awareness variables have been computed using the Kuder-Richardson formula cited by Anastasi (1968). These are shown in Table 4.2

Table 4.2: Reliability coefficients r_{II} for Rhyme and Initial Phoneme awareness

	Rhyme		Initial Phoneme	
	'92	'93	'92	'93
R	0.7	0.6	0.39	0
Y 1	0.62	0.74	0.62	0.88
Y 2	0.76	0.62	0.8	0.79

With the exception of the values for Initial Phoneme awareness scores obtained from the R-groups (5-year-old children) these coefficients indicate acceptable levels of reliability. The issue of the unreliability of Initial Phoneme awareness as a measure of children's performance at 5-years-old will be discussed below (in §4.1.2.4).

The data has also been screened for conformity to a normal distribution. Coefficients of Kurtosis and Skew for all variables are shown in Appendix 2. Within limits as outlined by Tabachnick & Fidell (1989) the coefficients for phonological awareness indicate that the data is distributed 'normally' within each group.

4.1.2.3 *Changes with age*

The results of the tests of phonological awareness have been analysed for changes with age by the use of simple between-groups anovas with *post-hoc* Scheffé pairwise comparisons. The results of these analyses are shown in Table 4.3 and Figure 4.1 below.

Table 4.3a: Comparison of changes in Rhyme awareness between groups (Anova, post hoc Scheffé)

	Overall F	R vs. Y2	R vs. Y1	Y1 vs. Y2
Rhyme '92 (n=45)	5.07*	3.68*	3.92*	0.00ns
Rhyme '93 (n=45)	8.35**	8.34*	2.0ns	2.2ns
Rhyme comb'd (n=90)	13.1**	12.3*	6.4*	0.92ns

*p<0.05;**p<0.01

Table 4.3b: Comparison of changes in Initial Phoneme (IPh) awareness between groups (Anova, post hoc Scheffé)

	Overall F	R vs. Y2	R vs. Y1	Y1 vs. Y2
IPh '92 (n=45)	8.71**	8.4*	3.7*	0.9ns
IPh '93 (n=45)	10.1**	10.1*	1.8ns	3.4*
IPh comb'd (n=90)	21.5**	21.5*	6.4*	4.3*

*p<0.05;**p<0.01

The age-related patterns of group-mean scores are graphically illustrated in Figure 4.1, below.

Fig 4.1a: Changes in Rhyme awareness (Rhy) between'92 groups

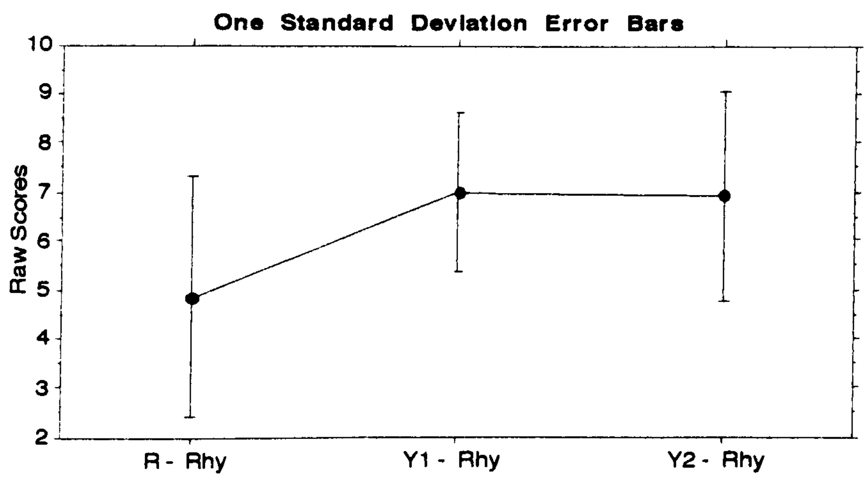


Fig 4.1b: Changes in Rhyme awareness (Rhy) between '93 groups

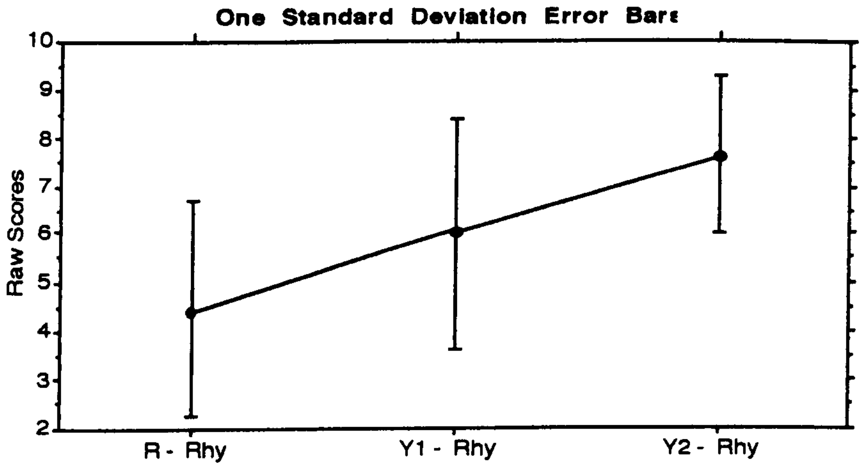


Fig 4.1c: Changes in Rhyme awareness (Rhy) with age for groups in '92 and '93 combined

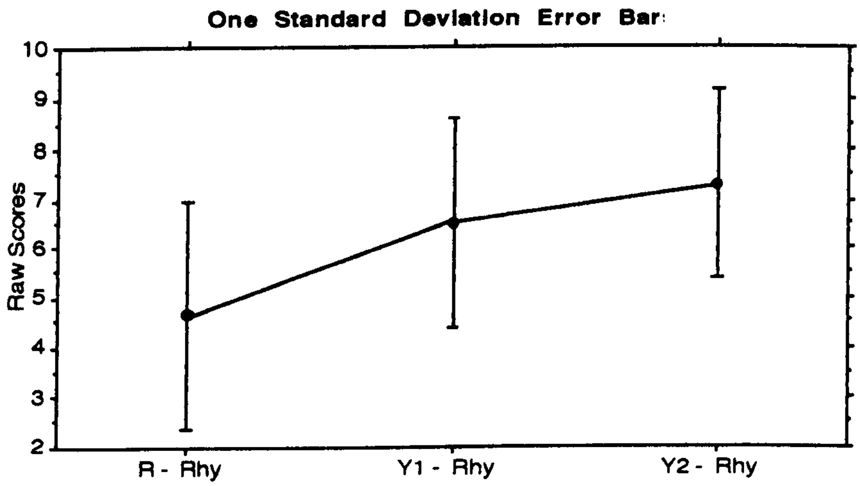


Fig 4.1d: Changes in Initial Phoneme awareness (IPh) between '92 groups

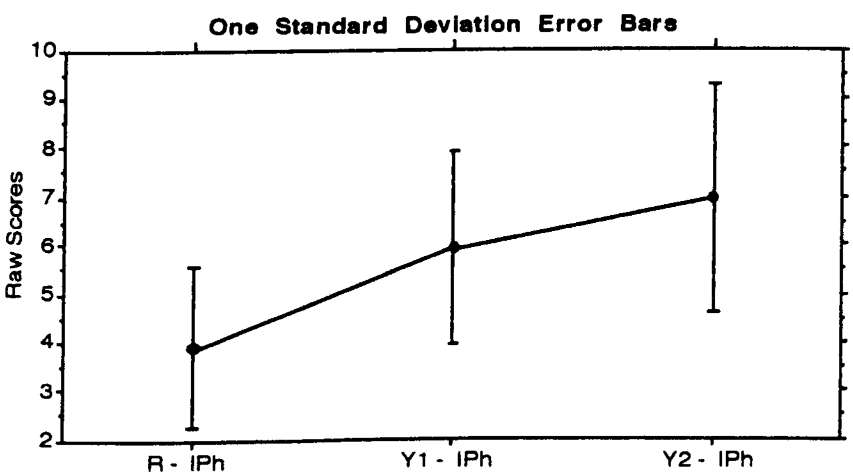


Fig 4.1e: Changes in Initial Phoneme awareness (IPh) between '93 groups

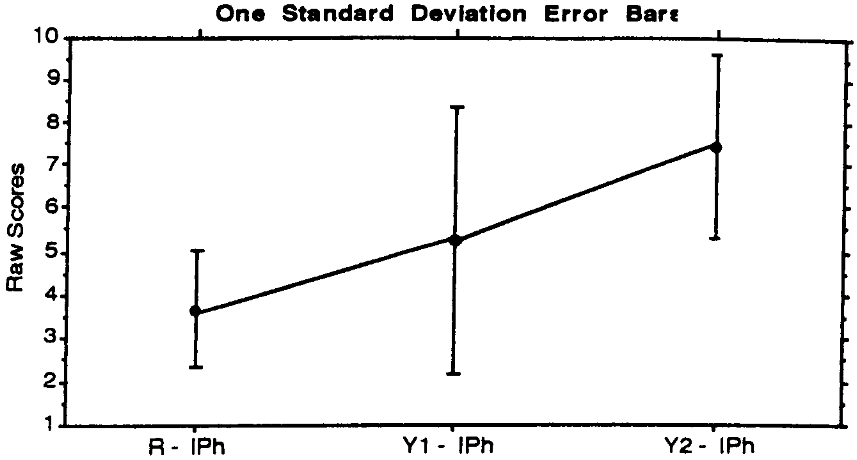
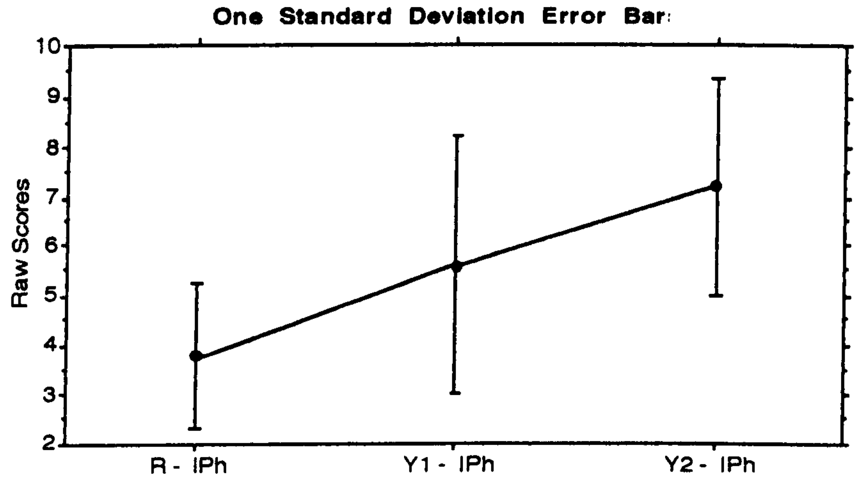


Fig 4.1e: Changes in Initial Phoneme awareness (IPh) between groups in '92 and '93 combined



In addition to the examination of age related trends within each variable, the difference between children's awareness of Rhyme and Initial Phonemes has also been tested using two-tailed t-tests of the differences between mean scores for each age group. The results of these tests are shown in Table 4.4 (below).

Table 4.4: Values of t (with probabilities, two-tailed tests) for differences between mean scores in Rhyme and Initial Phoneme awareness for 5- (R), 6- (Y1), and 7-year-old (Y2) children in '92, '93 and the combined data set

	R	Y 1	Y 2
'92	2.23 (.04)	2.17 (.05)	0
'93	2.18 (.05)	0.98 (.34)	0.34 (.74)
Combined	3.16 (.004)	2.04 (.05)	0.26 (.79)

This shows that for the 5- and 6- year-old children in this study there were significant differences between mean levels of awareness, the children at these ages generally showing greater awareness of rhyme than initial phonemes. By the age of 7-years (Y2) however the means of children's performance in both measures were very similar (see also Table 4.1 for the group means).

4.1.2.4 *Summary and discussion*

The mean performances in both measures of phonological awareness (Rhyme and Initial Phoneme awareness) at age 5-years are at levels that might have occurred by chance. (There were 9 three-choice trials in each measure. Chance level is therefore a score of 3, and a score greater than 6 would be significantly above chance with $p<0.05$.) However the acceptable level of reliability shown by the rhyme test at age 5-years shows that as a group there was reasonable consistency in the children's responses to test items. Mean scores in the rhyme test are better than chance at age 6- and 7-years, and also show acceptable reliability. The age-related increases in performance in the measure may therefore be considered to reflect real changes in the children's awareness of rhyme.

In the test of awareness of initial phonemes the mean level of performance does not indicate above chance levels until the children were aged 7-years. There are acceptable levels of reliability for the measure at age 6- and 7-years. Taken overall it is therefore possible to accept that there was an age-related increase in these children's awareness of initial phonemes. The measure of initial phoneme awareness however shows a lack of statistical reliability for the 5-year-old children. This indicates that this data must be treated with especial caution, since this finding suggests that there was little consistency in the children's responses as a group at that age. In terms of statistical analyses there is therefore a considerable, and unacceptable, amount of error variance in these scores. The nature of the demands made by the initial phoneme test would however appear to be similar to those involved in the rhyme test. The difference in the reliability of performance is therefore unlikely to arise because of superficial differences between tasks - the children were able to perform this *type* of task. The children's difficulty in this measure (Initial Phoneme awareness) at age 5-years may however be understood with reference to earlier work.

There is existing evidence (reviewed in §4.1.1) of differences between children's awareness of word-initial and -final sounds. This evidence indicates that phonemes are harder for children to identify and isolate than syllables and rhymes. The results of Kirtley, Bryant, MacLean & Bradley (1989) indicated increases in proficiency in detecting which words shared the same initial phoneme between the ages of 5- and 7-years, and that differences between words were easier to detect on the basis of initial than final phonemes. Children as young as 3-years 8-months were found to be able to detect initial phonemes by MacLean, Bryant & Bradley (1987) using a task similar to the one employed in this present study. However in discussing the results MacLean *et al* (1987) noted that some 45% of the children in their study were unable to do this task.

Thus with respect to the present findings (Tables 4.1 and 4.4) it seems reasonable to conclude that awareness of rhymes and initial phonemes increased with age, and, as predicted, identifying the initial phonemes of words was very much more difficult than identifying rhymes for the youngest children (the 5- and 6-year-olds) in this study. The responses to the initial phoneme test items appear to be random for the younger children, yielding a poor reliability coefficient for the youngest (5- year old) children. Children in this study who were a year older (Y1, 6-years-old) were more consistently able to make decisions about which words shared the same initial sound and thus the test shows an acceptable coefficient of reliability at age 6-, and again at 7-years.

4.2 The relationship between phonological awareness and word reading.

This section reports the results of tests carried out to establish if a predicted relationship between phonological awareness and reading was confirmable for the children who participated in this study. The developmental relationship (over a space of 12 months) between phonological awareness and word recognition and reading will also be reported. In §4.3 the data available from the main study of hearing children at ages 5-, 6-, and 7-years, will be contrasted with the data from the 7-year-old partially-hearing children.

4.2.1 Introduction

A close association between phonological awareness and reading ability has now been clearly established (Adams, 1990; Goswami and Bryant, 1990; Share, 1995; Wagner and Torgesen, 1987; Yopp, 1988; all provide reviews of the evidence.)

This relationship (between phonological awareness and reading) is thought by Morrison (1993, p 281), for instance, to be critical because awareness of the phonological structure of spoken language is necessary for the appreciation of the alphabetic principle and the code that links graphemes and phonemes.

Clearly it is possible that awareness of the phonemic or phonological components of words and language could also be enhanced or gained from reading. The influence of knowledge about spelling was examined by Ehri and Wilce (1980) who found that 'phonemic segmentation skill may be a consequence as much as a prerequisite to learning to read words.' (ibid p 371).

These reciprocal influences have been further examined in a number of experimental and developmental studies (eg Cataldo & Ellis, 1988; Ellis, 1990; Mann, 1986; Tunmer & Nesdale, 1985; Wimmer, Landerl, Linortner & Hummer, 1991). These studies suggest that while awareness of rhymes and initial phonemes may precede the acquisition of literacy, the awareness of initial phonemes may also be enhanced by the experience of literacy. Kirtley, Bryant, MacLean & Bradley (1989) in comparing the abilities of groups of children aged 5-, 6-, and 7-years to detect phonological differences between words, found a particularly strong relationship between children's abilities to categorise words by the final consonant and their scores in a test of word reading. Kirtley *et al* (1989) suggested that being able to break the phonological unit, the rime, into constituent phonemes may be a major step in learning to read.

Overall therefore the likely relationship between aspects of phonological awareness and reading may be summarised in the following way. Firstly, children will, before learning to read, have usually acquired an ability to apprehend segments of sounds within words. At this stage of their development the 'size' of these segments are initially syllabic. It seems however that children then become aware of the 'rime' that may be shared by rhyming syllables. As awareness of rime develops so the other component of the syllable, the onset, will become available for conscious manipulation. Since in some cases the onset will consist of a single phoneme, children will, in due course acquire the recognition of phonemes as units in themselves. During the course of instruction in reading children will also learn to recognise the salience of letter groups and individual letters as corresponding to the phonological segments that they perceive in their oral language (Goswami, 1990; Goswami & Bryant, 1990). The evidence from the research noted above indicates that children who have an early awareness of rhyme become better readers sooner, since having gained awareness at that level they are better placed to gain awareness of the smaller phonological segments. As reading develops awareness of phonemes develops, although some early awareness of phonemes should facilitate the child's progress in reading (Ehri & Wilce, 1985). It also seems likely that spelling promotes the use of phonological processing (Mommers, 1987). This in turn helps children use explicit knowledge of phonemes to form letter-sound correspondences in reading (Cataldo & Ellis, 1988). Morais (1991) concluded that phonemic awareness emerges only as a consequence of instruction on a written code. Barron (1991) also concluded that awareness of individual phonemes followed from the acquisition of literacy, whereas awareness of onsets (and rimes) did not.

On this basis it should be expected that for children who have been exposed to very little formal instruction in reading, in this study those aged 5-years (in the R groups), rhyme awareness should be established and should relate to later success in reading (ie a significant correlation should be found between initial levels of rhyme awareness and scores in reading tests a year later; as found by Bradley & Bryant, 1983). According to Morais, Alegria & Content (1987) awareness of initial phonemes would not be expected to become apparent until the children had begun to receive instruction in literacy.

In the measure of awareness of 'initial phonemes' developed and used in this present study however, the initial sounds to all words used coincides with the onset since all stimuli are monosyllables. Similarly in the test of awareness of rhyme used here, the rhyme coincides with the word's rime in every case. As indicated by Barron (1991) and Treiman & Zukowski (1991) awareness of onsets and rimes may develop without concurrent instruction in literacy.

A strong hypothesis that may be forward from the views of Barron (1991) and

Treiman & Zukowski (1991) would be that the children would show reasonable proficiency in both tests of phonological awareness at age 5-years, but that this would not be related to reading. Alternatively, if awareness of onsets, or initial phonemes, depends to an extent on instruction or learning, then, more in line with the views of Morais *et al* (1987) and Morais (1991), successful performance in the test of awareness of initial phonemes will come later than success in the test of awareness of rhymes, and follow from instruction in literacy.

According to a strong version of a Morais-type hypothesis reading levels at age 5-years should predict awareness of initial phonemes at 6-years, and awareness of initial phonemes at 6-years should predict levels of awareness of initial phonemes at age 7-years. For the oldest children in this study (ie those in Y2, aged 7-years), who had had two years of instruction in reading, awareness of initial phonemes should be associated with word reading and recognition skills.

In §4.1 (above) it has been shown that for the 5-year-old children awareness of rhyme was becoming established, and children a year older in the same environment showed levels of awareness of rhymes that were statistically consistent and above chance. It was not until age 7-years however before awareness of initial phonemes showed as being reliably above chance. This suggests that the strongest form of the hypothesis due to the views of Barron (1991) and Treiman & Zukowski (1991) is not supported by the data from the children in this study.

In the following section therefore the data will be examined to establish firstly whether, as would be predicted, the children's performance in each of the measures of phonological awareness is associated with the measures of reading administered at the same age. Subsequently (in §4.2.3.2) the relationship between the two aspects of phonological awareness and reading over the 12-month period of the longitudinal survey will be examined. A second line of enquiry leads to considerations about the differential relationship between awareness of rhyme and initial phonemes and reading.

4.2.2 Methodology

Children's performance in the measures of phonological awareness will be assessed in relation to their performance in two measures of reading.

The first test of reading (the Carver test of word recognition, described in more detail in Chapter 3) looks at how well children can determine which printed word (amongst a list of words and non-words) matches a word spoken by the researcher. This test therefore can be thought of as relying on the children's implicit knowledge of the sounds within words and knowledge of the correspondence between printed symbols and sounds.

In the second test of reading (the BAS test of word reading) children are asked to read aloud individual words from a printed list of single words. This task may therefore require some explicit knowledge of the correspondence between letters and sounds, and an ability to decode printed symbols into sounds.

The data has been analysed by means of hierarchical regressions in which scores from Raven's matrices have been entered first to control for the effects of non-verbal ability.

The results and analysis of the cross-sectional study are reported first. The analysis of the longitudinal study follows that.

4.2.3.1 *Results of cross-sectional study*

The means and standard deviations of scores are shown below in Table 4.5. The possible range of scores in the Carver test are from 0 to 10. The other scores have ranges as before (see Table 4.5, below).

Table 4.5: Means (sd) of scores in Phonological awareness (Rhy and IPh), Word Recognition (Carver test), Word Reading (BAS test), non-verbal ability (Raven's matrices) and Age (in months) for groups of children in '92 and '93. n=15 for all groups.

	'92			'93		
	R	Y 1	Y 2	R	Y 1	Y 2
Rhy	4.87 (2.4)	7.0 (1.7)	6.93 (2.1)	4.47 (2.2)	6.0 (2.4)	7.6 (1.6)
IPh	3.93 (1.7)	5.93 (2.0)	6.93 (2.3)	3.67 (1.4)	5.27 (3.1)	7.47 (2.1)
Carver	2.0 (1.5)	3.4 (2.6)	6.6 (2.5)	1.73 (1.5)	4.07 (2.3)	7.47 (2.4)
BAS	O	1.53 (3.5)	17.4 (17)	O	5.73 (14)	17.4 (19)
Ravens	15.5 (2.7)	18.2 (4.2)	19 (4.4)	12.3 (3.1)	15.9 (3.5)	18.7 (5.3)
Age	58 (1.2)	69.8 (1.6)	81.9 (1.2)	56.5 (1.9)	69.8 (1.6)	81.2 (1.7)

In order to provide an overview of the relationship between phonological awareness and reading the data has also been collapsed into two mixed-age groups for data obtained in '92 and '93. The overall means for these two groups are shown in Table 4.6.

Table 4.6: Means (sd) of scores in Phonological awareness (Rhy and IPh), Word Recognition (Carver test), Word Reading (BAS test), non-verbal ability (Raven's matrices) and Age (in months) for groups of children in '92 and '93. n=45 for both groups.

	'92	'93
Rhy	6.27 (2.3)	6.02 (2.4)
IPh	5.6 (2.3)	5.47 (2.8)
Carver	4 (2.9)	4.42 (3.2)
BAS	6.31 (12.7)	7.71 (15.4)
Ravens	17.6 (4.0)	15.7 (4.8)
Age	69.9 (9.9)	69.3 (10.5)

4.2.3.1.1 *Data Screening and treatment*

Scores in the Carver test were found to have acceptable coefficients of kurtosis and skew for all groups (see Appendix 2). There were insufficient BAS non-zero scores in the R and Y1 groups (ie for the 5- and 6-year-old children) to justify detailed analysis involving this variable in these groups. BAS scores for the Y2 groups were also found to have significant positive skew. The scores in these groups have been transformed to have acceptable coefficients of normality by taking the square root of scores. For the pooled groups (n=45) it was found necessary to use the transformation x:log(1+x) to achieve acceptable coefficients of skew and kurtosis for the BAS scores in '92 and '93. No other variables for any other groups were found to have values of the coefficients of kurtosis and skew that lay outside acceptable limits as defined by Tabachnick & Fidell (1989).

In order to achieve homogeneity of variance within anovas, Age has been categorised and entered as Age Group. Under these conditions F_{max} (as described by Kirk, 1968) in the analysis of variance was found to lie within acceptable limits.

The reliability coefficient, r_{11}, has been computed (using Kuder-Richardson formula 20, as described by Anastasi, 1968) for the children's responses to the Carver test. These coefficients are shown in the following Table (4.7) where it can be seen that with the exception of the data scores obtained from the 5-year-old (R-group) children in '93, all coefficients indicate acceptable reliability.

Table 4.7: Reliability coefficients for Carver Word-Recognition Test

	r
'92	
R	0.55
Y1	0.63
Y2	0.71
'93	
R	0.39
Y1	0.69
Y2	0.77

4.2.3.1.2 *Analysis*

For the tests of reading, changes with age have been confirmed by simple anovas performed on the data in '92 and again in '93. The results are summarised below in Table 4.8. The distributions of scores within groups for the Carver test results permitted pairwise comparisons between groups. However the BAS test, as already noted, did not yield any non-zero scores in the R-groups (5-year-old children) and a large number of children in Y1 groups (6-year-old children) also did not achieve any score. The analysis for BAS is therefore provided for illustrative purposes only, as an indicator of the magnitude of the trend across ages for performance in this measure.

Table 4.8: Results of anova for reading tests in '92 and '93 with post-hoc Scheffé pairwise comparisons

	'92	'93
Carver		
F Overall	16.4**	27.9**
R vs. Y1	1.45 ns	4.57*
R vs. Y2	15.6*	27.6*
Y1 vs. Y2	7.57*	9.71*
BAS†		
F Overall	25.7**	21.8**
Y1 vs. Y2	15.2*	9.63*

*p<0.05; **p<0.01; † Y2 √BAS transformed scores

It can be seen that there are statistically significant overall increases in children's word recognition and reading between the ages of 5- and 7-years, with a particular increase in levels of reading between the ages of 6- and 7-years.

In examining the relationship between phonological awareness and reading the first step has been to examine the matrix of bivariate correlations. These are shown in Table 4.9.

Table 4.9a: Matrix of correlations between variables for phonological awareness (Rhy and IPh), Word Recognition (Carver), Word Reading (BAS), Non-verbal ability (Ravens) and Age for children in '92. (n=45)

	1	2	3	4	5	6
1. Rhy	1					
2. IPh	0.738**	1				
3. Carver	0.508**	0.717**	1			
4. BAS†	0.393**	0.633**	0.858*	1		
5. Ravens	0.275ns	0.398**	0.541**	0.499**	1	
6. Age	0.359*	0.538**	0.659**	0.703**	0.39**	1

*p<0.05;**p<0.01; † transformed scores

Table 4.9b: Matrix of correlations between variables for phonological awareness (Rhy and IPh), Word Recognition (Carver), Word Reading (BAS), Non-verbal ability (Ravens) and Age for children in '93. n=45

	1	2	3	4	5	6
1. Rhy	1					
2. IPh	0.701**	1				
3. Carver	0.644**	0.75**	1			
4. BAS†	0.659**	0.756**	0.87**	1		
5. Ravens	0.37**	0.45**	0.474*	0.525**	1	
6. Age	0.535**	0.585*	0.762**	0.705*	0.578*	1

*p<0.05;**p<0.01; † Transformed scores.

Both these matrices show that across the age range 5- to 7-years both measures of phonological awareness are associated with scores in word recognition and word reading. There are also associations with non-verbal ability and age - as might be expected.

In order to assess the relationship between phonological awareness and reading hierarchical regression techniques have been used so that the effects of the variance in age and non-verbal ability are first removed before evaluating the effect of a phonological awareness variable on the variance in reading. The results of these analyses are shown in Table 4.10. This shows the cumulative variance (Adj-R^2), adjusted for sample size, together with the test of significance (F-to-enter) of the predictive effect of the additional variance due to the entry of that variable.

Table 4.10a: Hierarchical regression of Word Recognition (Carver test) onto Age, Raven's matrices (non-verbal ability) and phonological awareness (Rhy or IPh) for children aged 5- to 7-years in'92 and '93 (n=45 in each regression)

	'92		'93	
DV=Carver				
	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Age	0.421		0.571	
Raven's	0.507	8.46**	0.563	0.17ns
then, either				
Rhy	0.559	5.99**	0.635	9.24**
or				
IPh	0.639	16.4**	0.702	20.6**

**p<0.01

Table 4.10b: Hierarchical regression of Word Reading (BAS test) onto Age, Raven's matrices (non-verbal ability) and phonological awareness (Rhyme or Initial Phoneme) for children aged 5- to 7-years in '92 and '93 (n=45 for each regression)

	'92		'93	
DV=log(1+BAS)				
	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Age	0.483		0.486	
Raven's	0.533	5.63**	0.495	1.81ns
then, either				
Rhy	0.535	1.23ns	0.643	11.20**
or				
IPh	0.589	6.71**	0.629	21.17**

**p<0.01

These results show consistent significant relationships between both aspects of phonological awareness and both measures of reading, with the exception of the regression of log(1+BAS) scores onto Rhyme awareness in '92. With the exception of that result there is therefore confirmation of an overall association between phonological awareness and reading, as predicted. The relationship between reading and awareness of initial phonemes seems to be rather more striking (with greater shared variance) than the relationship between awareness of rhymes and reading.

In order to determine if the associations are specific to any age-group the procedure has been repeated for each age group of children. For this purpose 3 groups of 30 children have been formed, one each for all the R (5-year-old), Y1 (6-year-old), and Y2 (7-year-old) groups in '92 and '93. The correlations are shown in Table 4.11 and the results of the regressions are shown in Table 4.12. Since these groups are homogeneous with respect to age only Ravens and the phonological awareness variable have been entered as independent variables, thereby keeping the variables:cases ratio within safe working limits (Tabachnick & Fidell, 1989).

All variables for these combined groups have again been screened for conformity to the normal distribution, and non-significant values of kurtosis and skew were found (see Appendix 2) for non-verbal ability (Raven's matrices), phonological awareness (Rhyme and Initial Phoneme) and word recognition (Carver) variables. However for word reading (BAS) there were insufficient children in R and Y1 (5- and 6-year-old) groups achieving any score to permit regressions of those scores. In Y2 (7-year-old children) the BAS scores were found to have a significant, positive, coefficient of skew. This was corrected by the use of the square root transformation of scores.

Table 4.11a: Matrix of correlations between variables for Phonological awareness (Rhy and IPh), Word Recognition (Carver), Nonverbal ability (Ravens) and Age for 5-year-old children n=30

	1	2	3	4	5
1. Rhy	1				
2. IPh	0.759**	1			
3. Carver	0.426*	0.518**	1		
4. Ravens	0.124ns	0.01ns	-0.186ns	1	
5. Age	0.006ns	0.207ns	0.108ns	0.191ns	1

*p<0.05;**p<0.01

Table 4.11b: Matrix of correlations between variables for Phonological awareness (Rhy and IPh), Word Recognition (Carver), Nonverbal ability (Ravens) and Age for 6-year-old children n=30

	1	2	3	4	5
1. Rhy	1				
2. IPh	0.486**	1			
3. Carver	0.451**	0.603**	1		
4. Ravens	0.188ns	0.422*	0.27ns	1	
5. Age	0.024ns	0.167ns	0.164ns	0.301ns	1

*p<0.05;**p<0.01

Table 4.11c: Matrix of correlations between variables for Phonological awareness (Rhy and IPh), Word Recognition (Carver), Word Reading (BAS, transformed), Nonverbal ability (Ravens) and Age for 7-year-old children n=30

	1	2	3	4	5	6
1. Rhy	1					
2. IPh	0.781**	1				
3. Carver	0.456**	0.611**	1			
4. √ BAS	0.554**	0.586**	0.721**	1		
5. Ravens	0.145ns	0.166ns	0.461**	0.469**	1	
6. Age	-0.027ns	0.144ns	0.324ns	0.214ns	0.427*	1

*p<0.05;**p<0.01

These bivariate correlations suggest there are associations between phonological awareness scores and reading, but also some effect of non-verbal ability. As outlined above therefore the hierarchical regressions have been undertaken to remove the effect of non-verbal ability and thereby clarify the predictive effect of phonological awareness on reading. The results of these regressions are summarised in Table 4.12 below.

Table 4.12a: Results of hierarchical regressions of Carver word recognition scores onto Raven's matrices (non-verbal ability) and phonological awareness (of Rhymes, or Initial Phonemes) scores for groups of 5-, 6- and 7-year old children. n=30 for each group.

	R		Y1		Y2	
DV=Carver						
	Adj-R2	F-to-enter	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Raven's	0		0.04		0.185	
then, either						
Rhyme	0.183	7.27**	0.183	5.89**	0.32	6.59**
or						
Initial Phoneme	0.253	10.5**	0.317	12.4**	0.47	16.1**

**p<0.01

Table 4.12b: Results of hierarchical regressions of the square root of BAS word reading scores onto Raven's matrices (non-verbal ability) and phonological awareness scores for groups 7-year old children

DV=√BAS		
	Adj-R2	F-to-enter
Raven's	0.192	
then, either		
Rhyme	0.421	12.1**
or		
Initial Phoneme	0.448	14.0**

**p<0.01

The analysis of the data in this way suggests that the general prediction of associations between phonological awareness and reading was upheld at each of the ages studied here. The associations are significantly greater than chance, and over and above any effect of non-verbal ability.

However, to provide a detailed view of each group of 15 children aged 5-, 6-, and 7-years-old in this study in '92 and '93 the regressions have also been performed using the data for each of those 6 groups. The results of those analyses are shown in Table 4.14, with correlations shown in Table 4.13.

Again coefficients of kurtosis and skew were inspected for departures from normality (Appendix 2) and, with the exception of BAS (word reading) scores for the Y2 (7-year-old) groups, the coefficients were found to be within reasonable limits. The BAS scores were again transformed by taking square roots of scores. Since most children aged 5- and 6-years (R & Y1 groups) did not achieve any score in the BAS test, this variable has not been included in the analyses of these groups.

Table 4.13a: Matrix of correlations between variables for Phonological awareness (Rhy and IPh), Word Recognition (Carver), Nonverbal ability (Ravens) and Age for 5-year-old children in '92 n=15

	1	2	3	4	5
1. Rhy	1				
2. IPh	0.742**	1			
3. Carver	0.508*	0.708**	1		
4. Ravens	0.031ns	-0.178ns	-0.136ns	1	
5. Age	-0.099ns	0.108ns	0.237ns	-0.302ns	1

*p<0.05;**p<0.01

Table 4.13b: Matrix of correlations between variables for Phonological awareness (Rhy and IPh), Word Recognition (Carver), Nonverbal ability (Ravens) and Age for 5-year-old children in '93 n=15

	1	2	3	4	5
1. Rhy	1				
2. IPh	0.781**	1			
3. Carver	0.325ns	0.274ns	1		
4. Ravens	0.153ns	0.114ns	-0.381ns	1	
5. Age	0.005ns	0.267ns	-0.022ns	0.135ns	1

**p<0.01

Table 4.13c: Matrix of correlations between variables for Phonological awareness (Rhy and IPh), Word Recognition (Carver), Nonverbal ability (Ravens) and Age for 6-year-old children in '92 n=15

	1	2	3	4	5
1. Rhy	1				
2. IPh	0.46ns	1			
3. Carver	0.431ns	0.751**	1		
4. Ravens	0.259ns	0.563*	0.614**	1	
5. Age	-0.138ns	0.225ns	0.195ns	0.388ns	1

*p<0.05;**p<0.01

Table 4.13d: Matrix of correlations between variables for Phonological awareness (Rhy and IPh), Word Recognition (Carver), Nonverbal ability (Ravens) and Age for 6-year-old children in '93 n=15

	1	2	3	4	5
1. Rhy	1				
2. IPh	0.478ns	1			
3. Carver	0.586*	0.592*	1		
4. Ravens	0.026ns	0.32ns	-0.051ns	1	
5. Age	0.165ns	0.141ns	0.125ns	0.206ns	1

*p<0.05

Table 4.13e: Matrix of correlations between variables for Phonological awareness (Rhy and IPh), Word Recognition (Carver), Word Reading (BAS, transformed), Nonverbal ability (Ravens) and Age for 7-year-old children in '92, n=15

	1	2	3	4	5	6
1. Rhy	1					
2. IPh	0.829**	1				
3. Carver	0.485*	0.469ns	1			
4. √ BAS	0.489*	0.468ns	0.785**	1		
5. Raven	0.139ns	0.191ns	0.557*	0.117ns	1	
6. Age	-0.089ns	-0.029ns	0.127ns	-0.157ns	0.524*	1

*p<0.05;**p<0.01

Table 4.13f: Matrix of correlations between variables for Phonological awareness (Rhy and IPh), Word Recognition (Carver), Word Reading (BAS, transformed), Nonverbal ability (Ravens) and Age for 7-year-old children in '93. n=15

	1	2	3	4	5	6
1. Rhy	1					
2. IPh	0.711**	1				
3. Carver	0.38ns	0.754**	1			
4. √ BAS	0.662**	0.728**	0.671**	1		
5. Raven	0.176ns	0.157ns	0.411ns	0.639**	1	
6. Age	0.051ns	0.299ns	0.511*	0.429ns	0.373ns	1

*p<0.05;**p<0.01

In the following hierarchical regressions Age and Ravens (non-verbal ability) have been included as a preliminary explanatory variables since it appears from the matrices of correlations that there are some effects of age and non-verbal abilities. It is recognised that this procedure puts the number of IVs at the limit recommended by Tabachnick & Fidell (1989).

Table 4.14a: Results of hierarchical regressions of Carver word recognition scores onto Raven's matrices (non-verbal ability) and phonological awareness (Rhymes or Initial Phonemes) scores for groups of 5-, 6- and 7-year old children in '92. n=15.

'92	R		Y1		Y2	
DV=Carver	Adj-R2	F-to-enter	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Age	0		0		0	
Raven's	0	0.06ns	0.275	6.58*	0.239	6.10*
then, either						
Rhyme	0.168	4.81*	0.309	1.58ns	0.355	3.16ns
or						
Initial Phoneme	0.401	10.95**	0.516	6.98**	0.32	2.44ns

*p<0.05;**p<0.01

Table 4.14b: Results of hierarchical regressions of Carver word recognition scores onto Raven's matrices (non-verbal ability) and phonological awareness (Rhyme or Initial Phonemes) scores for groups of 5-, 6- and 7-year old children in '93

'93	R		Y1		Y2	
DV=Carver	Adj-R2	F-to-enter	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Age	0		0		0.204	
Raven's	0.004	2.05ns	0	0.08ns	0.204	0.99ns
then, either						
Rhyme	0.105	2.36ns	0.173	5.55*	0.261	1.93ns
or						
Initial Phoneme	0.046	1.52ns	0.265	7.63**	0.618	14.03**

*p<0.05;**p<0.01

Table 4.14c: Results of hierarchical regressions of the square root of BAS word reading scores onto Raven's matrices (non-verbal ability) and phonological awareness scores for groups 7-year old children in '92 and '93

Y 2	'92		'93	
DV=√BAS	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Age	0		0.122	
Raven's	0	1.94ns	0.36	5.83*
then, either				
Rhyme	0.127	2.75ns	0.704	14.9**
or				
Initial Phoneme	0.1	2.33ns	0.782	21.5**

*$p<0.05$;**$p<0.01$

4.2.3.1.3 *Conclusions from cross-sectional study*

The analyses of each age group demonstrate that there were relationships between phonological awareness and reading for the children in this study. In general there appears to be a greater association between reading and initial phoneme awareness, with more variance in reading scores shared with scores in the test of awareness of initial phonemes than with scores in the test of awareness of rhyme at each age. However when the groups of 15 children of each age tested in each of the cohorts ('92 and '93) the picture is less clear. In these groups it seems that the relationship between phonological awareness (of either type) and reading (of either type) was unlikely to have been uniform across all groups, but for both groups of 6-year-old children there are significant associations between awareness of initial phonemes and word recognition. It should be noted that from the comparison of mean scores in word recognition at 6- and 7-years (Table 4.8) it seems that in this educational environment there were, typically, significant increases in word reading in the year between age 6- and 7-years. It is possible that the significant relationship between initial phoneme awareness and word recognition that is apparent at age 6-years forms part of a springboard for the progress in the ensuing year.

It is clearly possible for either statistical and/or psychological reasons that some groups of children may not show performance in aspects of reading that is significantly associated with their phonological skills. Indeed Bryant & Bradley (1987) also point out that in their longitudinal studies the amount of variance shared between initial phonological awareness and final reading was often quite small, and never more than 10%. Bradley & Bryant (1983) studied much larger groups of children than was the case in this project. One consequence of smaller groups studied here is an increased risk of Type 2 errors, ie failing to detect an effect when one actually exists.

There are other methodological problems that emerge with the results of this study. It is possible, for instance, that the apparent relationship between Initial Phoneme awareness and reading in the R (5-year-old) group in '92 may be spurious because of the very low reliability, and increased error variance, of the scores for Initial Phoneme awareness (as reported in Table 4.2). It is however also possible that the increase in error variance that may be associated with low reliability has also obscured a relationship between Initial Phoneme awareness in the corresponding group of 5-year-old children in '93.

4.2.3.2 *The longitudinal survey*

The predictive effects of one variable on another over time may reveal causal relationships. Within the literature there are well documented accounts of causal effects of phonological awareness on reading that have been established in purely longitudinal surveys (Bradley & Bryant, 1983) and from training studies (Bradley & Bryant, 1983; Hatcher, Hulme & Ellis, 1994). In view of the issues to be explored in later chapters of this thesis it is important to establish whether or not there exist similar causal effects that are evident for the children in this study over a twelve month period.

It is of specific interest here to determine if, as would be expected from earlier studies (Bradley & Bryant, 1983; Maclean, Bryant & Bradley, 1987), phonological awareness at T1 was predictive of reading ability at T2. Alternative hypotheses (supported by the views of Barron, 1991; Ellis, 1990) would be that the relationship is at least partially reciprocal, and that at certain ages reading enhances phonological awareness. According to Morais (1991) awareness of initial phonemes is only likely to arise as a consequence of instruction in reading. With the children who participated in this study, the effects of prior reading ability could only be apparent for the children initially aged 6-years, since the other group (children initially aged 5-years) had only been attending school for one month when they were first tested and, as was confirmed by the test of reading (BAS) administered at that time, were all non-readers.

4.2.3.2.1 *Data Screening*

The coefficients of kurtosis and skew for the scores for these two groups have been inspected and found to lie within acceptable limits, with the exception of BAS scores which, because of positive skew in the distribution of scores, have been transformed by taking the square root of scores for the group of 13 children initially aged 5-years.

4.2.3.2.1.1 *Cautionary note*

It had been hoped that a larger number of children would be available for assessment at both T1 and T2. Of the children who participated in the research in '92 (T1) there were unfortunately only 11 children initially aged 5-years, and 13 who were initially aged 6-years available at the time of the second round of tests in '93 (T2). With the size of the groups of children initially aged 5-years and those initially aged 6-years there are some constraints on the number of variables that can be entered into hierarchical regressions. Tabachnick & Fidell (1989) suggest that there should be at least 5 times more cases than independent variables. With 15 participants it should therefore be just acceptable to have 3 IVs. With only 11 or 13 participants only 2 IVs should strictly be permissible, otherwise there is an increased risk of obtaining spuriously well fitting solutions. There is also the problem that with samples of this size the chance of Type 2 errors may be thought to be unacceptably high. Difficulties in the analysis of this data also arise because of the small differences between the mean scores for a number of variables, as may be seen in Table 4.15 (below). This will severely reduce the scope of inferences that might be made about the developmental relationship (ie direction of causality) between variables. However, despite these cautions, the analysis of the data grouped in this way has been conducted in order to outline the intended procedure, but also to provide some illustration of possible relationships.

In order to obtain a developmental overview, and to circumvent some of the methodological and statistical issues discussed above though with some loss of detail, the data has been subsequently reanalysed using a combined group of all 24 children. With a group of this size it is possible to perform hierarchical regressions with prior entry of age, nonverbal ability and preexisting skills in the domain of the dependent variable, before entering the independent variable of interest, without breaching Tabachnick & Fidell's (1989) recommended minimum ratio of five times more cases than IVs. The analysis of this combined group is reported in §4.2.3.2.4, below.

4.2.3.2.2 *Analysis of longitudinal data in two homogeneous age groups*

The mean scores for the children forming the longitudinal data are shown in Table 4.15 together with the value of t for the test of the difference between the mean scores at T1 ('92) and T2 ('93) and p, the probability of that difference occurring by chance. Since the changes would be expected to all be increases, and to reduce the chance of Type 2 error, one-tailed tests have been employed here, as recommended by Minium (1978).

Table 4.15a: Means (standard deviations in brackets) of raw scores obtained from 11 children initially aged 5-years seen at T1 and at T2, with the results of the t-tests (one-tailed) of the differences between means. (T1 - T2 interval is 12 months).

	T 1	T 2	t	p
Rhyme	5.0 (2.5)	5.8 (2.5)	1.42	0.091
Initial Phoneme	4.1 (1.7)	5.8 (3.0)	2.59	0.012
Carver	2.0 (1.6)	4.2 (2.5)	4.64	0.0003
BAS	0 (0)	6.62 (15)	1.59	0.069
Ravens	15.5 (3.0)	16.1 (3.4)	0.54	0.3
Age	57.8 (1.1)	69.8 (1.1)		

Table 4.15b: Mean scores (sd) of scores obtained from 13 children initially aged 6-years seen at T1 and at T2, with the result of the t-tests of the differences between means. (T1 - T2 interval is 12 months).

	T 1	T 2	t	p
Rhyme	7.3 (1.6)	7.8 (1.8)	1.4	0.096
Initial Phoneme	6.6 (1.7)	7.5 (2.3)	1.57	0.074
Carver	3.9 (2.7)	7.5 (2.7)	6.31	0.0001
BAS	2.1 (4.0)	18.8 (22.0)	3.06	0.006
Ravens	18.4 (4.5)	18.4 (5.7)	0.17	0.43
Age	69.7 (1.7)	81.7 (1.7)		

Thus it can be seen that within these groups the increases in phonological awareness over twelve months were not consistently greater than might be expected by chance. There were however considerable concurrent increases in word recognition and reading.

The first stage in the analysis of this longitudinal data has been to calculate the coefficients of correlation between scores at T1 and T2. These are shown in the following two tables (Table 4.16)

Table 4.16a: Correlations between variables at T1 and T2 for children initially aged 5-years. n=13

	1	2	3	4	5	6	7	8
1. Rhyme 1	1							
2. Rhyme 2	0.623*	1						
3. Initial Phoneme1	0.718**	0.742**	1					
4. Initial Phoneme2	0.741**	0.608*	0.632*	1				
5. Carver 1	0.473ns	0.462ns	0.711**	0.782**	1			
6. Carver 2	0.596*	0.612*	0.892**	0.607*	0.755**	1		
7. √BAS2	0.597*	0.601*	0.864**	0.486ns	0.708**	0.873**	1	
8. Age	-.093ns	0.077ns	0.234ns	0.134ns	0.241ns	0.105ns	-.022ns	1
9. Ravens1	0.023ns	0.079ns	-.205ns	0.134ns	-.141ns	-.067ns	-.096ns	-.316ns

**p<0.01;*p<0.05

Table 4.16b: Correlations between variables at T1 and T2 for children initially aged 6-years. n=11

	1	2	3	4	5	6	7
1. Rhyme 1	1						
2. Rhyme 2	0.726**	1					
3. Initial Phoneme1	0.286ns	0.476ns	1				
4. Initial Phoneme2	0.512ns	0.818**	0.591*	1			
5. Carver 1	0.526ns	0.375ns	0.829**	0.477ns	1		
6. Carver 2	0.393ns	0.441ns	0.778**	0.746**	0.756**	1	
7. BAS1	0.366ns	0.315ns	0.775**	0.357ns	0.866**	0.515ns	1
8. BAS2	0.521ns	0.472ns	0.791**	0.517ns	0.895**	0.594ns	0.971**
9. Age	-.044ns	-0.018ns	0.474ns	0.169ns	0.386ns	0.559ns	0.36ns
10. Ravens1	0.29ns	0.349ns	0.757**	0.308ns	0.824**	0.529ns	0.847**

**p<0.01;*p<0.05

Table 4.15b - continued

	9
9. Age	1
10. Ravens1	0.362ns

These tables show significant auto-correlations (ie that children who were doing well in a measure at T1 seem generally to be doing well at T2), and some significant correlations between phonological awareness at one time and reading at another time of testing.

For the 5 → 6 year old transition initial awareness of rhyme and initial phonemes both seem to have been associated with word recognition and word reading a year later. Initial word recognition scores were not associated with later awareness of rhyme but were, as was predicted, associated with later awareness of initial phonemes.

For the children aged 6-years when first tested however awareness of rhymes was not associated with either word reading or word recognition a year later. Awareness of initial phonemes was associated with recognition and reading scores a year later at age 7-years. For these children however neither reading nor recognition scores at age 6-years appear to be predictive of phonological awareness a year later.

In order to clarify these apparent predictive developmental relationships however requires more rigorous analysis which should take account of general cognitive ability and preexisting skills. A series of hierarchical regressions might be conducted so that the predictive effect of one variable (or set of variables) on another can be assessed after statistical control for the variance in other variables has been established. In principal the developmental relationship between phonology and reading could be studied in this way and any possible effect due to non-verbal ability and age should be removed by entering those scores ahead of the independent variables of interest. Under such conditions it would be possible to detect if there are different causal relationships across different ages. With the constraints on the number of variables that can safely be used as a result of the available size of groups (as noted above) this procedure cannot, unfortunately, be adhered to strictly.

Two sets of regressions have therefore been conducted. In one set phonological awareness scores form the independent variable with reading scores as dependent variables. In the second set reading scores form the independent variables and phonological awareness scores are taken as the dependent variables, in turn. In each case non-verbal ability (Raven's matrices scores) are entered in the regression ahead of the IV of interest. If there had been sufficient data points (ie at least 15) then a second IV would have been entered to control for preexisting ability in the domain of the DV in that regression. Since there are fewer than 15 cases, and taking account of Tabachnick & Fidell's (1989) strictures, only 2 IVs can be used.

The results of these regressions are shown below in Table 4.17 (where reading is regressed onto phonological skills a year earlier), and in Table 4.18 in which the opposite direction of causality is tested by regressing children's phonological skills onto reading scores of a year earlier.

For the group of children who were initially aged 5-years-old it can be seen above (Table 4.16a) that non-verbal ability did not display any significant bivariate association with other variables. Ravens matrices scores therefore need not necessarily be entered as a preliminary variable in the regressions for this group. As a precaution however this will be done, but it seems appropriate to also perform a set of regressions onto preexisting skill including any initial word-recognition ability. Thus in Table 4.17 a second regression may be seen in which scores in the Carver test have been entered first to control for any initial variance in reading. Also in the regression of phonological awareness at T2 (Table 4.18) the first IV in the regression will be either Rhyme 1 or Initial Phoneme 1, as appropriate to match the DV. In this way it should be possible to be clearer that any relationship between the IV of interest and the DV is not due to the influence of preexisting skills in the domain of the DV.

For the children aged 6-years at the start of the study Ravens scores appear to be significantly correlated with several other variables (see Table 4.16b, above). However Ravens scores do not show a significant correlation with respect to phonological awareness scores at T2 (Rhyme 2 or Initial Phoneme 2), but do show substantial correlations with initial phoneme, word recognition and word reading scores at T1 (Initial Phoneme 1, Carver 1 and BAS 1, respectively). It is therefore appropriate and possible to perform hierarchical regressions involving the entry of phonological awareness scores obtained at T1 as statistical controls for preexisting levels of awareness.

Table 4.17a: Hierarchical regressions of Word Recognition (Carver test) onto phonological awareness (Rhyme or Initial Phoneme awareness) a year earlier for children initially aged 5-years (R->Y1 group, n=13) and children initially aged 6-years (Y1->Y2 group, n=11) with statistical control for non-verbal ability (Ravens 1)

DV=Carver test at T2: R->Y1; n=13;			Y1->Y2; n=11	
	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Ravens 1	0		0.2	
either				
Rhyme 1	0.234	5.60*	0.178	.76ns
or				
Initial Phoneme1	0.771	42.1**	0.518	6.94*

*p<0.05;**p<0.01

Table 4.17ai: Hierarchical regressions of Word Recognition (Carver test) onto phonological awareness (Rhyme or Initial Phoneme awareness) a year earlier for children initially aged 5-years (R->Y1 group, n=13) with statistical control for initial word recognition (Carver 1)

DV=Carver test at T2: R->Y1; n=13;		
	Adj-R2	F-to-enter
Carver 1	0.532	
either		
Rhyme 1	0.573	2.06ns
or		
Initial Phoneme1	0.79	14.55**

**p<0.01

Table 4.17b: Hierarchical regressions of Word Reading (BAS test) onto phonological awareness (Rhyme or Initial Phoneme awareness) a year earlier for children initially aged 5-years (R->Y1 group, n=13) and children initially aged 6-years (Y1->Y2 group, n=11) with statistical control for non-verbal ability (Ravens 1)

DV=√BAS scores at T2: R->Y1; n=13;			Y1->Y2; n=11	
	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Ravens 1	0		0.416	
either				
Rhyme 1	0.241	5.67*	0.514	2.81ns
or				
Initial Phoneme 1	0.704	30.22**	0.608	5.41*

*p<0.05;**p<0.01

Table 4.17bi: Hierarchical regressions of Word Reading - BAS test onto phonological awareness (Rhyme or Initial Phoneme awareness) a year earlier for children initially aged 5-years (R->Y1 group, n=13)with statistical control for initial word reading (using Carver 1 as a proxy)

DV=√BAS scores at T2: R->Y1; n=13;		
	Adj-R2	F-to-enter
Carver 1	0.455	
either		
Rhyme 1	0.507	2.15ns
or		
Initial Phoneme 1	0.717	11.19**

**p<0.01

Table 4.18: Hierarchical regressions of Phonological awareness (either Rhyme or Initial phoneme) onto Reading (either Carver -Word Recognition; or BAS - Word Reading) test scores a year earlier for children initially aged 5-years (R->Y1 group, n=13) and children initially aged 6-years (Y1->Y2 group, n=11)

DV=Rhyme at T2: R->Y1; n=13;			Y1->Y2; n=11		
	Adj-R2	F-to-enter		Adj-R2	F-to-enter
Rhyme 1	0.333		Ravens 1	0.03	
Carver 1	0.309	0.62ns	Carver 1	0.176	.2ns
			or		
			√BAS 1	0	0.03ns
DV=Initial Phoneme scores at T2					
IPh 1	0.345		Ravens 1	0	
Carver 1	0.548	5.96*	Carver 1	0.061	1.64ns
			or		
			√BAS 1	0	0.52ns

*p<0.05

Table 4.18i: Hierarchical regressions of Phonological Awareness scores at T2 (either Rhyme or Initial phoneme) onto Reading (either Carver -Word Recognition; or BAS - Word Reading) at T1, with statistical control for initial phonological awareness for children aged 6-years at T1 (Y1->Y2 group, n=11)

DV=Initial Phoneme scores at T2			DV=Rhyme scores at T2		
	Adj-R2	F-to-enter		Adj-R2	F-to-enter
IPh 1	0.278		Rhy 1	0.475	
Carver 1	0.188	.007ns	Carver 1	0.409	0.001ns
or			or		
√BAS 1	0.24	.55ns	√BAS 1	0.425	0.231ns

4.2.3.2.3 *Conclusion*

These analyses indicate that for the children initially aged 5-years their awareness of rhymes at 5-years may appear to be predictive of reading levels a year later, but when their initial word recognition ability is taken into account awareness of rhymes ceases to be a significant predictor of later reading. Initial awareness of phonemes however remains significantly associated with reading ability a year later even when variance due initial word recognition scores has been discounted.

The obverse causal prediction, that reading ability may predict the acquisition of phonological awareness, is also supported by this analysis with respect to the development of initial phonemes at age 6-years. Reading ability at T1 however does not appear to predict awareness of rhyme at T2 (6-years-of-age).

For the children initially aged 6 years at the start of the study rhyme awareness was not found to be either an antecedent or consequence of word recognition or reading. Awareness of initial phonemes at 6-years of age does however seem to be predictive of performance in the tests of word recognition and reading at age 7. Contrary to expectation however neither the test of word recognition nor the test of word reading appears to predict levels of awareness of phonemes a year later at age 7-years.

The overall conclusions that may be drawn at this stage are that reading skills may be predicted from phonological skills a year earlier. The findings are as would be expected from previous research (eg Bradley & Bryant, 1983; Maclean, Bryant & Bradley, 1987; Wimmer, Landerl, Linortner & Hummer, 1991). A tentative note is due here because statistically these are not robust findings, partly because of the rather small group sizes, partly because of a problem with lack of reliability in the Initial Phoneme measure for 5-year-old (R-group) children.

The finding of a significant predictive relationship between performance in reading at age 5-years and awareness of initial phonemes a year later does also seem to concur with other findings (eg Barron,1991; Ellis,1990; Morais, 1991) which indicate that awareness of individual phonemes follows from the acquisition of literacy. The conjectures of Barron (1991) and Treiman & Zukowski (1991) that awareness of onsets might precede the acquisition of literacy do not appear to be supported by the evidence since the children in this study did not show any consistent levels of performance greater than chance at the start of the investigations. The indications are to the contrary, and more in support of the views of Morais (1991) in so far as it is evident that between the ages of 5- and 6-years initial scores in word recognition predict later scores in the test of initial phoneme awareness, but scores in rhyme are not similarly related to earlier word recognition. The methodology of this study does not however allow for a direct assessment of the effect of reading instruction on the acquisition of phonemic awareness. It must suffice here to conclude that the indications are that for children aged 5-years although their awareness of rhymes and initial phonemes at that age was predictive of their abilities in reading and word recognition at age 6-years, their performance in word recognition at age 5-years was predictive of their awareness of initial phonemes, only, a year later. This at least suggests that there might be some predisposition to becoming phonemically aware for children with better word recognition abilities.

4.2.3.2.4 *Analysis of longitudinal data in one heterogeneous age group*

In order to provide a more robust overall analysis of the data, the scores from all children who were seen at T1 and T2 were gathered in one group (with n=24). Pooling the results from the 24 children who were tested at T1 and twelve months later at T2 in this way yielded mean scores and correlations between variables as shown in Table 4.19 and 4.20 respectively. The data has also been screened for significant levels of kurtosis and skew, and as a result it was found necessary to transform Ravens scores at T1 and BAS scores at T2 by taking square roots of the scores. The BAS scores at T1 contained too few non-zero scores to be susceptible to any valid transformation, and this variable will not, therefore, be used.

Table 4.19: Mean scores (sd) of scores for Phonological awareness (Rhyme and Initial Phoneme), Word Recognition (Carver test), Word Reading (BAS), Nonverbal ability (Ravens) and Age obtained from 24 children initially aged 5- and 6-years seen at T1 and at T2, with the result of the t-tests (one-tail) of the differences between means.

	T 1	T 2	t	p
Rhyme	6.04 (2.4)	6.75 (2.4)	1.95	0.03
Initial Phoneme	5.25 (2.1)	6.58 (2.8)	3.02	0.003
Carver	2.88 (2.3)	5.71 (3.1)	7.29	0.0001
BAS	0.96 (2.9)	12.2 (19.2)	3.25	0.002
Ravens	16.9 (4.0)	17.1 (4.6)	0.29	0.39
Age	63.3 (6.2)	75.3 (6.2)		

For this overall group it can be seen that there were significant differences between performance at T1 and T2 in phonological awareness and reading.

Table 4.20: Correlations between variables for Phonological awareness (Rhyme and Initial Phoneme), Word Recognition (Carver test), Word Reading (BAS), Nonverbal ability (Ravens) and Age at T1 and T2 for children initially aged 5- and 6-years, n=24

	1	2	3	4	5	6	7
1. Rhyme 1	1						
2. Rhyme 2	0.721**	1					
3. Initial Phoneme1	0.678**	0.71**	1				
4. Initial Phoneme2	0.711**	0.714**	0.653**	1			
5. Carver 1	0.557**	0.488*	0.798**	0.628**	1		
6. Carver 2	0.638**	0.636**	0.891**	0.693**	0.787**	1	
7. √BAS2	0.654**	0.685**	0.869**	0.649**	0.806**	0.841**	1
8. √Ravens1	0.295ns	0.33ns	0.462*	0.304ns	0.556**	0.416*	0.444*
9. Age at T1	0.464*	0.414*	0.659**	0.342ns	0.472*	0.612**	0.47*

*p<0.05;**p<0.01

It would seem from the bivariate correlations in Table 4.20 that both aspects of phonological awareness are strongly associated with reading, but also that age and non-verbal abilities show some significant relationship with phonology and reading. This is clearly to be expected in a group which is heterogeneous with respect to age. It is therefore necessary (and possible) to enter independent variables in the order Age, Ravens, preexisting skill, before the IV of interest in a series of hierarchical regressions. These regressions are summarised in Table 4.21, for regression of reading onto earlier phonological awareness, and in Table 4.22, for tests of the reciprocal relationship of phonological awareness as might be predicted by earlier reading ability. Since, as was noted above, BAS scores at T1 contained a large number of zeros and were not susceptible to transformation, the regression of Word Reading at T2 (BAS2) will not have an entry for preexisting skills in that measure. For the same reason no regression has been undertaken of phonological awareness at T2 onto BAS scores at T1.

Table 4.21: Hierarchical regression of children's reading (Carver/BAS) scores at T2 onto phonological awareness (Rhyme/Initial Phoneme) at T1. (n=24)

DV=Carver test scores at T2		
	Adj-R2	F-to-enter
Age	0.346	
√Ravens 1	0.352	1.21ns
Carver1	0.656	19.6**
Rhyme 1	0.672	1.95ns
or		
Initial Phoneme1	0.776	11.7**
DV=√BAS test scores at T2		
	Adj-R2	F-to-enter
Age	0.185	
√Rav 1	0.231	2.32ns
Rhyme 1	0.436	8.61**
or		
Initial Phoneme1	0.745	43.3**

**p<0.01

Table 4.22: Hierarchical regression of phonological awareness (Rhyme/Initial Phoneme) onto earlier skill in word recognition (Carver test). (n=24)

DV=Rhyme awareness at T2		
	Adj R2	F-to-enter
Age	0.134	
√Ravens 1	0.127	0.84ns
Rhyme 1	0.469	14.5**
Carver 1	0.443	0.08ns
DV=Initial Phoneme awareness at T2		
Age	0.077	
√Ravens 1	0.069	0.82ns
Initial Phoneme 1	0.357	10.41**
Carver 1	0.357	1.02ns

**p<0.01

These analyses of the pooled data are more robust since it has been possible to remove contributions due to age, non-verbal ability and preexisting reading ability as part of the analyses. The analyses show that there exist, for the children in this study, predictive relationships between phonological awareness at T1 and reading skills at T2. For the children aged 6- or 7-years at the end of the study it seems that it was more likely that their reading would be better if they had better phonological awareness a year earlier. However, conversely, it does not seem that their phonological awareness was greatly influenced by earlier reading ability.

Another way of testing the views of Morais (1991), that acquisition of certain facets of phonological awareness (specifically awareness of individual phonemes) required instruction in literacy, is to compute the change in reading ability. According to the Morais-type hypothesis the change in literacy should be related to later levels of awareness of initial phonemes. This prediction has been tested by subtracting scores at T1 from scores obtained at T2 and relating this derived score to awareness of phonemes at T2.

The derived scores were checked for significant kurtosis and skew and it was found necessary to find the square roots of the derived scores to counteract positive skew and kurtosis for BAS(T2-T1). The change score for word recognition [Carv(T2-T1)] did not require any transformation. The derived scores [Carver(T2-T1); √BAS(T2-T1)] have then been entered in hierarchical regressions of Initial Phoneme awareness scores obtained at T2 (IPh2).

As before the variance in IPh2 that might be due to the effects of age, non-verbal ability or IPh1 (the scores in Initial Phoneme obtained at T1) were entered in the regression ahead of the change scores. The results may be seen in Table 4.23 (below).

Table 4.23: Hierarchical regression of Initial Phoneme awareness scores at T2 onto the changes in children's word recognition or reading scores. n=24

DV=Initial Phoneme scores at T2		
	Adj R2	F-to-enter
Age	0.077	
√Ravens 1	0.069	0.82ns
Initial Phoneme 1	0.357	10.4**
Carver(T2-T1)	0.332	0.26ns
or		
√BAS(T2-T1)	0.353	0.89ns

**$p<0.01$

This indicates that allowing for awareness of initial phonemes at T1, changes in either measure of reading were not associated with later performance in the test of initial phoneme awareness for these children. This would suggest that greater progress in reading did not, for these children, lead to any greater levels of awareness of initial phonemes. This contrasts to the results of Table 4.18 where a significant predictive relationship was reported between word recognition (Carver test) scores at 5-years and Initial Phoneme awareness at 6-years, even after awareness of initial phonemes at T1 had been taken into account. In discussing those results (Table 4.18) it was suggested that all that could be inferred from those findings was that there existed some predisposition or sensitivity to the acquisition of initial phonemes, but that it could not be held that the process of becoming a reader was causally linked to acquiring awareness of initial phonemes. These results (Table 4.23) add to that view, and indicate that changes in reading ability over time were not associated with later awareness of initial phonemes.

It is possible however that the effect of reading experience is lost in the larger, heterogeneous, group. The question remains for the 5-year-old children - did the changes in their word recognition predict initial phoneme awareness ? This question can be answered from a re-examination of the longitudinal data for the 13 children initially aged 5-years, and performing a further regression of Initial Phoneme scores obtained when the children were aged 6-years onto the derived change in reading scores (Table 4.24).

Table 4.24: Results of Hierarchical Regression of Initial Phoneme awareness scores obtained from children aged 6-years onto the derived 'change in word recognition ability' scores. n=13

DV=Initial Phoneme scores at T2		
Regression 1	**Adj R2**	**F-to-enter**
Ravens 1	0	
Carv(T2-T1)	0	0.29 ns

Thus it can be seen that changes in reading for these children between the ages of 5- and 6-years were not associated with their awareness of initial phonemes at age 6-years. It is possible to conclude therefore that it seems unlikely that the experience of reading over 12 months was associated with these children's awareness of initial phonemes at the end of the year. However it has been found (see Table 4.18) that their performance in the word recognition test independent of their phonological skills was predictive of their later phonological skill. It is also notable that this association is specific to the ages 5- to 6-years, as a comparable effect was not found for children aged 6- to 7-years.

4.2.4 Summary and Discussion

It has been shown in this section that in general performance aspects of phonological awareness may be associated both concurrently and developmentally with performance in tests of word recognition and word reading. Although there was some indication of an association between awareness of rhymes and word recognition, the most consistent predictive relationships that have been found here were between awareness of initial phonemes and word-reading and word-recognition at the same age. This was a finding replicated for 6-year-old children whose word-recognition scores were associated with awareness of initial phonemes after taking account of non-verbal abilities in both the '92 and '93 samples.

The finding of a lack of awareness of Initial Phonemes at age 5-years challenges the hypothesis due to Barron (1991) and Treiman & Zukowski (1991) that awareness of onsets (initial phonemes) might be apparent in children who had had no instruction in literacy. The absence of any effects at age 5-years, but the presence of awareness of initial phonemes at age 6-years related to word-recognition is, however, partially supportive of the views of Morais *et al* (1987).

In further confirmation of the views of Morais *et al* (1987), the analysis of relationships between variables over a twelve month period indicated that awareness of initial phonemes was predicted by scores obtained a year earlier (at age 5-years) in the test of word recognition. Awareness of initial phonemes at 5- and 6-years was, however, also found to predict performance in word reading and word recognition a year later at 6- and 7-years respectively. Contrary to the findings of Bradley & Bryant (1983) no such consistent results were found for awareness of rhymes.

The longitudinal findings have been interpreted as lending some support to the views of Morais *et al* (1987) and Morais (1991) who reported that awareness of phonemes might arise, causally, from instruction in literacy. This general conclusion is, however, modified by the finding that between the ages of 6- and 7-years awareness of initial phonemes did not appear to be predicted by either initial word recognition or word reading scores, nor by the change in word recognition scores.

The alternative hypothesis that had been put forward derived from the views of Barron (1991) and Treiman & Zukowski (1991) that awareness of onsets and rimes may be shown by children before they have become readers. This was explored on the basis that in the measures of rhyme and initial phoneme awareness that have been used throughout this study, the stimuli are all monosyllables whose rhymes/initial phonemes respectively coincide with the rime/onset of the syllable. It has been seen earlier in this chapter (§4.1) that for the children in this study awareness of rhyme and initial phonemes become substantive abilities at different ages, with awareness of initial phonemes (or onsets) not being shown at levels consistently greater chance before the children were aged 7-years. It has also been shown that awareness of initial phonemes may be predicted by word recognition scores obtained a year earlier at age 5-years. Whilst it cannot be concluded on the basis of the methodology and evidence here that instruction in literacy is responsible for the acquisition of phonemic awareness, it cannot be concluded, either, that awareness of onsets is a skill that children can unambiguously achieve before becoming literate. Thus the evidence here provides a counter example to the predictions derived from Barron (1991) and Zukowski & Treiman (1991).

Finally it should be noted that while awareness of both initial phonemes and rhymes accounted for significant proportions of the variance in concurrent attainments in word recognition, the cumulative total of variance shared with word recognition or word reading in the regressions reported in Table 4.11 is less than 50%. It may be concluded therefore that are other concurrent influences on reading apart from phonological awareness. Some investigation of other possible influences appear in later chapters of this thesis.

4.3 A comparison of hearing and hearing-impaired children's phonological awareness and the relationship with reading.

In this section data from the group of 15 partially hearing children aged 7-years will be compared to the results for the children without any hearing impairment.

4.3.1 Introduction

There is not a substantial literature on partially-hearing children's use of phonological codes in reading.

Locke (1978) compared the performance of hearing and profoundly deaf children in a task in which the children had to silently read a passage while marking every example they could find of a predetermined letter. The hearing children (aged 12- to 13-years) were found to detect significantly more pronounced than silent letters, whereas the hearing-impaired children (aged 11- to 16-years) detected equal numbers of silent and pronounced letters. The findings were interpreted as indicating that the hearing-impaired children did not convert print into speech.

Using a similar paradigm to Locke (1978), Chen (1976) had found that hearing and partially-hearing college students were significantly much more likely to miss silent *e*'s, than severely hearing-impaired students. This again was interpreted as suggesting that people with severe hearing difficulties would also exhibit a lack of phonological processing.

Hanson & Fowler (1987), however, found that deaf readers (college students) did have access to phonological information despite having prelingual and profound loss of hearing. It was further suggested by Hanson & Fowler (1987) that the acquisition and use of phonological codes might not be tied to the auditory modality.

In one of the very few studies involving children with differing degrees of hearing (Conrad, 1979), it was found that children (aged 16) with losses of up to 85dB appeared to be significantly less reliant on phonological codes in working memory than their hearing peers, but were also significantly better in this respect than other children of the same age who were profoundly deaf.

Pattison (1983) also found that partially-hearing children (aged 12 to 16 years) made less use of phonological codes than normally hearing children of the same reading age, though more than profoundly deaf children did.

Merrills (1988), however, concluded that inferior word recognition processes in the deaf were explained by substantial deficits in phonological awareness. These deficits, it was suggested, deprived the deaf of a self-teaching mechanism that would otherwise have been considered vital to the acquisition of independent reading skills.

Since the above brief review indicates that there might be some gradation in the use of phonological codes that is allied to the degree of hearing impairment, the purpose of the following investigation is to establish how a group of partially-hearing children aged approximately 7-years compared to hearing children of the same age or younger in terms of their performance in the measures of phonological awareness. Following that analysis the partially-hearing children's scores in the tests of reading are tested for association with phonological awareness in a similar manner to that which has already been used in the examination of the hearing children's reading.

4.3.2 Results

The mean scores for the partially-hearing children are shown in Table 4.25

Table 4.25: Mean (sd) of raw scores in Phonological awareness (Rhyme and Initial Phoneme), Word Recognition (Carver test), Word Reading (BAS), Nonverbal ability (Ravens) and Age for partially-hearing group. (n=15)

	Mean	sd
Rhyme awareness	6.2	1.6
Initial Phoneme awareness	6.2	2.4
Carver test	6.07	2.7
BAS test	20.2	18
Ravens Matrices	17.1	3.4
Age	82.7	4.8
Hearing loss	61.4	6.5

4.3.2.1 *Data screening*

The coefficients of kurtosis and skew for this data have also been inspected for departures from a normal distribution and all values have been found to lie within acceptable limits (see Appendix 3).

4.3.2.2 *Analysis*

To compare the mean performance of the partially-hearing children with the children who do not have any hearing difficulties a series of comparisons between the combined (n=30) groups of children without hearing difficulties and the partially-hearing group (n=15) were carried out. The results of these are summarised in Table 4.26. It was felt by taking the largest group of children without hearing difficulties a generally more robust comparison between the hearing and partially-hearing children would be obtained. This procedure is made possible by the use of non-parametric tests of rank-order differences between groups.

Table 4.26: Mean (and sd) of scores in Rhyme, Initial Phoneme, Carver, BAS and Ravens obtained from Partially-Hearing (P-H, n=15) and Hearing children (H, n=30 for each age group) with Mann-Whitney test (z) for differences between Groups

	P-H (n=15)	Hearing n=30		
Age group:	**Y 2**	**Y 2**	**Y 1**	**R**
Mean Rhyme	6.2	7.28	6.5	4.67
sd	1.61	1.89	2.08	2.28
z: H vs P-H		-2.03*	-.671ns	-2.47*
Mean IPh	6.2	7.2	5.6	3.8
sd	2.4	2.2	2.6	1.5
z: H vs P-H		-1.40ns	-.78ns	-3.29**
Mean Carv	6.1	7	3.7	1.9
sd	2.7	2.4	2.5	1.5
z: H vs P-H		-1.17ns	-2.54*	-4.33**
Mean BAS	20.2	17.4	3.6	0
sd	18	18.1	10.3	0
z: H vs P-H		-.61ns	-3.74**	
Mean Ravens	17.07	18.9	17.07	13.9
sd	3.41	4.78	3.97	3.31
z: H vs P-H		-1.22ns	-0.09ns	-2.68**

*p<0.05;**p<0.01

The results of this non-parametric analysis suggest that the hearing-impaired children's levels of phonological awareness and non-verbal abilities are probably more comparable to the 6-year-old (Y1) children who had no hearing difficulties. However these partially-hearing children's word recognition (Carver test) and word reading (BAS test) scores were closest to the hearing children of the same age, ie the Y2 (7-year-old) group of children.

The correlations between variables for the partially-hearing children are shown below in Table 4.27

Table 4.27: Coefficients of correlation between Phonological awareness (Rhy and IPh), Word Recognition (Carver test) Word Reading (BAS) Nonverbal ability (Ravens) variables and Age for partially-hearing children. (n=15)

	1	2	3	4	5	6
1. Rhy	1					
2. IPh	-0.381ns	1				
3. Carver	0.288ns	0.357ns	1			
4. BAS	0.372ns	0.226ns	0.644**	1		
5. Ravens	-0.158ns	-0.142ns	0.412ns	0.099ns	1	
6. Age	0.237ns	0.165ns	0.239ns	0.474ns	-0.194ns	1

**p<0.01

Although there do not appear to be any significant associations between phonological awareness and reading, hierarchical regressions have been undertaken to get some information on the effect size (ie R^2) for comparison with findings available in the literature and the earlier findings reported in this chapter for the relationship that obtained in the hearing children who have been studied.

In this case the tables summarising the regressions also contain R^2 values as well as the more conservative values (Adj-R^2) which are adjusted for the sample size.

Table 4.28: Hierarchical regression of partially-hearing children's Reading scores (Carver word recognition, or BAS word reading) onto nonverbal ability (Ravens matrices) and phonological awareness (Rhyme or Initial Phoneme). n=15

DV=Carver			
	R2	Adj-R2	F-to-enter
Ravens	0.17	0.106	
Rhyme	0.298	0.181	2.19ns
or			
Initial Phoneme	0.346	0.237	3.23ns
DV=BAS			
Ravens	0.01	0	
Rhyme	0.164	0.025	2.22ns
or			
Initial Phoneme	0.068	0	0.76ns

It can be seen that although the entry of either phonological awareness variable does not share statistically significant amounts of variance with either DV in these regressions the amount of variance (R^2) that the phonological variables adds to the regression (up to 17% in the case of Initial Phoneme awareness in the regression of Carver scores) is comparable to the amounts proportions of variance cited by Bradley & Bryant (1983) as being shared between their sound categorisation tasks and measures of reading.

4.3.2.2.1 *Conclusion*

Thus while it can be seen that the partially-hearing children had reading levels close to the hearing children of the same age (7-years), there appears to be no evidence of a statistically significant association between the partially-hearing children's reading or word recognition skills and their phonological awareness. This would suggest that the partially-hearing children were unlikely to be using phonological skills in word reading, despite having an ability to demonstrate phonological awareness at levels comparable to the children aged 6- and 7-years without hearing difficulties, who appeared to be using their knowledge of sounds to help them read. This would suggest that success in these reading tasks is by no means entirely dependent on phonological skills.

Clearly however there is a possibility of Type 2 error, ie of failing to detect a relationship between variables when in fact there is one. From the tables provided by Cohen & Cohen (1983), and making an assumption that for the population of children aged 7-years there is a correlation of approximately 0.5 between either measure of phonological awareness and either test of reading (an assumption derived from the results of the investigation conducted earlier in this chapter), it seems that there is a probability of about 0.5 of failing to detect a relationship. Following the suggestion of Cohen & Cohen (1983) it would be necessary to have a group of at least 28 children to achieve sufficient power to be able to confidently accept there was no association between phonological awareness and reading given the same assumption of the correlation that might be found in the population. Since these conditions are not met it is not possible at this stage to do other than comment that for this group of partially-hearing children the relationship between phonological awareness and reading appeared to be statistically small enough to have been found by chance.

4.4 Summary and discussion

In this chapter it has been shown that for the children aged 5-, 6- and 7-years with *no hearing difficulties*

1) There were overall increases with age in awareness of rhymes and initial phonemes;
2) Awareness of rhyme was evident before the acquisition of literacy; whereas awareness of initial phonemes emerged later, possibly as a consequence of the acquisition of literacy;
3) There were overall associations between phonological awareness and word recognition and reading;
4) Reading was predictable from phonological skills a year earlier;
5) Experience of reading did not in general promote growth in phonological skills.

In comparison, the *partially-hearing* children, aged 7-years, were found to have

1) Phonological skills at levels comparable to children aged 6- to 7-years;
2) Word recognition and reading scores similar to hearing children aged 7-years;
3) No significant association between phonological awareness and reading skills.

For the children without any hearing difficulty, phonological awareness accounted for up to 29% of the variance in word recognition scores (at the same age) once the effects of non-verbal ability had been discounted (see Table 4.10a). In one group of 15 children aged 7-years (Table 4.12b), however, it seems that awareness of initial phonemes might account for an additional 41% of the variance in word recognition following removal of the variance due to non-verbal ability.

It is therefore evident that phonological awareness might make quite a substantial contribution to the development of word reading, as has been found in other studies (eg Bradley & Bryant, 1983; Maclean, Bryant & Bradley, 1987; Hatcher, Hulme & Ellis, 1994; Wagner, Torgesen & Rashotte, 1994). However, since phonological awareness does not consistently account for large proportions of the variance in reading, other factors, not examined here, may also be implicated. The partially-hearing children provide some confirmation of this. Thus although they achieved reading scores very similar to the hearing children of the same age, and had only slightly poorer phonological skills, it seems evident that the partially-hearing children's phonological awareness scores were not significantly associated with their performance in word reading. On this basis it would seem that the partially-hearing children do not appear to be using phonological skills in reading. Since, however, statistical tests lack sufficient power with groups of the size employed here, it is not possible to confidently eliminate the chance of Type 2 errors being made, ie that for these partially-hearing children, too, there was a relationship between phonological awareness and reading. To eliminate the possibility of Type 2 errors further experimental study is required with larger groups.

However it might be that phonological awareness, as judged by the tests used here, may not be necessary or sufficient to account for performance in tests of word recognition or reading. No clear conclusion can however be drawn here about the skills that any of the children used in their reading, since the measures used do not assess any specific skill but are merely measures of progress in reading. To test for specific skills would require further experimental study, for example using tests of non-word reading and word priming tasks (as used, for example, by Pring & Snowling, 1986) to test for understanding of grapheme-phoneme correspondences and use of analogies (Goswami, 1990).

No conclusions can be drawn about the influence of phonological awareness on the development of the partially-hearing children's reading. It would be of great interest to conduct a longitudinal study of partially-hearing children and the development of their phonological skills in relation to reading. A hypothesis to be tested in such a study could be that the partially-hearing children acquire awareness of phonological segments from their experience of reading.

In these present investigations, although there was some evidence (Table 4.18) to suggest that word recognition ability at the age of 5-years might be indicative of the same children's awareness of initial phonemes a year later, as might be expected from the studies of Cataldo & Ellis (1988), Ellis (1990) and Morais (1991), in general it seems unlikely that for any of the hearing children who participated in these investigations there was any consistent influence of reading on the acquisition of phonological awareness.

In subsequent chapters some other possible influences on children's phonological awareness and word reading will be considered, starting with a series of analyses of the possible relationship between speech perception and phonological awareness.

Chapter Five

Categorical Speech Perception and Phonological Awareness

5.0 Overview

This chapter[1] gives details of investigations into possible relationships between children's categorical labelling of speech sounds and their skills in the phonological awareness tasks.

Three possibilities are considered. Firstly, that there is an innate relationship between the perception of speech and the development of children's awareness of linguistic and phonological segments. Secondly, that there is a developmental need for children to have skills in the perception of speech in order to acquire phonological awareness. Finally, that there is no close association between phonological awareness and the perception of speech although both may show increases with age. These possibilities are considered in turn. The data used will be that obtained from the groups of hearing children aged 5-, 6- and 7-years and the group of partially-hearing children.

5.1 Introduction

Intuitively, speech processing and reading words may seem closely connected. Conrad (1972), for example, investigated vocalisations during reading and concluded that 'silent speech' during reading was likely, but not inevitable. Perfetti and McCutchen (1982), however, observed that speech-like processes are not *logically* required in reading, and Liberman (1989) remarked on the paradoxical difficulty children face in learning to read when they already seem to perceive speech with ease. There is, however, a considerable literature demonstrating that awareness of patterns of sounds within language is linked to reading skills (see, for example, Adams, 1990; Goswami & Bryant, 1990; Wagner & Torgesen, 1987, and Chapter 4 (above) for reviews of this field). The development of this awareness in children is poorly understood, and there are still conflicting views on the possible role of the auditory processing of speech. The aim of this chapter is to explore one aspect of the possible relationship between the perception of speech and the awareness of linguistically

[1] A version of this chapter has now been published - Gibbs (1996).

relevant patterns of sounds in the context of the first years of word reading.

Within the available literature and the views outlined below, there seems, unfortunately, to be some potential for confusion of terms. Thus, for example, Bradley and Bryant (1983) referred to the 'categorisation of sounds'. Others (eg Shankweiler & Liberman, 1976) have similarly explored the relationship between reading and 'speech processes'. These investigations have undoubtedly made vital contributions to our understanding of underlying processes, but have in fact frequently worked on the basis of 'speech processing' which actually occurs at deeper levels of analysis (ie *post*-auditory and intra-mental) rather than at the purely auditory or perceptual level. This chapter will explore the relationship between the auditory perception and categorisation of speech sounds and the awareness of patterns of linguistically significant sounds. It is this latter ability which is known as phonological awareness. Snowling and Hulme (1994) for example define phonological awareness as the ability to reflect on the sound structures of spoken words. The term 'phonological awareness' may subsume an awareness of syllables or phonemes (Morais, 1991), but in general implies an awareness of contrasting units of sound which are associated with contrasting meanings.

From linguistic and psychological perspectives a line of approach adopted by early investigators of the development of phonological awareness was that awareness of the systematic patterning of sounds in language was developmentally contingent on the perception of speech sounds (Sapir, 1925; Fries, 1963). In the 1970s there was, as Nittrouer (1994) has pointed out, a widely accepted view that linguistic stimuli were perceived differently from non-linguistic stimuli. According to this view, when attending to speech the listener disregarded acoustic information and automatically perceived a linguistic stimulus as belonging to a phonemic category. Non-linguistic signals, it was argued, might, however, be discriminated as neighbours on a continuum. On the basis of this type of argument it would be expected that children would naturally perceive linguistic information categorically, and that no learning was required to acquire mature sensitivity to phonological contrasts.

Smith (1973) for instance gave a detailed description of a child's phonological development and argued that the child perceived speech in terms of the adult phonological distinctions that were available to him. In respect of the acquisition of literacy Chomsky (1970), concluded that

> 'The teacher of reading is not introducing the child to some new and obscure system that is only distantly related to the spoken language' (Op. cit. p4)

and

> 'The same processes that enable him [the reader] to understand spoken speech enable him to associate a structural description - in particular, a surface structure - with this lexical representation.' (ibid p 12)

Eimas, Siqueland, Jusczyk & Vigorito (1971) investigated the perception of speech by infants. They discovered that infants aged 1- and 4-months could discriminate between certain consonant sounds in an apparently categorical manner. Reinforcing the views of Chomsky (1965) and others Eimas *et al* concluded that their evidence indicated that the mechanisms underlying such perceptual ability were possibly innate, and that infants perceived speech in a linguistic mode.

There are now, however, those who have adopted an alternative standpoint and hold that awareness of constituent phonemic information is not a simple correlate of language acquisition, and that phonemic segments and acoustic structure do not stand in one-to-one correspondence. Lindau and Ladefoged (1986, p466) for instance reported that there was no evidence of 'a unique acoustic property that was an invariant correlate of a phonological feature'. Burnham, Earnshaw & Quinn (1987) reviewed the work of Eimas, Siqueland, Jusczyk & Vigorito (1971) and, countering Eimas *et al's* conclusions, showed how linguistic experience modified categorical speech perception.

A model of the identification of isolated speech sounds was proposed (Pisoni & Sawusch, 1975; Studdert-Kennedy, 1974) in which three consecutive stages led from audition to phonological analysis. The first stage was an *'Auditory stage'* during which a preliminary auditory analysis of the raw signal took place and results were placed in 'auditory memory'. During the subsequent *'Phonetic stage'* the contents of this 'auditory memory' would be examined for 'acoustic cues' so that phonetic segments, (for example [g]), are identified, labelled and placed in a 'phonetic memory' that is categorical in nature. This implies that at this stage the speech sounds would have been 'forced' into discrete categories, and no distinction would then be possible between allophones (acoustically discriminable variations of a phoneme). Finally, during the *'Phonological stage'* the listener would refer to knowledge of sequences of phonetic segments and make any necessary adjustments to the preliminary identification to achieve conformity to the rules and known representations. More recently Snowling and Hulme (1994) have stressed the importance of the reliability of these underlying phonological representations as forming a basis for subsequently learning the mappings between phonology and orthography.

With respect to speech sounds in which, for instance, the onset of the voicing feature (VOT) is varied, Burnham, Earnshaw & Quinn (1987) and Hazan, Fourcin & Abberton (1991) have found that the awareness of the voicing contrast is a relatively late perceptual acquisition, and the ability to give consistent categorical labels for individual speech sounds drawn from a VOT continuum may not be fully developed until around 6 years of age. Burnham, Earnshaw & Quinn (1987) in fact held that the nature of the linguistic environment (and therefore the linguistic experience of children) was a determining factor in the development of categorical perception of certain contrasts.

An alternative three factor model of the identification of speech was developed and tested by Werker and Logan (1985). Rather than the consecutive stages of processing outlined by Pisoni & Sawusch (1975) and Studdert-Kennedy (1974), Werker & Logan (1985) suggested that, at least in adults, there is evidence for three *distinct* possible perceptual strategies. Thus at the *"phonemic"* level, under conditions resembling everyday oral communication, syllables would be classified according to the phonological categories or representations used to contrast meaning in the native language. Under some other conditions it would be possible to elicit responses that accord with a level of *"phonetic"* perception in which sensitivity to phonetic distinctions occurring in some other (non-native) languages might be observed. Finally Werker and Logan (1985) discriminated a third set of conditions under which there might be *"auditory"* processing of acoustic differences in 'speech sounds' that do not correspond to any phonetic boundaries that phonologically contrast meaning in any language. Neither Pisoni & Sawusch (1975), Studdert-Kennedy (1974) or Werker & Logan (1985), however, give any indication of possible developmental mechanisms.

From a developmental perspective Burnham (1986) and Burnham, Earnshaw & Quinn (1987) have proposed that speech perception is only partially developed at birth and through 'attunement' over succeeding years perceptual abilities may be facilitated, maintained or lost. Thus perceptual abilities would be maintained or developed in a sympathetic linguistic environment, whereas in the absence of particular sounds in the linguistic environment the ability to perceive those sounds or contrasts would be lost.

With respect to the facilitative processes in English, Zlatin & Koenigsknecht (1975) had already found evidence of a progressive narrowing of the perceptual gap between categories that can be consistently labelled (using a Voice-Onset Time continuum and stimuli such as *goat/coat*) over an age range of two to six years.

Burnham (1986) further proposed that loss of perception of speech contrasts (described as lying on a 'robust' to 'fragile' continuum, with more 'robust' contrasts having stronger psychoacoustic bases) probably occurs in two distinct phases related to the robustness/fragility and salience of particular contrasts. The first phase of loss occurs between six to twelve months of age, the second between four and eight years. In the first phase Burnham *Op. cit.* suggested that nonnative 'fragile' contrasts are lost through lack of *phonetic exposure* (Werker & Logan, 1985), whereas in the second phase nonnative 'robust' contrasts are lost due to lack of *phonological experience* (Werker & Logan *Op. cit.*).

Children at about the age of 6 years, Burnham (1986) and Burnham, O'Connor & Earnshaw (1986) proposed, would have sufficient competence in language and segmentation skills to be able, or even be required by environmental/educational factors, to use a *phonemic* processing strategy when listening to speech. With increased automation of phonemic processing, it is suggested, *phonetic* processing of speech might then be possible using more readily available residual attentional resources.

Overall Burnham's (*passim*) speculations suggest a possible refinement and ontogenetic development of speech processing which co-relates with increased competence in other language skills. These proposals gain some support from Ohala (1986) who found phylogenetic evidence of phonological control of speech perception, and Morais (1991) with evidence that awareness of individual phonemes is unlikely to develop without instruction (in literacy). Nittrouer & Studdert-Kennedy (1987) found that by the age of 7 years children were able to use perceptual strategies very similar to those used by adults and attend to phonemic segments, but that younger children (aged 3 & 4 years) were more likely to be listening for whole words or syllables in speech. Nittrouer (1994) suggested that the varying use young children make of acoustic information relates to the development of their phonemic processing ability.

Within the literature on Phonological Awareness and Reading evidence has been found suggesting that imperfect speech perception (at the level of audition and phonetic labelling) might be associated with poor reading and phonological difficulties. Brady (1991), for example, suggested that deficits observed in speech perception may reflect a more general difficulty in encoding language. Werker and Tees (1987), and Reed (1989) using age-matched samples of readers and 'reading disabled' children found differences in categorical speech perception related to reading performance, and proposed that this would indicate less robust phonological processing or representation resultant from perceptual deficits. Significant differences between 10-year old dyslexics and age-matched controls in tests of identification and discrimination of synthesised consonants were also found by Godfrey, Syrdal-Lasky, Millay and Knox (1981). Godfrey *et al* (1981) likewise suggested this indicated inconsistencies in the phonetic classification of auditory cues. De Weirdt (1988) also viewed speech perception as 'the input process for phonological material' (ibid p164) and gave experimental evidence, from tests of reading and perception of synthetic stop consonants in 6-year old children, which was held to support a hypothesis that auditory perception is a source of phonological processing difficulties. De Weirdt's conclusion, and that of others who have inferred that phonological difficulties are consequent on perceptual difficulties (ie following the linguistic lead of Chomsky *et al*), is still hypothetical since the association between speech perception and phonological awareness does not yet seem to have been directly demonstrated. Bird & Bishop (1992) in fact provided counter-evidence that suggests that the difficulties experienced by children with phonological impairments may not be explained by problems in auditory discrimination.

An alternative approach to investigating problems in auditory discrimination has been taken by Snowling, Hulme, Smith and Thomas (1994) who explored the effect of the manipulation of phonetic characteristics (voicing and place of articulation) within tests of phonological awareness. The tests were similar to those used by Bradley and Bryant (1978 and *passim*). Snowling *et al* (1994) found that judgment in the phonological task became more difficult as the phonetic characteristics of the target consonant became less different from those of the distractor stimuli.

Although the Snowling *et al* (1994) finding demonstrated that the task of performing phonological analyses can be made harder by manipulating the characteristics of stimuli, it does not demonstrate that deficits in speech perceptual ability would be associated with, or lead to, difficulties in developing an awareness of phonological contrasts. What follows is an investigation of the possibility that children's ability to label speech sounds categorically is associated with their phonological awareness.

On the basis of the above review at least three alternative hypotheses might therefore be formulated.

Firstly, and largely due to the 'innateness' argument put forward by Chomsky (1965, 1970), it might be held that that speech perception and phonological awareness will be associated, concurrently, because

(i) auditory processing skills are inevitably implicated within phonological awareness tasks;

(ii) linguistic stimuli are automatically perceived within phonemic categories.

If this hypothesis is to be upheld evidence of significant simple correlations between performance in tasks assessing speech perception and phonological awareness should be found.

Secondly the development of phonological awareness could be dependent on good speech perception as children learn that speech may be segmented and they acquire abilities to identify sounds within phonemic categories. In this case a longitudinal study would demonstrate that skills in speech perception at Time 1 would be associated with performance in a measure of phonological awareness at Time 2. It would critically be the converse case that impaired speech perception would be associated with generally lower levels of phonological awareness.

The third possibility, arising from the proposals of Burnham (1986), Burnham, Earnshaw & Quinn (1986) and Nittrouer & Studdert-Kennedy (1987), might be that while both phonological awareness and speech perception skills develop with age there would be no close association between performance in the measures. However, awareness of phonological segments at the level of syllables would, in younger children at least, be associated with performance in a task assessing the ability to identify individual phonemes within the context of words, but at this age skills in speech perception would not be associated with performance in the same phonemic identification task. Only when relative competence in phonological awareness has been achieved might it be evident that speech perception and the identification of individual phonemes were associated.

These three possibilities form the basis of the investigations that are described in the following sections.

5.2 Methodology

5.2.1 Design

To test the general hypothesis that there *is* a relationship between speech perception and phonological awareness a measure of labelling speech sounds on a Voice Onset Time continuum has been employed. Children's performance on this measure has been used to study the simple correlations with their performance on the two measures of phonological awareness.

By sampling children in the first three years of formal education at two times separated by 12 months it was hoped to be able to draw conclusions on the basis of replication of cross-sectional data with a longitudinal analysis also available. This latter aspect should allow for a direct evaluation of developmental precedence.

To evaluate the alternative proposals (partly due to Burnham (1986), Burnham, Earnshaw & Quinn (1986), Burnham, O'Connor & Earnshaw (1986) and Nittrouer & Studdert-Kennedy (1987)) the effect of variables in predicting children's performance in the identification of initial phonemes will be assessed across age and hearing ability when the effects of reading ability are controlled. Specifically it is proposed that if children are using a *phonemic* processing strategy then awareness of rhyme would facilitate the identification of initial phonemes and speech tokens. If, however they have access to phonetic information, as Burnham and colleagues (*passim*) and Nittrouer & Studdert-Kennedy (1987) suggest should be the case with older children with greater competence in language and, therefore, more readily available residual attention, performance in the speech perception task should predict performance in the initial phoneme task. Step-wise regression techniques will therefore be used to analyse the data available from the cross-sectional and longitudinal surveys, with performance in reading entered first to control for the effects of instruction and learning in that domain. A test of the effect of impaired speech perception (arising from hearing difficulties) will be undertaken using the group of children with partial and prelingually acquired loss of hearing.

5.2.2 Results

5.2.2.1 *Cross-sectional study*

The children's mean ages and raw scores (and standard deviations) are shown in Table 5.1. This gives the results for both samplings in '92 and '93. Speech Perception ranges from 1 (random labelling ability) to 5 (consistently accurate labelling), and scores in both measures of Phonological Awareness can range from 0 (low) to 9 (all rhyming/alliterative pairs identified). Scores in the Carver test can range from 0 to 10. Age at time of testing is given in months.

Table 5.1: Means (and sd's) of raw scores in categorical Speech Perception, Rhyme and Initial Phoneme (phonological awareness), Carver (Word Recognition), BPVS (vocabulary), Ravens (nonverbal ability) and Age in '92 & '93 (n=15 for each group)

	SpP	IPh	Rhy	Carver	BPVS	Ravens	Age
R Group '92	3.3 (1.8)	3.9 (1.7)	4.9 (2.4)	2 (1.5)	10.9 (2.7)	15.5 (2.7)	58 (1.2)
R Group '93	2.9 (1.5)	3.7 (1.7)	4.5 (2.2)	1.7 (1.5)	8.7 (3.2)	12.3 (3.1)	56.5 (1.9)
Y1 Group '92	3.9 (1.5)	5.9 (2.0)	7 (1.6)	3.4 (2.6)	12.3 (2.7)	18.2 (4.2)	69.8 (1.6)
Y1 Group '93	2.9 (1.2)	5.3 (3.1)	6 (2.4)	4.1 (2.3)	10.5 (2.1)	15.9 (3.5)	69.8 (1.3)
Y2 Group '92	4.3 (1.2)	6.9 (2.3)	6.9 (2.1)	6.6 (2.5)	13.6 (2.5)	19 (4.4)	81.9 (1.2)
Y2 Group '93	4.6 (0.9)	7.5 (2.1)	7.6 (1.6)	7.5 (2.4)	13.5 (3.5)	18.7 (5.3)	81.2 (1.7)

SpP= Speech Perception; IPh = Initial Phoneme; Rhy = Rhyme; BPVS=British Picture Vocabulary Scale; Ravens=Ravens Coloured Matrices.

5.2.2.1.1 *Data screening and treatment*

The reliabilities of the speech perception scores have been checked (using the Kuder-Richardson formula cited by Anastasi, 1968) both during pilot testing and using the results gathered during the main study reported here. The coefficients (r_{II}) derived from the substantive study are as follows (Table 5.2 below).

Table 5.2: Reliability coefficients r_{II} of Speech perception scores

	Sp. P'n
R Group '92	0.82
R Group '93	0.84
Y1 Group '92	0.68
Y1 Group '93	0.75
Y2 Group '92	0.67
Y2 Group '93	0.67

These coefficients are at an acceptable level for all groups.

Checks for skew and kurtosis were carried out using the procedures described by Tabachnick & Fidell (1989) and the data was found not found to be consistently normally distributed. When it has been appropriate to effect transformations of the data these will be noted in the text.

5.2.2.1.2 *Data Analysis*

As the data are best considered as based on ordinal scales of measurement, detailed analysis was conducted using non-parametric tests. Preliminary analysis of the data for changes across age was undertaken using the Kruskal-Wallis analysis of variance by ranks (with correction for tied ranks) and subsequent Mann-Whitney pairwise (two-tailed) tests. The results of this analysis are shown in Table 5.3.

Table 5.3:Comparison of changes in Speech Perception between age groups in '92, '93 and combined groups using Kruskal-Wallis (KW) for overall trend and Mann-Whitney (two-tail) pairwise comparisons

	Overall KW	R vs Y2	R vs Y1	Y1 vs Y2
'92	2.69ns	1.54ns	1.09ns	0.63ns
'93	13.0**	3.05**	0.17ns	3.35**
Combined	13.1**	3.31**	0.98ns	2.94**

**p<0.01

The changes between group mean scores in '92 and '93 are shown in Figure 5.1, and categorical labelling functions showing mean performance for children in each age group are shown in Figure 5.2 which may be compared with the idealised examples shown in Figure 3.1 in Chapter 3:

Fig 5.1a: Mean scores in Speech Perception in '92

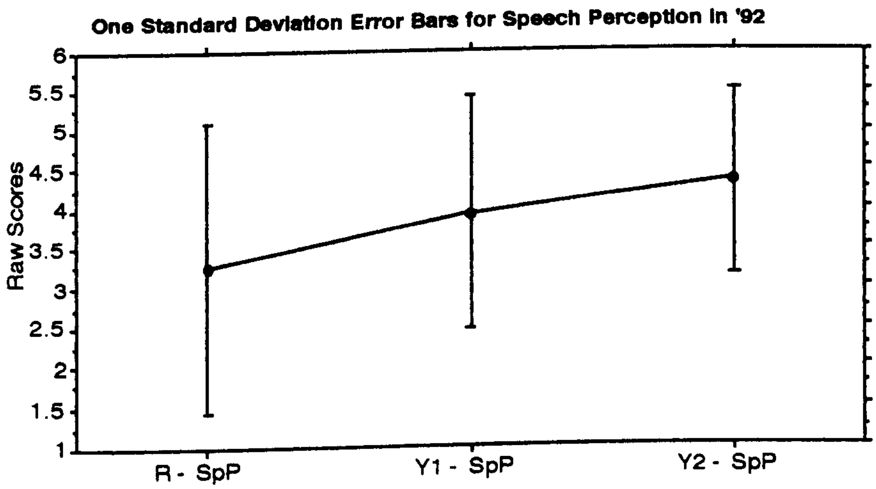


Fig 5.2b: Mean scores in Speech Perception in '93

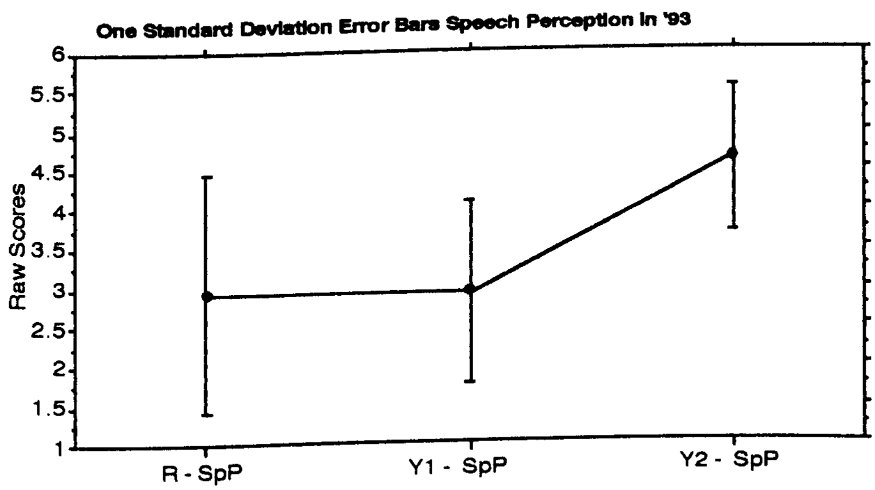


Table 5.2c: Mean scores in Speech Perception for combined group

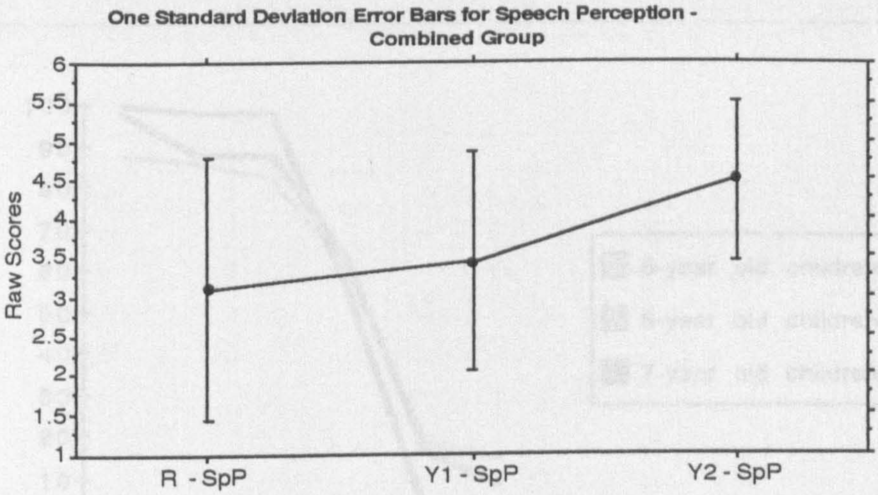


Fig 5.2a: Mean Categorical Labelling Functions for Speech Perception at T1

The vertical axis relates the % of items identified as /g/; the horizontal axis are Voice Onset Times increasing in 20ms steps

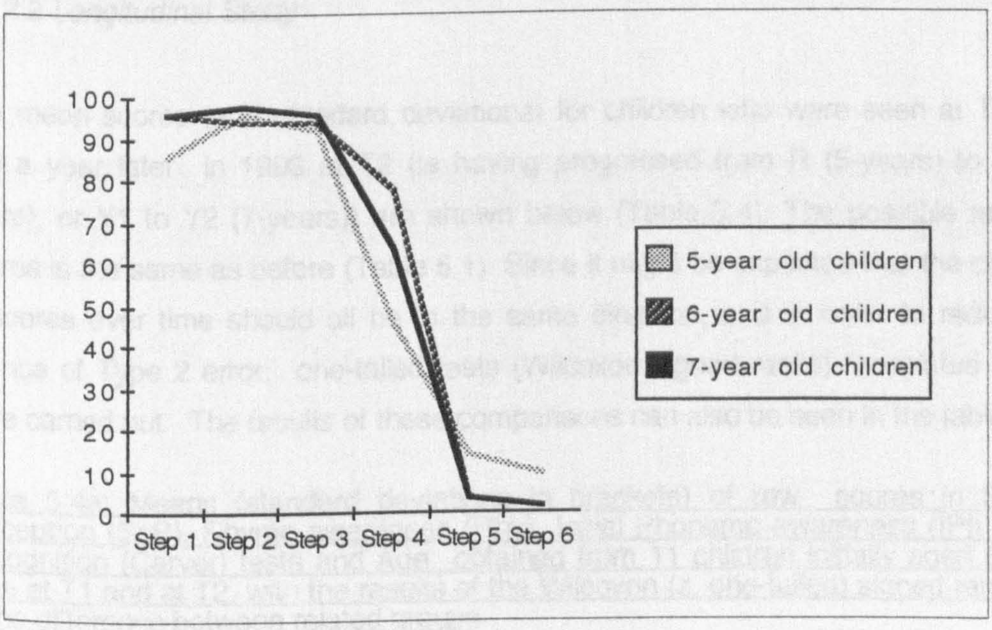
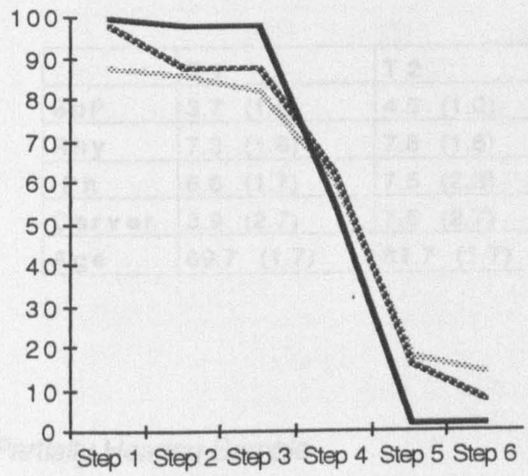


Fig 5.2b: Mean Categorical Labelling Functions for Speech Perception at T2

The vertical axis relates the % of items identified as /g/; the horizontal axis are Voice Onset Times increasing in 20ms steps



5.2.2.2 *Longitudinal Study*

The mean scores (and standard deviations) for children who were seen at T1 ('92) and a year later in 1993 at T2 (ie having progressed from R (5-years) to Y1 (6-years), or Y1 to Y2 (7-years)) are shown below (Table 5.4). The possible range of scores is the same as before (Table 5.1). Since it might be expected that the changes in scores over time should all be in the same direction, and in order to reduce the chance of Type 2 error, one-tailed tests (Wilcoxon signed ranks) for related groups were carried out. The results of these comparisons can also be seen in the table.

Table 5.4a: Means (standard deviations in brackets) of raw scores in Speech Perception (SpP), Rhyme awareness (Rhy), Initial Phoneme awareness (IPh), Word Recognition (Carver) tests and Age obtained from 11 children initially aged 5-years seen at T1 and at T2, with the results of the Wilcoxon (z, one-tailed) signed ranks test of the difference between related groups

	T1	T2	z	p
SpP	3.1 (1.9)	2.8 (1.1)	0.78	0.3
Rhy	5.0 (2.5)	5.8 (2.5)	1.49	0.07
IPh	4.1 (1.7)	5.8 (3.0)	2.15	0.02
Carver	2.0 (1.6)	4.2 (2.5)	2.88	<0.01
Age	57.8 (1.1)	69.8 (1.1)		

Table 5.4b: Mean scores (sd) of raw scores in Speech Perception (SpP), Rhyme awareness (Rhy), Initial Phoneme awareness (IPh), Word Recognition (Carver) tests and Age obtained from 13 children initially aged 6-years seen at T1 and at T2, with the results of the Wilcoxon (z, one-tailed) signed ranks test of the difference between related groups

	T 1	T 2	z	p
SpP	3.7 (1.6)	4.5 (1.0)	1.6	0.05
Rhy	7.3 (1.6)	7.8 (1.8)	1.28	0.1
IPh	6.6 (1.7)	7.5 (2.3)	1.44	0.07
Carver	3.9 (2.7)	7.5 (2.7)	2.82	<0.01
Age	69.7 (1.7)	81.7 (1.7)		

5.2.2.3 *Partially Hearing Sample*

The mean scores (and standard deviations) together with age at time of testing, and average hearing thresholds are shown in Table 5.5. The range of possible scores is as before.

Table 5.5: Means (and standard deviations) for raw scores in Speech Perception (SpP), Rhyme awareness (Rhy), Initial Phoneme awareness (IPh), Word Recognition (Carver) tests and Age obtained from 15 Y2 Partially-hearing children aged approximately 7-years

SpP	Rhy	IPh	Carver	Age	Hearing Level (dB)
3.2 (1.4)	6.2 (1.6)	6.2 (2.4)	6.1 (2.7)	82.7 (4.8)	61.4 (6.5)

From inspection of these results in Table 5.5 and comparing them to the data on 7 year-old children (Table 5.1) a difference in mean levels of Speech Perception is apparent. This difference is confirmed by the Mann-Whitney test as significantly different from the performance of the combined hearing sample of 7-year old children with $z=-3.12$ ($p<0.01$). The comparisons of other variables have been reported in the previous chapter. For convenience the relevant parts are reproduced here in Table 5.5a, below.

Table 5.5a: Mann-Whitney (z) tests of differences between performance in Speech Perception (SpP), phonological awareness (Rhy, IPh), word recognition (Carver), and nonverbal ability (Ravens) by Partially-Hearing (P-H) children (n=15) and children without hearing difficulties (n=30)

	P-H (n=15)	Hearing n=30		
Age group:	Y 2	Y 2	Y 1	R
Mean SpP	3.2	4.5	3.4	3.1
sd	1.4	1	1.4	1.7
z: H vs P-H		-3.57**	-.443ns	-.269ns
Mean Rhyme	6.2	7.28	6.5	4.67
sd	1.61	1.89	2.08	2.28
z: H vs P-H		-2.03*	-.671ns	-2.47*
Mean IPh	6.2	7.2	5.6	3.8
sd	2.4	2.2	2.6	1.5
z: H vs P-H		-1.40ns	-.78ns	-3.29**
Mean Carver	6.1	7	3.7	1.9
sd	2.7	2.4	2.5	1.5
z: H vs P-H		-1.17ns	-2.54*	-4.33**
Mean Ravens	17.07	18.9	17.07	13.9
sd	3.41	4.78	3.97	3.31
z: H vs P-H		-1.22ns	-0.09ns	-2.68**

**$p<0.01$; *$p<0.05$

5.3 Are speech perception and phonological awareness concurrently associated ?

To test for association between Speech Perception and Phonological Awareness Spearman correlations were calculated for each year of the hearing sample. These are shown in Tables 5.6 (for '92 sample) and 5.7 (for the '93 sample):

Table 5.6: Correlation coefficients between Speech Perception (SpP) and Phonological Awareness (Rhyme and Initial Phoneme) measures ('92; n=15 each group)

SpP	Rhy	IPh
R group	0.37ns	0.16ns
Y1 Group	0.24ns	-0.22ns
Y2 Group	0.26ns	0.16ns

Table 5.7: Correlation coefficients between Speech Perception (SpP) and Phonological Awareness (Rhyme and Initial Phoneme) measures ('93; n=15 each group)

SpP	Rhy	IPh
R group	0.01ns	0.34ns
Y1 Group	-0.27ns	0.03ns
Y2 Group	0.06ns	0.26ns

Table 5.8 shows the equivalent results for combined data sets at each age.

Table 5.8: Correlation coefficients between Speech Perception (SpP) and Phonological Awareness (Rhyme and Initial Phoneme) measures ('92 & '93 data pooled; n=30 each group)

SpP	Rhy	IPh
R Group	0.19ns	0.31ns
Y1 Group	0ns	-0.08ns
Y2 Group	0.25ns	0.16ns

In these analyses (above) whilst it is clear that there appears to be no association between performance in categorical labelling of speech and phonological awareness, it is possible that the abilities of 'outlying' children (ie those with very high or very low performance in a measure) is obscured and that any association between performance in two measures would not have been detected. To investigate this possibility the data was partitioned using the following procedure.

For each measure cut-off points 1/2 a standard-deviation either side of the group mean were established. Data points within the central region defined by these cutoffs were rejected. The remaining, reduced, data set was then recoded as 'high' or 'low' as appropriate, and point-biserial correlation coefficients (r_ϕ) were calculated. These coefficients are shown below in Tables 5.9 - 5.11 .

Table 5.9: Correlation coefficients (r_ϕ)between Speech Perception and Phonological Awareness (Rhy, IPh) measures for partitioned data ('92)

SpP	Rhy	IPh
R group	n=11, r=0.27ns	n=13 , r=0.38ns
Y1 Group	n=11, r=0.21ns	n=6, r=0ns
Y2 Group	n=11, r=0.26ns	n=10, r=0.1ns

Table 5.10: Correlation coefficients (r_ϕ) between Speech Perception and Phonological Awareness measures for partitioned data ('93)

SpP	Rhy	IPh
R group	n=9, r=-0.16ns	n=6, r=0.71ns
Y1 Group	n=6, r=-0.63ns	n=8, r=-0.07ns
Y2 Group	n=8, r=-0.22ns	n=10, r=0.22ns

Table 5.11: Correlation coefficients (r_ϕ) between Speech Perception and Phonological Awareness measures for partitioned data ('92 & '93 data pooled)

SpP	Rhy	IPh
R group	n=21, r=0.1ns	n=21, r=0.28ns
Y1 Group	n=18, r=0.03ns	n=13, r=-0.1ns
Y2 Group	n=17, r=0.17ns	n=19, r=0.29ns

Finally, to get a broad overview all groups were collapsed into one which was similarly partitioned and recoded 1/2-sd either side of the mean. Partial correlations (with age held constant) for the resultant data are shown in Table 5.12:

Table 5.12: Partial correlation (age constant) between Speech Perception and Phonological Awareness measures using partitioned data

	Rhy	IPh
Speech Perc'n	n=48 r=0.17ns	n=53 r=0.11ns

5.3.1 *First conclusion*

There is no evidence to suggest that speech perception and phonological awareness are concurrently associated and, on the basis of the data here, it may be thought unlikely that auditory processing ability is simply associated with phonological awareness. The power of the statistical analysis is, however, insufficient to be able to confidently eliminate the possibility of a Type 2 error. With even a group of 53 children (Table 5.12), according to Cohen & Cohen (1983) the power of the test of correlation, that is the probability of rejecting the null hypothesis when it is false, with α=0.05 and the population correlation coefficient assumed to be 0.3 (the conservative estimate recommended by Cohen & Cohen (1983)), is only 0.57. With the smaller groups that have been employed the power of the tests is clearly even less. The lack of statistical power inherent in this analysis will remain as a cautionary note throughout. None-the-less it remains the case that no concurrent association between speech perception and phonological awareness has been detected at a level significantly greater than chance.

Further, as the categorical labelling of speech tokens improves with age, it also seems unlikely that these stimuli are automatically perceived within phonemic categories by the 5-year old children. It is doubtful therefore that the model of Werker & Logan (1985) is a viable explanation of speech perception in children of this age.

5.4 Is phonological awareness developmentally dependent on speech perceptual ability ?

To determine if the development of phonological awareness is contingent on speech perception at an earlier age, performance in these measures has been studied on two occasions separated by 12 months. Mean scores (and standard deviations) in Speech perception and Phonological awareness have been reported in Table 5.4, above.

Tests for association (Spearman correlations) between Speech Perception at R or Y1 and skills in Phonological Awareness and Speech Perception a year later (ie at Y1 or Y2 respectively) have been calculated and are shown in Table 5.13. The coefficients suggest that speech perceptual skills at age 5 could be associated with evidence of phonological awareness a year later at age 6. The corresponding associations between ages 6 and 7 are not significant:

Table 5.13: Spearman Correlation coefficients between performance in Speech Perception at T1 and Phonological Awareness and Speech Perception at T2

Speech Perc'n (T1) x	Initial Ph. (T2)	Rhyme (T2)	Sp. Per'n (T2)
R->Y1 (n=13)	0.74*	0.6*	-0.14
Y1->Y2 (n=11)	0.12	0.07	0.52

*p<0.05

A critical further test of this hypothesis can be applied using the data derived from the children with impaired hearing. With reference to Table 5.5 the speech perception of the hearing impaired children is significantly worse than hearing children of the same age (and is comparable to children two years younger), however levels of phonological awareness in partially-hearing children are comparable to those found in children of the same age who don't have a hearing difficulty. These comparisons have been set out in Table 5.5, above.

The correlations (Spearman) between Speech Perception and Phonological Awareness measures for these Hearing Impaired Children are shown in Table 5.14:

Table 5.14: Correlation coefficients for Partially-Hearing children (n = 15; age 7-years) in Speech Perception and Phonological Awareness

	Rhyme	Initial Ph.
Speech Perc'n	-0.49 ns	0.51ns

5.4.1 *Second Conclusion*

Since, for children without hearing difficulties at age 5 years, a significant correlation was found between between speech perceptual ability and their phonological awareness at age 6 years (Table 5.13), it might be expected that children with a prelingual and permanent hearing impairment, who show significantly lower performance in the measure of speech perception, would show significantly poorer performance in phonological awareness. As it is the partially-hearing children show phonological awareness at a similar level to children of the same age with normal hearing. For these partially-hearing children too there is again no evidence of a significant association between speech perception and phonological awareness. It is evident therefore that although speech perception may be helpful in developing phonological awareness in the first year of learning to read, it is not an essential prerequisite. It seems therefore that phonological awareness is not necessarily directly contingent on categorical analysis and labelling of speech sounds.

5.5 **Is the development of phonological awareness facilitated by speech perception or preexisting awareness of syllables ?**

The preliminary analysis and comparison of age-group means indicated that performance in both speech perception and phonological awareness increases with age. It has also been seen (in the investigation of the first hypothesis) that there is no evidence that performance in speech perception is simply correlated with phonological awareness. In the investigation of the second hypothesis it has further been shown that speech perception is not an essential prerequisite of phonological awareness. If however, as seems likely, phonological awareness derives from other sources than merely the auditory perception of speech, is it possible that the acquisition of increasing competence in phonological awareness of phonemes is facilitated by superior speech perception or by existing awareness of syllabic information ?

This possibility (following the suggestions of Burnham, 1986; Burnham, Earnshaw & Quinn, 1986; Nittrouer & Studdert-Kennedy, 1987) will be investigated by testing whether syllabic awareness (of rhyme) or phonetic processing (speech perception), after statistical controls for reading level (to offset instructional effects on phonological awareness), are significant predictors in hierarchical step-wise regressions of performance in the Initial Phoneme test. If the speculations of Burnham and colleagues (*passim*) and Nittrouer & Studdert-Kennedy (1987) are born out it would be expected that rhyme awareness would predict initial phoneme awareness in the early stages of reading development, whilst speech perception (as an indicator of phonetic processing ability) would not predict skills in initial phoneme identification at that stage. As competence in language and phonological processing develops (and at around age 6, according to Burnham (1986) and Burnham, O'Connor & Earnshaw (1986)) it should be evident that children can use phonetic information in the identification of initial phonemes. Performance in speech perception should thus be found to predict performance in the task of initial phoneme identification at age 7 years as a conservative estimate of competence.

Before performing the regression analyses the data were checked for kurtosis and skew (using methods described by Tabachnick & Fidell, 1989). No significant departures from normality were detected, except for the scores in speech perception for the 7-year-old (Y2) children. For this data it was found necessary to reflect and take square roots of scores in order to reduce the highly positive kurtosis and negative skew which are artifacts of a ceiling effect. It was however also felt prudent to examine combined data sets for each age. Thus groups of 30 hearing children at each age form the basis of the following analyses.

The matrices of correlations (Spearman) between variables to be used in the hierarchical regressions are shown below in Table 5.15

Table 5.15a Correlations between Speech perception (SpP), phonological variables (Rhy, IPh) and Word Recognition (Carver) for the 5-year-old (R group) children. n=30

	SpP	Rhy	IPh	Carv
SpP	1			
Rhy	0.191ns	1		
IPh	0.31ns	0.787**	1	
Carver	0.389*	0.299ns	0.453*	1

**p<0.01;*p<0.05

Table 5.15b Correlations between Speech perception (SpP), phonological variables (Rhy, IPh) and Word Recognition (Carver) for the 6-year-old (Y1 group) children. n=30

	SpP	Rhy	IPh	Carv
SpP	1			
Rhy	-0.003ns	1		
IPh	-0.083ns	0.523**	1	
Carver	-.222ns	0.425*	0.512**	1

**p<0.01

Table 5.15c Correlations between Speech perception (SpP), phonological variables (Rhy, IPh) and Word Recognition (Carver) for the 7-year-old (Y2 group) children. n=30

	SpP	Rhy	IPh	Carv
SpP	1			
Rhy	-0.152ns	1		
IPh	-0.211ns	0.783**	1	
Carver	-0.171ns	0.502**	0.63**	1

**p<0.01

Table 5.15d Correlations between Speech perception (SpP), phonological variables (Rhy, IPh) and Word Recognition (Carver) for the partially-hearing (7-year-old) children. n=15

	SpP	Rhy	IPh	Carv
SpP	1			
Rhy	-0.49ns	1		
IPh	0.507ns	-0.378ns	1	
Carver	0.042ns	0.399ns	0.317ns	1

The results of the hierarchical step-wise regressions are summarised below (Table 5.16) in which adjusted cumulative proportions of variance (Adj-R^2, ie R^2 adjusted for sample size) in the dependent variable accounted for by the independent variables are shown against the F ratio for the addition of that variable.

In the first series of regressions the dependent variable is Initial Phoneme awareness and, after entering scores in the Carver word recognition test (to provide statistical control for the effects of learning on phonological awareness), scores in the test of Rhyme awareness are entered to establish if, as Burnham and colleagues (1986, 1987, *passim*) suggest, skills in phonology at the level of the syllable enable processing at a finer level of phonemic detail: the identification of word-initial phonological information.

Table 5.16: Stepwise hierarchical Regressions of Initial Phoneme onto Carver and Rhyme awareness.

Table 5.16a: R-group (Age 5 years, n=30)

	Adj-R2	F-to-enter
Carver	0.24	
Rhyme	0.59	25.3**

**p<0.01

Table 5.16b: Y1-group (Age 6 years, n=30)

	Adj-R2	F-to-enter
Carver	0.23	
Rhyme	0.3	3.92*

*p<0.05

Table 5.16c: Y2-group (Age 7 years, n=30)

	Adj-R2	F-to-enter
Carver	0.33	
Rhyme	0.65	26.2**

**p<0.01

Table 5.16d: Partially-Hearing children (Age 7 years, n= 15)

	Adj-R2	F-to-enter
Carver	0.06	
Rhyme	0.28	4.96*

*p<0.05

Alternatively, as postulated by Burnham (1986) and Burnham, O'Connor & Earnshaw

(1986) the competent use of a phonemic processing strategy, thereby facilitating the use of residual attentional resources for phonetic processing, would be indicated by a relationship between phonological awareness and the identification of speech tokens. Two further series of step-wise hierarchical regressions were therefore undertaken with Word Recognition (Carver test) followed by either Phonological awareness scores as the second independent variable, and Speech Perception as the dependent variable. The results are tabulated below in Table 5.17.

Table 5.17: Step-wise hierarchical regressions of Speech Perception on Carver and Rhyme awareness.

Table 5.17a: R-group (Age 5 years, n=30)

	Adj-R2	F-to-enter
Carver	0.07	
Rhyme	0.04	0.32 ns
Or		
Initial Ph.	0.053	0.63ns

Table 5.17b: Y1-group (Age 6 years n=30)

	Adj-R2	F-to-enter
Carver	0.01	
Rhyme	0	0.31 ns
Or		
Initial Ph.	0	0.06ns

Table 5.17c: Y2-group (Age 7 years, n=30)

	Adj-R2	F-to-enter
Carver	0.04	
Rhyme	0.01	0.41 ns
Or		
Initial Ph.	0.01	0.72ns

Table 5.17d: Partially-Hearing children (Age 7 years, n= 15)

	Adj-R2	F-to-enter
Carver	0	
Rhyme	0.203	5.55*
Or		
Initial Ph.	0.2	5.48*

*$p<0.05$

Thus it would seem that for the partially-hearing children, but not the children without hearing difficulties, their is some association between phonological awareness and categorical speech perception.

A final series of hierarchical regressions was carried out with the scores in Initial Phoneme awareness as the dependent variable. The rationale for this comes from the possibility that access to phonetic information ensures accurate identification of word-initial phonemic information.

Table 5.18: Stepwise hierarchical Regressions of Initial Phoneme onto Carver and Speech Perception.

Table 5.18a: R-group (Age 5 years, n=30)

	Adj-R2	F-to-enter
Carver	0.24	
Speech Per'n	0.23	0.63ns

Table 5.18b: Y1-group (Age 6 years n=30)

	Adj-R2	F-to-enter
Carver	0.23	
Speech Per'n	0.2	0.03ns

Table 5.18c: Y2-group (Age 7 years, n=30)

	Adj-R2	F-to-enter
Carver	0.33	
Speech Per'n	0.32	0.57ns

Table 5.18d: Partially-Hearing children (Age 7 years, n= 15)

	Adj-R2	F-to-enter
Carver	0.06	
Speech Per'n	0.301	5.48*

*p<0.05

5.5.1 *Third Conclusion*

It is evident that awareness of syllabic information (Rhyme awareness) is predictive of awareness of Initial phonemes at all three ages in children without hearing difficulties. It is not surprising (given the simple correlations reported in Tables 5.6, 5.7, & 5.8) that abilities in the test of Speech perception do not indicate any significant relationship with performance in Initial phoneme awareness even when, at age 7 years, competence has been achieved in both measures of phonological awareness (see Table 1). Thus within the groups of children with no hearing difficulties it does not seem that these children's skills in using phonetic information are utilised in phonological tasks. However for the partially-hearing children there does seem to be a predictive relationship between performance in speech perception and in the matching of word-initial segments in the phonological awareness task. This will be discussed below.

5.6 Summary and discussion

The cross-sectional study and the replications within that design described here show consistent age related increments in performance in the measures of Phonological Awareness and Categorical Speech Perception, with the possible exception of Speech Perception in the first cohort (ie in '92). Although some of the comparable developmental changes within the longitudinal data are slight, they are in the same direction and in line with what might be expected from the cross-sectional analysis. It seems therefore that the children in this study become more reliably aware of phonological contrasts and more able to provide consistent labels for speech sounds between the ages of 5 and 7 years. However while the group mean changes in Speech Perception appear to parallel the changes in Phonological Awareness, it has not been found that individual childrens' performance in Speech Perception is associated with their performance in either measure of Phonological Awareness. It has, however, been noted that the statistical analysis used lacks sufficient power to confidently discount the possibility of Type 2 error. It cannot be asserted that there was no concurrent association between speech perception and phonological awareness.

The age related trend in Speech Perception is in line with the findings of Burnham, Earnshaw & Quinn (1987), Hazan, Fourcin & Abberton (1991) and Simon and Fourcin (1978). Performance in Phonological Awareness also develops with age as would be expected from other studies (eg Cataldo & Ellis, 1988; Wagner, Torgesen & Rashotte,1994).

The initial unreliability of the measure of awareness of Initial Phonemes in the youngest children (who are, recall, in their first year of formal education and functionally non-readers) has been discussed in the previous chapter, where it was concluded that this was probably a consequence of the difficulty these children had with this task at age 5-years.

However as regards the general hypothesis examined in this study, there appears to be no evidence of a concurrent (in-line) association between children's skills in categorically labelling speech sounds (with varying 'Voice Onset' times) at the beginning of words and their competence in tests of phonological awareness of either rhyme or initial phonemes. Although it is evident that for the children in this study both the perception of speech becomes more clearly categorical with time (and here, with this measure, reaching maturity at about age 7), and that awareness of phonological contrasts develops over time, it is also apparent that the children who are better at consistently categorising speech sounds are not necessarily those who are good at the tasks assessing phonological awareness. Thus, contrary to the predictions of De Weirdt (1988), it seems that an ability in speech perception did not necessarily imply an ability in phonological awareness, for the children in this study.

The apparent lack of concurrent associations is linguistically in accord with the views of Harris (1973) who was critical of the Chomskian view of innateness and dismissive of attempts to relate templates (in this case auditory) to aspects of language which were held to be essentially interactional in their development. Evidence contradicting a simple link between speech discrimination skills and developmental phonological problems has also been found by Bird and Bishop (1992).

From the available longitudinal data it seems that between the ages of 5- and 6- years performance in categorically labelling speech at 5-years was associated with levels of phonological awareness at age 6-years. However it also seems evident that good speech perception is not an essential prerequisite, since the partially-hearing children (who have had a lifetime of significantly poorer speech perception) were able to demonstrate levels of phonological awareness close to those shown by children of the same age without any loss of hearing.

Overall it seems likely that abilities to categorically label speech tokens with varying voice onset times are not strongly associated with concurrent performance in the tasks assessing phonological awareness that have been used here. Thus while children do get better (as they get older) at ascribing the speech tokens that they hear to one or other of the categories defined for them, this is not a skill that, in general, is required in being able to distinguish between phonological representations. However there are two pieces of evidence that suggests that speech perception could be a developmental antecedent of phonological awareness. Firstly, there is the longitudinal evidence from the children initially aged 5-years, for whom speech perceptual skills at age 5 were associated with levels of phonological awareness at age 6-years. Secondly, there is the evidence that partially-hearing children's speech perception scores were, after statistical controls for variance which might be associated with learning to read, related to their awareness of initial phonemes.

No clear evidence has emerged from this study with respect to the conjectures of Burnham (1986) and Burnham, Earnshaw & Quinn (1987) and Nittrouer & Studdert-Kennedy (1987) who suggested that as competence in language segmentation skills developed children would have more readily available residual attentional resources to enable them to engage in processing speech in finer detail, for example at a phonetic level. The categorical labelling task is one in which children have to identify the phonetic variant that has been heard, or at least to recognise a token as an allophone of a particular category. In general, amongst the hearing children in this study it seems that awareness of rhymes (ie phonemic, or syllabic phonological information) but not speech perception (ie the awareness and labelling of phonetic variations) is associated with skills in the identification of word-initial sounds. The implication is therefore that awareness of linguistic features, rather than the accurate perception of speech, is helpful to the performance of other phonological awareness tasks.

However the predictive relationship between Speech perception and Initial phoneme awareness in the group of partially-hearing children is different. The partially-hearing children do seem to use their perceptual skills in the phonological task of identifying the pair of words which share the same initial phoneme. No evidence of a simple association between Speech Perception and Rhyme awareness was, however, found. The most parsimonious explanation for this is that within this population (of partially-hearing children) better perceptual skills do make a difference in the Initial Phoneme task. It is clearly not the case that there is a significant difference between hearing and partially-hearing children aged 7 years in terms of their mean levels of performance, or the range of performance in the phonological tasks, but those with better speech perception are more able to accurately perceive and match the stimuli in the Initial Phoneme task. The nature of the stimuli in the two phonological tasks should be considered here. The initial phonemes are relatively brief in duration and consonantal, whereas the rhyme stimuli contain vowels which typically have longer temporal duration and lower frequencies than consonants. This latter type of acoustic information may be more easily heard by the partially-hearing with typical high-frequency loss. In these partially-hearing children it was also notable that unlike the hearing children, performance in Initial Phoneme Awareness was not predicted by performance in Rhyme Awareness. It therefore seems probable that for the partially-hearing children performance in the Initial Phoneme task was limited by speech perceptual ability and not phonological awareness.

Chapter Six

Memory, phonological awareness and reading

6.0 Overview

This chapter provides a description of investigations into the relationships between memory, phonological awareness and reading.

In relation to the main theme of this thesis - the development of phonological awareness and factors that influence its development - in the first half of this chapter (6.1) the size of memory span and the relative efficiency of recall in connection with phonological awareness tasks are determined. Three conjectures about the relationship between phonological awareness and aspects of memory will be investigated in those sections.

These are, firstly, the possibility that the size of children's memory span is associated with performance in tests of phonological awareness. This will be tested by examining the correlations between children's scores in the measures of phonological awareness and the measure of memory span. Following that statistical regression techniques will be used to analyse the possible predictive effects of memory span on phonological awareness.

The second aspect of the relationship to be determined concerns the proposition that phonological awareness tasks themselves involve a memory load, and that the effects of this load are alleviated by the use of pictures. This will be investigated experimentally using separate, randomly selected, groups of children.

The third investigation will determine simply if children who are more efficient in memory processing are also more likely to do well in the measures of phonological awareness.

In the second half of the chapter (§6.2) the relationship between memory and word reading is examined. In this section both the number and type of items that can be held in short-term memory will be related to performance in reading. Here the phenomenon of the 'phonological similarity effect' is also re-examined to establish if the size of children's auditory memory span might account for the apparent relationship between a phonological similarity effect and competence in word reading.

Where appropriate and possible both cross-sectional and longitudinal data will be examined to establish the extent, nature and developmentally predictive ability of the relationship between variables.

6.1 Phonological awareness and memory

6.1.1 Introduction

Phonological effects within short-term memory have been recognised for some time. Conrad (1964) for instance found that adults made a significant number of confusion errors within a set of acoustically similar letters presented for recall. That finding was extended by Conrad & Hull (1964) who showed that adults made significantly more errors in recalling phonologically similar strings than in recalling phonologically dissimilar items.

The current view of short-term memory is often given in terms of the working memory model, first described by Baddeley & Hitch (1974). The phonological similarity effect, as observed by Conrad (1964), has been shown to be a function of phonological coding in memory (Baddeley, 1986). In its present formulation the working memory model consists of a 'central executive' and two 'slave' subsystems. One of these subsystems, the 'visuo-spatial scratchpad', is of no direct relevance to this present discussion being concerned with processing visual and spatial information. The other subsystem, the 'articulatory loop', was developed to account for the evidence that seemed to indicate an association between verbal coding and short-term memory. This position was summarised by Baddeley (1982). In that paper Baddeley (1982) also outlined the work undertaken by himself and colleagues showing how the articulatory loop could be involved in early reading processes. These views have been developed and are summarised by Gathercole & Baddeley (1993a). In the more recent formulations of working memory the 'articulatory loop' has been re-named the 'phonological loop' and this term will used hereafter.

It is thought that the phonological loop holds phonological segments which arise either from direct speech input or from the decoding of visually presented letters, while the central executive decodes each item prior to blending and mapping the segments onto a real word. In the more recent description of working memory (Gathercole & Baddeley, 1993b) the phonological loop has itself been considered as consisting of two subcomponents. The first of these is the short-term phonological store which can be accessed directly by spoken material. The contents of this short-term store are refreshed by the activity of the second subcomponent in which material is articulated subvocally. This second subcomponent is responsible for the rehearsal of material and also for converting visually presented verbal material into phonologically coded material which can then enter the phonological store. Of particular salience to the work to be reported in this chapter are findings relating to the functions of these two subcomponents. It will be important to note that the functions of the phonological loop are thought to be inhibited by simultaneous tasks.

One such scenario occurs when participants in experiments are required to continuously articulate an irrelevant word or phrase while simultaneously aiming to keep some other verbal material in memory. Under such conditions Murray (1967, 1968) found that short-term memory for lists of verbal material was greatly depressed, and that this was not because of simple distraction effects. In the working memory model this articulatory suppression effect is thought to arise because rehearsal in the articulatory rehearsal subcomponent is blocked. Baddeley, Lewis & Vallar (1984) examined articulatory suppression in the context of investigations of the phonological similarity effect. It was found by Baddeley *et al* (1984) that when the stimuli were presented visually under conditions of articulatory suppression the phonological similarity effect was not found. When the stimuli were auditorily presented however Baddeley *et al* (1984) found that the phonological similarity effect (that is that phonologically confusable items are not as well recalled as phonologically distinct items) persisted. This is thought to be the case (Gathercole & Baddeley, 1993b) because articulatory suppression blocks the activity of the articulatory rehearsal mechanism, so denying visual material access to the phonological store. Spoken material however has obligatory access to the phonological store, and thus even under conditions of articulatory suppression the effects of phonological similarity within the phonological store will still be found.

Contemporary with the studies (Baddeley *et al, passim*) of the phonological loop, Case, Kurland and Goldberg (1982) produced evidence from studies involving children (as young as 3-years) and adults that suggested that developmental increases in memory span might be due to increasing operational efficiency rather than increases in processing space. It is evident (from studies such as those by Miller (1956) and Dempster (1981)) that memory span does increase with age, but it does not seem sufficient, at least in the context of reading development, to hold that as a consequence of ageing there is a simple increase in memory 'slot' capacity. This conclusion has been reviewed by Gathercole & Baddeley (1993a), and by Brady (1991) who further suggested that the efficiency of phonological processes could be a limiting factor in working memory capacity. Brady (1991) argued that this is apparent because as operational efficiency increases greater available cognitive resources are preserved for the storage of phonological representations. The explanation for the observation of increased memory span with age that is favoured by Gathercole & Baddeley (1993a) is that within the phonological loop component of the working memory model there is a developmental increase in the efficiency of subvocal rehearsal. Increases in memory span in children (aged as young as 4-years) and adults were studied by Hulme, Thomson, Muir & Lawrence (1984) who found that the increases in memory span were largely associated with increases in the rate of subvocal rehearsal. Hulme *et al* (1984) also interpret their findings as showing no evidence for an increase in short-term memory capacity.

Although the increased efficiency of the articulatory rehearsal mechanism is thought to be a major determinant of the observed developmental increase in verbal memory span, there is some evidence that implicates the central executive. Whilst studies of the effect of word length on rate of articulation in adults by Baddeley, Thomson & Buchanan (1975), and in children by Nicholson (1981) have established that developmental increases in short-term recall are associated with increases in articulation rates, Hitch, Halliday & Littler (1989), using articulatory suppression techniques, showed that age differences in memory span (in children aged 8- and 11-years) could not be entirely attributed to faster rehearsal rates. The account for this given by Hitch *et al* (1989) involves separate contributions from the articulatory rehearsal loop and the central executive. This result was extended in work by Hitch, Halliday and Littler (1993) where it was reported that children as young as 5-years were thought to be using the articulatory rehearsal loop. The developmental increases in memory span that were also found by Hitch *et al* (1993), however, were again thought to be not entirely due to the rehearsal loop's increased efficiency. Since age differences in memory span were not found to be reduced by articulatory suppression (as would have been the case if older children's superior memory spans were solely due to faster articulatory rehearsal) Hitch *et al* (1993) suggested that articulatory suppression could have induced greater use of the central executive for short-term storage. Hitch *et al* (1993), however, admit that their evidence precludes that explanation, but they note that the role of central executive functions might be evident under more complex conditions than pertained in their experiment.

The work that is reported in this chapter concerns the relationship between phonological awareness and memory processes. There is some evidence (eg Liberman, Mann, Shankweiler & Werfelman,1982) that both memory and phonological awareness tasks may draw upon the child's stable phonological representations. On that basis an association between measures of phonological awareness and memory span should be expected. If, as Brady (1991) and Liberman *et al* (1982) suggested, the efficiency of processing phonological representations underpins verbal memory tasks, and as Tunmer, Herriman & Nesdale (1988) and Byrne & Fielding-Barnsley (1989) indicated that awareness of phonemes was a necessary antecedent for phonological recoding, then a more specific conjecture could be made that awareness of phonemes should predict performance in memory tasks.

Baddeley (1986), however, commented that the crucial factor for success in Bradley & Bryant's (1983) phonological awareness tasks could be working memory span since children had to hold the words in mind whilst arriving at a decision about their phonological characteristics. Bradley & Bryant (1983) had attempted to control for this by including a measure of children's recall of lists of unrelated words. They found that after memory differences had been taken into account the phonological awareness tasks were still significantly associated with reading. Though it is not clear in Bradley & Bryant's (1983) account that scores in memory were themselves significantly related to either the phonological awareness task or the outcome measure of reading the possibility arises that there is some interdependence between the effects of phonological awareness and memory tasks. This possibility was further developed in a longitudinal study undertaken by Gathercole, Willis & Baddeley (1991b). In that study rhyme awareness and memory span showed clearly dissociable links with reading, but a factor analysis showed that both memory span and rhyme awareness were strongly associated with a general phonological processing factor.

One of the tasks to be undertaken in this chapter therefore is to report on investigations which explore relationships between children's performance in tasks assessing phonological awareness and memory span. Of importance in the light of the above discussion and the main theme of this thesis is to determine if memory span is a predictor of performance in the phonological awareness tasks that have been used in this study. In order to do this three investigations are reported.

Firstly, changes in memory span between ages and the association between Memory Span and measures of Phonological Awareness will be evaluated in children at three ages: 5, 6 & 7 years of age. Gathercole, Willis & Baddeley (1991b) indicated that memory and rhyme awareness shared some common process. The results of their study showed a highly significant correlation between memory span and phonological awareness at age 5 years, but none at age 4 years. Previous investigations of the correlation between memory and awareness are however not always consistent in their findings. Mann & Liberman (1984) and Fowler (1988) both found significant associations between phonological awareness and memory tasks. Alegria, Pignot & Morais (1982) and Blachman (1983) however failed to detect such relationships. In this study the possibility that memory span might be associated with phonological awareness will be investigated by testing for associations between children's awareness of either rhyme or initial phonemes and aspects of working memory.

Secondly, children's performance in measures of phonological awareness will be compared when the assumed memory load is manipulated. The overall design of this present research requires the use of tests of phonological awareness with young and hearing-impaired children. On this basis the measures were designed with the use of pictures to retain children's attention and to offset any memory load. A similar approach had been adopted by Maclean, Bryant & Bradley (1987). An investigation reported here is intended to evaluate the validity of the assumption that memory load may be reduced by the addition of pictures. This assumption has been explored in an experiment in which children's awareness of rhyme and alliteration was tested with, and without, the presence of pictures.

The phonological tasks used here are amenable to 'implicit' processing rather than 'explicit' analysis (Cataldo and Ellis, 1988). Thus in these tasks children are not required to retain phonological segments (for instance 'onsets' and 'rimes') for conscious manipulation as they might, for example, in a 'spoonerism' type of task (Walton & Brooks, 1995). Without pictures to reduce the memory load however the phonological awareness tasks do, at least according to Baddeley (1986), entail the retention of three words within working memory while phonological comparisons are made. Thus if 'memory load' is a feature of the phonological awareness tasks it would be expected that children would demonstrate superior performance in the phonological awareness tasks when pictures are present and reduce the memory load.

If, as predicted by Brady (1991), increasing efficiency of phonological processes liberates greater storage space it should be possible to detect an association between phonological skills and memory. In the third part of this investigation therefore a measure of Word Recall (a method similar to that used as a control by Bradley and Bryant, 1983) is used to assess children's ability to hold three (unrelated) words in memory for immediate recall. The measure of Word Recall is used as an indicator of the efficiency of storage and recall (these two aspects of memory are not disambiguated here) within these phonological tasks. Higher scores in this task are viewed as an indication of greater efficiency on the basis that there are fewer inaccuracies in recall. Many other workers in this field (eg Hitch, Halliday & Littler, 1989) have adopted a paradigm in which efficiency is taken to be indicated by a rate of response measure. The necessary technology for such an approach was beyond the scope of this research and, further, as Hitch *et al* (1993) commented speed of response is not necessarily the most appropriate measure of operational efficiency. It was felt here that with an adequate number of trials a measure of efficiency derived from the accuracy of recall was feasible since accuracy is, by definition, a component of efficiency. Thus, if memory efficiency is implicated in the phonological awareness measures, children who show greater proficiency in the word recall task would be expected to show superior performance in phonological awareness.

6.1.2 The study of changes in memory span over time, and the associations with phonological awareness

6.1.2.1 *Methodology*

The measures used for memory span and phonological awareness have been described in detail in Chapter 3.

The test of memory span requires children to repeat strings of alphabetic letter names. Starting with strings consisting of two letters children were presented with two strings and if both these were accurately repeated the length of string was increased by one letter. This procedure was continued until the child was unable to recall both strings of the same length.

Two tests of phonological awareness have been used: one assessing children's awareness of rhymes, the other awareness of word-initial phonemes. In both tests children were asked to identify which two words (out of three per test item) shared the same phonological segment. Words were spoken by the experimenter and for each item children were simultaneously shown a strip of three line drawings corresponding to the three words in that item.

The hearing children to whom the tests were given are those described elsewhere in the description of the main study and form the samples drawn in 1992 and 12 months later in 1993. The partially-hearing children have also been described in Chapter 3.

Testing of individual children was conducted on separate occasions for each measure.

The first part of this investigation is to establish that the measure of memory span discriminates between the performance of children of different ages. In the second part the extent of association between memory span and phonological awareness is examined.

6.1.2.2 *Results*

The means and standard deviations of the scores in Memory Span for each of the six groups in the cross-sectional study are shown in Table 6.1. Scores are the number of letter strings correctly recalled in serial order. Scores could range from 0 to 14. In practice the scores obtained from the children studied here did not exceed 8.

Table 6.1: Mean (sd) of Memory Span tests for groups of 5- (R), 6- (Y1) and 7-year-old (Y2) children in '92 and '93

	'92		'93	
R	3.6	(0.91)	3.2	(1.15)
Y 1	4.07	(1.67)	4	(0.66)
Y 2	5.47	(1.06)	4.93	(1.39)

6.1.2.2.1 *Data Screening and Treatment*

6.1.2.2.1.1 *Validity and Reliability*

The validity and reliability of the measure MeS was first established using an independent randomly selected sample of 45 children aged 5 to 7 (15 at each age). These children were given both the Memory Span test and the British Ability Scales Recall of Digits Test (Elliott, Murray & Pearson, 1983) in order to confirm construct validity. For these children the Pearson coefficient for the correlation between Memory Span (letters) and Digit Span was found to be 0.65 ($p<0.01$) suggesting that both measures are closely related. The Memory Span (letters) data obtained from this group of children was also subjected to the Kuder-Richardson test of reliability (Anastasi, 1968) and r_{11} was found to be 0.63. These two calculations indicated that the measure MeS was sufficiently valid and reliable for use in the experimental and cross-sectional studies.

The reliability coefficients (Kuder-Richardson, r_{11}) for the 3 age groups in 1992 and '93 have subsequently been calculated and are shown in Table 6.2 (below).

Table 6.2: Reliability coefficients for Memory Span (MeS) scores obtained for each age group

	MeS
R '92	0.7
R '93	0.69
R comb	0.69
Y1 '92	0.81
Y1 '93	0.18
Y1 comb	0.72
Y2 '92	0.47
Y2 '93	0.69
Y2 comb	0.51

Although two of these coefficients (for Y1 at '93, Y2 at '92) show low coefficients of reliability, in view of the overall r_{11} and the significant correlation with the BAS digit span obtained from the independent sample of 45 children the measure (MeS) has been taken as adequately reliable for use in the study. Although the low coefficient for that group may be an artifact of a restricted range of scores, clearly any inferences from results involving the Y1 ('93) group would need to treated with caution.

6.1.2.2.1.2 *Normality*

The memory span data has been checked for kurtosis and skew using the checks suggested by Tabachnick and Fidell (1989, p72/3). The coefficients are presented in Appendix 2. As can be seen there all values are within reasonable limits with the exception of the Y1 combined group (n=30) which shows a significant degree of positive kurtosis. This is consequent on the large number of children in that group obtaining the same score. The phenomenon has not proved susceptible to a transformation to reduce the degree of kurtosis without introducing other statistical complications. This group of scores will therefore be left untransformed, but caution will be exercised in any inferences made from the results of that group.

Homogeneity of variance was also evaluated using F_{max} procedures (Kirk, 1968). For all groups values are within appropriate limits.

6.1.2.3 *Analysis*

6.1.2.3.1 *Changes with age*

For the full set of memory span data obtained from all 90 children an analysis of variance (3 x 2 factorial between subjects) for Age-group (ie R, Y1, Y2) by Year of testing ('92, '93) yielded a main effect of Age Group with F(2,84)=18.0 (p<0.01). The Age x Year interaction was not significant. Pairwise comparisons (t-Scheffé) indicated significant increases between R (ie 5 years old) and Y2 (7 years old), and between '92 and '93. These comparisons, and those for groups of 45 children in '92 and in '93 are shown in Table 6.3 and Figure 6.1.

Table 6.3: Comparison of Memory Span (MeS) changes between age groups in '92, '93 and the combined data set (Anova, post hoc t-Scheffé)

	Overall F	R vs. Y2	R vs. Y1	Y1 vs. Y2
MeS '92 (n=45)	8.97**	8.28*	0.52ns	4.66*
MeS '93 (n=45)	9.24**	9.22*	1.96ns	2.67ns
MeS comb'd (n=90)	18.0**	17.5*	2.16ns	7.3*

*p<0.05; **p<0.01

Fig 6.1 (a): Changes in Memory Span (MeS) with age for groups in '92

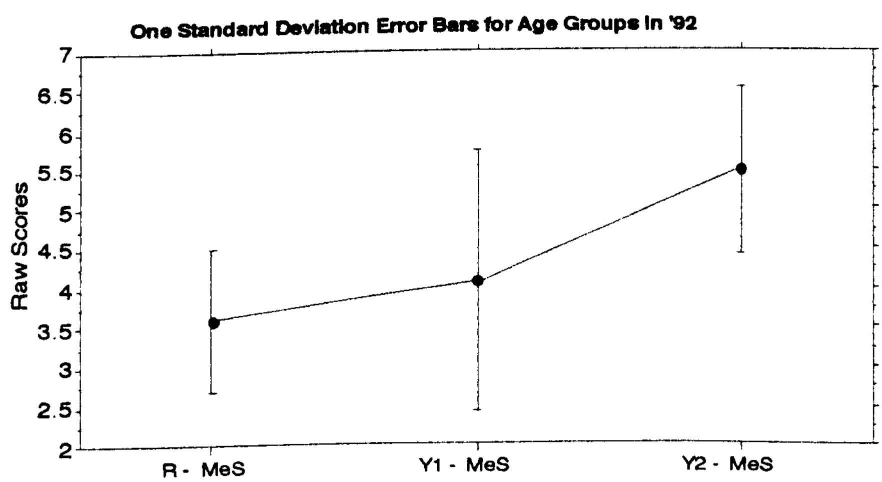


Fig 6.1 (b): Changes in Memory Span (MeS) with age for groups in '93

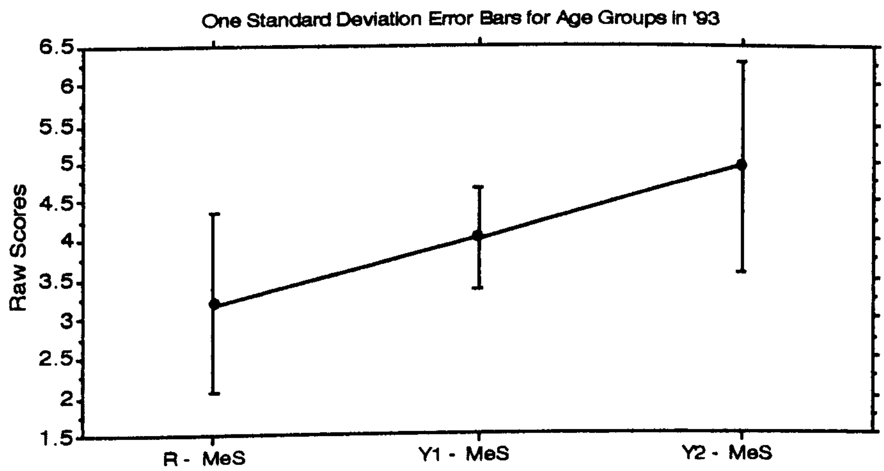
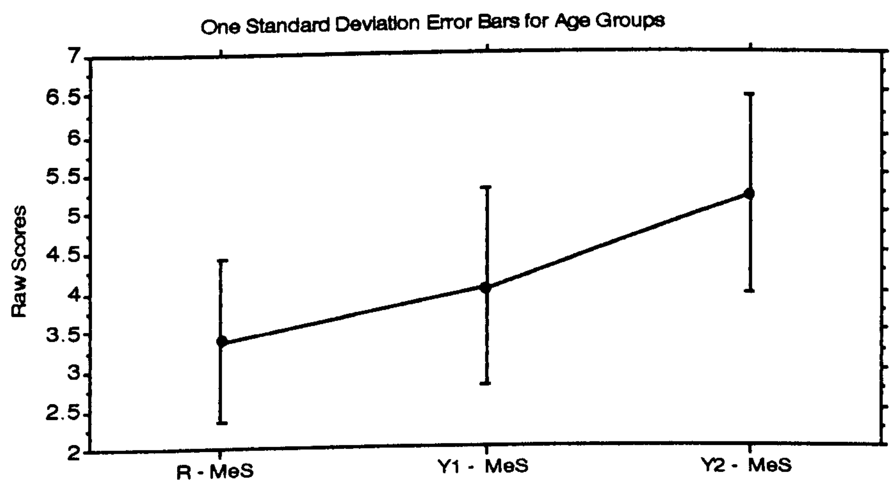


Fig 6.1 (c): Changes in Memory Span (MeS) with age for groups in '92 and '93 pooled



6.1.2.3.1.1 *Summary*

It is evident that the measure of Memory Span (MeS) shows increases in performance with age. This is clear, and replicated in '92 and '93, when 5-year-old children (R group) are compared with 7-year-old children (Y2). Overall the change in mean level of performance between 6-year-old (Y1) and 7-year-old (Y2) children is also greater than might be expected by chance. The memory spans of 5-year-old (R group) and 6-year-old children (Y1) however do not appear to show differences that are detected by the measure MeS.

6.1.2.3.2: *The relationship between Memory Span and Phonological Awareness*

As it has been shown that Memory Span and Phonological Awareness both increase with age, it is now appropriate to establish if there is an association between performance in these two variables over time. This will be done firstly by examining the correlations over time using the data available from the samples of 45 children tested in each year. In order to address the question of whether the increase in memory span predicts the increases in phonological awareness hierarchical regressions will be subsequently employed. This technique will also be used to establish, by studying the available longitudinal data, if either of two possible causal relationships might be eliminated.

In order to undertake these analyses the data was inspected as collapsed groups (with n=45) for skew and kurtosis, as indicators of normality. For all variables kurtosis and skew were within acceptable limits on both occasions.

In order to establish firstly if there were associations between children's performance in the measures of phonological awareness and their memory spans Pearson correlations have been computed for each sample of 45 children aged 5- to 7-years. The coefficients are shown in Tables 6.4a and 6.4b respectively in which the associations with age and nonverbal abilities (Raven's matrices) are also shown.

Table 6.4a: Coefficients of correlations between Phonological Awareness (Rhy, IPh), Memory Span (MeS), Raven's matrices and Ages in '92

	Rhy	IPh	MeS	Ravens	Age
Rhy	1				
IPh	.738**	1			
MeS	.29*	.484**	1		
Ravens	0.37*	0.398**	0.251ns	1	
Age	.359*	.538**	.533**	0.39**	1

*p<0.05;** p<0.01

Table 6.4b: Coefficients of correlations between Phonological Awareness variables (Rhy, IPh), Memory Span (MeS), Raven's matrices and Ages in '93

	Rhy	IPh	MeS	Ravens	Age
Rhy	1				
IPh	0.701**	1			
MeS	0.498**	0.566**	1		
Ravens	0.37ns	0.45**	0.339*	1	
Age	0.535**	0.585**	0.575**	0.578**	1

*p<0.05;** p<0.01

Thus performance in the measures of memory span and phonological awareness appears to be associated across ages. It is, however, also evident that age is closely associated with developments in memory and phonological awareness. To test if, once the effects of age have been taken into account, either Rhyme or Initial Phoneme awareness was associated with a significant amount of the variance in Memory Span scores hierarchical regressions were used. These were planned with one of the measures of phonological awareness (Rhyme or Initial Phoneme) as the dependent variable in each case, and independent variables entered in the order: Age, the test of nonverbal ability (Raven's matrices), and lastly Memory Span.

The unique contributions of either of the phonological variables, as indicated by F-to-enter tests of the squared semi-partial correlations, are shown in Table 6.5.

Table 6.5a: Hierarchical regressions of Rhyme (Rhy) with Memory Span (MeS) as IV entered after Age and Raven's matrices (n=45)

DV=Rhy	'92		'93	
	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Age	0.109		0.269	
Ravens	0.11	1.07ns	0.258	0.33ns
MeS	0.101	0.58ns	0.298	3.40*

* p<0.05; ** p<0.01

Table 6.5b: Hierarchical regressions of Initial Phoneme (IPh) with Memory Span (MeS) as IV entered after Age and Raven's matrices (n=45)

DV=IPh	'92		'93	
	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Age	0.273		0.327	
Ravens	0.299	2.61ns	0.331	1.23ns
MeS	0.335	3.28*	0.398	5.69**

* p<0.05; ** p<0.01

It appears from this analysis that memory span has some predictive effect on levels of phonological ability that is independent of age or nonverbal ability. This is in line with the view of Baddeley (1986) that memory span might be an important factor in children's performance in this type of phonological awareness task.

6.1.2.3.2.1 *Developmental Effects*

If memory span is not just an aspect of the demands of the phonological awareness task, which is a possibility, then a developmental effect would be apparent with children being facilitated in their acquisition of phonological awareness by prior memory span. Two alternative hypotheses are possible. Firstly that there would be no developmental effect, or secondly, and conversely, that phonological awareness is the prerequisite for the developmental increases in memory. This latter possibility would be predicted by the views of Brady (1991), Liberman *et al* (1982), Tunmer *et al* (1988) and Byrne & Fielding (1989) who considered that efficiency of phonological processes is the underpinning mechanism for memory tasks and that since awareness of phonemes was an antecedent of phonological recoding, awareness of phonemes should predict performance in memory tasks.

A set of hierarchical regressions was therefore performed on the data available from children who were tested at T1 and T2 (separated by twelve months). These children's mean scores are shown in Table 6.6. In Table 6.7 the intercorrelations between the variables are shown. Because of the memory span scores were found to be positively skewed, and the Raven's scores were found to show significant positive skew and kurtosis, the scores obtained for memory span have been transformed by taking the square root of scores and Raven's matrices at T1 have been transformed by taking natural logarithms of the scores . After transformation the data was found to conform to reasonable assumptions of normality in respect of kurtosis and skew.

Table 6.6: Means scores in Rhyme (Rhy) and Initial Phoneme (IPh) awareness, Memory Span (MeS), Non-verbal ability (Rav) and Age (in months) for children seen at T1 and T2 (n=24)

	Mean	sd
Rhy1	6.04	2.37
Rhy2	6.75	2.4
IPh1	5.25	2.13
IPh2	6.58	2.83
MeS1	3.92	1.25
MeS2	4.63	1.25
Rav1	16.92	4
Age1	63.25	6.24

An anticipated possible weakness in the data was not found. It has been recognised (see Chapter 4) that scores in the test of initial phoneme awareness obtained from the two groups of 5-year old children (R groups) did not demonstrate reasonable levels of reliability. Unreliability is a measure of error variance, and unreliable variables may appear to be spuriously associated (Tabachnick & Fidell, 1989). The reliability coefficients (Kuder-Richardson, cited by Anastasi, 1968) for IPh for the children comprising this longitudinal survey were therefore computed. It was found for these groups that at T1 r_{II}=0.53, and at T2 r_{II}=0.79 which are of sufficient magnitude to justify confident inclusion of the variables in the ensuing analysis.

The inter-correlations of variables to be used in the planned hierarchical regressions are shown in the next table (Table 6.7).

Table 6.7: Intercorrelations of phonological awareness, memory span at T1 and T2, nonverbal ability and age at T1. (n=24)

	Rhy1	Rhy2	IPh1	IPh2	√(MeS1)	MeS2	ln(Rav1)	Age1
Rhy1	1							
Rhy2	.721**	1						
IPh1	.678**	.71**	1					
IPh2	.711**	.714**	.653**	1				
√(MeS1)	.435*	.314ns	.506*	.539*	1			
MeS2	.36ns	.389ns	.578**	.448*	.775**	1		
ln(Rav1)	.294ns	.334ns	.442*	.3ns	.181ns	.029ns	1	
Age1	.464*	.414*	.659**	.342ns	.403ns	.472*	.403ns	1

* p<0.05; ** p<0.01

Table 6.8 summarises the hierarchical regressions that were performed with phonological awareness at T2 (ie either IPh2 or Rhy2) as the dependent variable. In these regressions children's scores in the corresponding phonological awareness variable at T1 have been entered as an independent variable prior to (transformed) memory span scores in order to remove any variance in phonological awareness due to abilities at T1. With this precaution it can be seen that neither initial phoneme or rhyme awareness at T2 could be predicted from memory span at T1.

Table 6.8: Hierarchical regression of phonological awareness (Rhy, IPh) at T2 onto memory span (MeS) at T1 with controls for age, nonverbal ability and preexisting phonological awareness.

	DV=IPh2		DV=Rhy2	
	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Age1	0.077		0.134	
ln(Rav1)	0.067	0.78ns	0.129	0.88ns
IPh1/Rhy1	0.358	10.50**	0.47	14.5**
√MeS1	0.405	2.59ns	0.442	0.02ns

**p<0.01

The converse alternative hypothesis that memory spans at T2 might be predicted by phonological awareness twelve months earlier has also been tested in a similar way. Thus following the variables for age and nonverbal ability at T1, memory span (transformed) at T1 precedes scores in the phonological awareness variable (either Rhy1 or IPh1) obtained at T1. The results are summarised in Table 6.9.

Table 6.9: Hierarchical regression of memory span (MeS) scores at T2 onto phonological awareness (Rhy, IPh) at T1 with controls for age, nonverbal ability (Rav) and preexisting memory span

DV=MeS2	T1	
	Adj-R2	F-to-enter
Age1	0.187	
ln(Rav1)	0.183	0.87ns
√MeS1	0.618	24.9**
Rhy1	0.598	.01ns
or		
IPh1	0.645	2.52ns

**p<0.01

It can be seen that performance in the test of memory span at T2 was not associated with phonological awareness at T1. Thus the views of Brady (1991) and Liberman *et* *al* (1982) that increasing phonological skills would underpin performance in memory tasks do not appear to be supported by this evidence.

6.1.2.3.3 *Summary*

It has been shown that performance in the tasks assessing memory span increases with age, as does performance in phonological awareness (see §4.1.2.3). An association between awareness of initial phonemes and memory span that was independent of the effects of age and nonverbal ability was found in '92 and '93. Although awareness of rhymes was associated with memory span in '93, no association had been found in '92. Longitudinally however no predictive effects of either memory span on phonological awareness or, conversely, of phonological awareness on memory span were found.

This suggests that the measure of memory span may be a factor determining children's performance in the test of awareness of initial phonemes. The possibility of an effect of memory on performance in the phonological awareness tasks is further explored in the next sections of this chapter.

6.1.3 Manipulation of memory load within phonological tasks

6.1.3.1 *Introduction*

As the phonological awareness tests were intended to be used with samples of young children (aged 4- or 5-years) as well as those with hearing difficulties and older children, it was thought it would be helpful to minimise the burden of memory that, for the younger children at least, might be implicated in attending to lists of words. Pictures were therefore produced to accompany the stimuli. A similar procedure had been adopted by Maclean, Bryant and Bradley (1987) on the assumption that for the very young children in their study the addition of pictures would relieve the memory burden implicit in the phonological tasks.

The hypothesis that the phonological awareness tasks are easier with pictures to relieve the memory burden is tested in this section. Possible associations between measures of memory and performance in phonological awareness tasks will also be investigated further.

6.1.3.2 *Methodology*

A within subjects factorial design was adopted for this experiment. Children were drawn from three year groups (R,Y1 & Y2: ie at ages approximately 5-, 6- & 7-years) in two primary schools. These schools drew from different socioeconomic catchment areas. In School A 16% of children had free school meals, whereas in School B the proportion was 34% with free school meals. The children were randomly selected from all those aged 5- to 7-years that the schools identified as having no significant learning difficulties. Six children in each school year (R,Y1 & Y2) were selected from each school with an overall requirement that there should be equal numbers of boys and girls, with ages at the time of first testing as close as possible to 5-, 6- & 7-years. Details of the children's ages are given in Table 6.10.

All children were given phonological awareness tests under two conditions, with, and without pictures. Half the children were assigned to the with-pictures condition first and approximately four weeks later were given the no-pictures version. The other half of the children were given the tests in the opposite order, and tested at the same times with four weeks between test administration. Children were tested individually in a quiet room.

The with-picture Phonological Awareness tests were those that have already been described. The no-picture versions consisted of the same triplets of verbal stimuli but with items placed randomly in a different order.

In order to assess the efficiency of children's memory all children were given the 'Word Recall' test immediately following administration of the second phonological test. The test of Word Recall consists of the entire set of 18 word triplets used in the Rhyme and Initial Phoneme tests. In the Word Recall test triplets are alternately drawn from the Rhyme and Initial Phoneme tests. The order of placement of triple word items in Word Recall is random and different from that within the separate tests. A score of 2 is given if an item was recalled in correct serial order, and 1 is scored if the three words in an item were recalled in non-serial order. The maximum possible score is therefore 36. Finally children were also given the Memory Span test.

6.1.3.2.1 *Data Screening and treatment*

All data was inspected for kurtosis and skew within age groups using the method described by Tabachnick and Fidell (1989, p72/3), and in all cases found to be within acceptable limits. Variances were also subjected to $F_{max,0.01}$ (as described by Kirk, 1968) and all values found to be smaller than $F_{max,crit}$.

6.1.3.3 *Results and analysis*

The means (and standard deviations) of group scores are shown in Table 6.10. The ranges of possible scores are as follows: Phonological Awareness (both Rhyme and Initial Phoneme): 0 - 9; Word Recall: 0 - 36; Memory Span has a minimum of 0 and no upper limit, though no child here achieved more than 7. Age is given in months at time of first testing.

Table 6.10: Mean (and sd) of scores in phonological awareness (Rhy, IPh) with and without pictures (Pics, ~Pics), Word Recall (Recall), and Memory Span (MeS) (n=12 for each group)

	Rhyme		Initial Phoneme		Recall	MeS	Age
	Pics	~Pics	Pics	~Pics			
R	5.2 (2.5)	4.4 (2.3)	5.8 (1.9)	4.9 (2.2)	29.3 (7.6)	4.2 (1.9)	58.7 (2.0)
Y 1	7.1 (1.7)	6.4 (2.4)	7.3 (1.8)	7.6 (1.7)	33.3 (2.7)	4.9 (1.2)	71.8 (1.1)
Y 2	8.1 (0.8)	7.3 (1.3)	8 (1.3)	7.8 (1.5)	35.6 (0.8)	5.5 (0.9)	82.8 (2.3)

6.1.3.3.1 *Do pictures make the tasks easier ?*

For the results of each of Rhyme and Initial Phoneme Awareness tests the data were analysed by a Split-plot anova with Age Group (R,Y1,Y2) and Order (ie whether the Pictures condition was administered first or second) as between subjects factors, and the picture/no-picture Condition as a within subjects repeated factor.

For Rhyme awareness none of the possible interactions were significant, and the main effect of order of presentation was also non-significant [$F(1,30) = 1.13$ ns]. The main effects of both Age Group and Condition were however greater than might be expected by chance with F(2,33) = 8.94 ($p<0.01$) and F(1,33) = 6.45 ($p<0.05$) respectively.

In the case of Initial Phoneme awareness again all interactions were non-significant, with no significant effect due to order of presentation [F(1,30) = 1.54ns]. However, although as would be expected the main effect of Age Group was significant with F(2,33) = 8.56 ($p<0.01$), there was no evidence of an effect due to Condition [F(1,33) = 1.76 ns]. These results are summarised in Table 6.11.

Table 6.11: Summary of Analyses of Variance (F values) for effects of Order of Presentation (Order), Age Group (Age) and Pictures (Pics, ~Pics) on performance in Phonological Awareness

	Order	Age	Pics/~Pics
Rhyme	1.13 ns	8.94**	6.45*
IPh	1.54 ns	8.56**	1.76 ns

*$p<0.05$;**$p<0.01$

This suggests that performance in the test of rhyme awareness is easier with the addition of pictures, but there is no comparable and significant facilitative effect of pictures in the test of initial phoneme awareness.

It has been seen earlier in this chapter that initial phoneme scores may be more closely associated with memory span than are rhyme scores. Thus within the working memory model word-initial sounds may be held more easily in the phonological loop while phonological comparisons are made, possibly under the control of the central executive. Rhymes are not held in the short-term store so efficiently (see §6.2.2), and, therefore, children's performance in the identification task would be assisted by the external aide-memoire provided by pictures. This point is discussed more fully in §6.1.4 (below). The obverse of this explanation means that the operation of the phonological loop does not benefit from external aids, at least when dealing with material and strings of this nature and size.

Having established that the addition of pictures eases performance in rhyme awareness, the contribution of memory to the tasks will be assessed.

6.1.3.3.2 *The Contribution of Memory to Phonological Awareness tasks*

The changes in performance in the two measures of memory (MeS and Word Recall) were analysed using one-way between subjects anovas with Age Group as the independent variable (as a proxy for age) and Memory (either memory span or word recall) as the dependent variable. For memory span $F(2,33) = 2.78$ ($p=0.08$); and for word recall $F(2,33) = 5.71$ ($p<0.01$). There is therefore a trend of increasing performance in both aspects of memory (span and efficiency) with age (as would be expected), which is significantly greater than would be expected by chance in the case of Word Recall (efficiency).

It is also evident (see Table 6.12) that Word Recall and Memory Span are associated, as demonstrated by the correlation of 0.65 ($p<0.01$). This relationship is further confirmed by the results (shown in Table 6.13) of a hierarchical regression that was undertaken with Age and Word Recall as independent variables (entered in that order) and Memory Span as dependent variable.

Table 6.12a: Inter-correlations of Rhyme (with (Pics) & without (~Pics) pictures), memory (Span & Word Recall) and Age. (n=36)

	Rhy (Pics)	Rhy (~Pics)	MeSp	Recall
Rhyme (Pics)	1			
Rhyme(~Pics)	0.74**	1		
Memory Span	0.356*	0.269 ns.	1	
Word Recall	0.453**	0.511**	0.653**	1
Age	0.576**	0.567**	0.414**	0.539**

* p<0.05; ** p<0.01

Table 6.12b: Inter-correlations of Initial Phoneme (with (Pics) & without (~Pics) pictures), memory (Span & Word Recall) and Age. (n=36)

	IPh (Pics)	IPh (~Pics)	MeSp	Recall
IPh (Pics)	1			
IPh (~Pics)	0.823**	1		
Memory Span	0.413**	0.326*	1	
Word Recall	0.62 **	0.582**	0.653**	1
Age	0.522**	0.556**	0.414**	0.539**

* p<0.05; ** p<0.01

Table 6.13: Hierarchical Regression of MeS scores onto Word Recall and Age (n=36)

DV= MeS	Adj-R2	F-to-enter
Age	0.147	
Recall	0.398	15.2**

** p<0.01

This suggests that greater accuracy of recall (as a proxy for efficiency) is, as predicted by Brady (1991), an associate of superior memory span.

To assess the contributions of both Memory Span and Word Recall to performance in Phonological Awareness (no picture condition) fixed order hierarchical regressions of the two measures (Rhyme and Initial Phoneme) were undertaken. Independent variables were entered in the order Age, Memory Span, and Word Recall. The results of this analysis (see Table 6.14a) suggest that memory efficiency (word recall) makes significant contributions (as indicated by tests of the squared semi-partial correlations) to performance in the measures of phonological awareness, whereas performance in memory span makes virtually no contribution to phonological awareness.

Table 6.14a: Hierarchical regressions of Phonological Awareness (without pictures) scores onto Memory measures. (n=36)

	DV = Rhyme		DV = Initial Phoneme	
	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Age	0.242		0.261	
MeS	0.225	0.29	0.258	0.86
Word Recall	0.302	4.62**	0.37	6.89**

**p<0.01

It can be seen that once age and memory span have been statistically controlled phonological awareness (of both rhyme and initial phoneme) was significantly associated with performance in the measure Word Recall.

It will also be noted that in the above regression the phonological variable scores are those derived from the no-picture condition, and that there is no association between memory span and phonological awareness scores. This appears to be contrary to the earlier findings (§6.1.2.3.2) that initial phoneme awareness was associated with memory span scores. This prompts a need to check the relationship between memory span and phonological awareness scores (with picture condition) obtained from this independent sample. The appropriate hierarchical regression is summarised below in Table 6.14b.

Table 6.14b: Hierarchical regressions of Phonological Awareness (with pictures) scores onto Memory measures. (n=36)

	DV = Rhyme		DV = Initial Phoneme	
	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Age	0.312		0.251	
MeS	0.309	0.85ns	0.278	2.28ns
Word Recall	0.302	0.68ns	0.381	6.50**

**p<0.01

It is evident that in the case of rhyme awareness (with pictures), in contrast to the results (above) obtained with the same verbal stimuli (and the same participants) but without the use of pictures, there was no significant association between word recall and rhyme awareness once the effects of age have been controlled. The finding that there was no significant association with memory span (once the effects of age have been discounted) is in agreement with a finding obtained in §6.1.2.3.2. On the other hand awareness of initial phonemes was still associated with word recall scores. The association between scores in the tests of awareness of initial phonemes (with pictures) and memory span, whilst not statistically significantly greater than might be expected by chance, approached a level of significance in agreement with the earlier finding (§6.1.2.3.2).

6.1.3.3.2 *Summary*

The presence of pictures made a significant improvement to the performance of children in the test of awareness of rhyme. There was no significant difference between children's performance under the two conditions (pictures/no pictures) in the analogous test of awareness of initial phonemes.

In the word recall test the efficiency of children's retention and recall of three-word items increased significantly with age. Performance in this test was also associated with performance in the memory span test as predicted by Brady (1991) who suggested that greater efficiency in memory processes is associated with apparently larger memory spans.

The results of fixed order hierarchical regressions indicate that performance in word recall was related to performance in both measures of phonological awareness when pictures were not available. Memory span did not however appear to make a significant contribution to scores in these (no picture) phonological awareness tasks.

Success in word recall presumably depends on children's ability to rehearse the list of words presented to them. Since this task involved immediate recall of three words it is unlikely that children would have engaged in conscious rehearsal strategies prior to recall. The effect observed is, therefore, more likely to be due to the 'efficiency' of working memory. In the working memory model this efficiency is a function of the articulatory rehearsal subcomponent within the phonological loop. Memory span (as will be discussed in §6.2.1.4) however is more likely to be a function of the central executive. Because children with greater efficiency of rehearsal processes within working memory would be more efficient at retaining three words in memory for comparison when there are no visual aids to support performance, they would be more efficient at retaining the three words of an item in the phonological awareness tests and to compare them.

6.1.4 Overall summary and discussion

It has been shown that while performance in the measure of memory span increases with age (as does phonological awareness), memory span and phonological awareness are not consistently associated independent of age effects. Replicated associations between memory span and awareness of initial phonemes that are independent of age and nonverbal ability have been found, but a comparable effect involving awareness of rhymes has not been replicated.

The demands of memory within measures of phonological awareness (as assumed by MacLean, Bryant & Bradley, 1987) do however appear to be alleviated with the addition of pictures, facilitating higher levels of performance in the test of awareness of rhyme. Performance in the analogous test of awareness of initial phonemes does not, for the children in this experiment, however seem to have been facilitated (or hindered) by simultaneous presence of pictures.

The presence of a memory component within phonological awareness tasks is more clearly demonstrated by children's ability to repeat the items in the word recall test.

This test of the accuracy and therefore the efficiency of memory processes shows a trend of increasing performance with age. Word recall scores also show a significant correlation with scores in the memory span test, and both are therefore presumed to represent aspects of working memory. In support of the view put forward by Brady (1986, 1991) and Hitch, Halliday & Littler (1993) that increased operational efficiency of memory might be associated with apparently greater size of memory span, it was found in a regression that scores in word recall were predictive of scores in memory span.

However, in the regression analyses of phonological awareness these two aspects of working memory are dissociated. In terms of the working memory model (Baddeley and Hitch, 1974; Baddeley and colleagues, *passim*) the dissociation of memory span and efficiency with respect to phonological awareness could be indicative that the phonological loop within which verbal material is temporarily stored is relatively more efficient for some children than others, but that 'size' of memory is relatively immaterial in respect of the phonological awareness tasks. Further, since word recall (but not memory span) appears to make a distinct contribution to measures of phonological awareness when pictures are not available, it is suggested that this demonstrates the presence of an effect due to the articulatory rehearsal subcomponent.

The addition of pictures facilitated the rhyme test (but not the test of initial phonemes) and reduced the association with word recall. Thus whilst the articulatory rehearsal subcomponent is active for both rhymes and initial phonemes when pictures do not support performance, the addition of pictures appears to reduce articulatory rehearsal of rhymes. Since rhyming stimuli may be harder to hold in working memory anyway (this assertion will be evidenced in §6.2.3) it is possible that with pictures the auditory material does not enter the phonological loop. This could be understood in the following terms.

Without pictures as external aide-memoires the three word items that comprise the rhyme test when auditorily presented will gain direct access to the phonological loop. Storage could be in the phonological short-term store in which rhyming would decay more rapidly than non-rhyming stimuli. This differential rate of decay is seen as the phonological similarity effect (see §6.2.3, below). This effect is such that phonologically confusable (ie rhyming) material is less accurately held in the phonological store. These stimuli would normally be refreshed by the other subcomponent of the phonological loop, the articulatory rehearsal mechanism. (It is suggested here that the efficiency of that subcomponent is indicated by performance in the word recall test.) The articulatory rehearsal mechanism is, however, also thought to be responsible for phonologically coding visually presented verbal material. Thus when pictorial representations of verbal material are simultaneously presented, articulatory rehearsal of the auditorily presented stimuli would be suppressed. This phenomenon has some similarity with the effects of unattended speech (Salamé & Baddeley, 1982) and articulatory suppression (Baddeley, Lewis & Vallar, 1984). Salamé & Baddeley (1982) showed that when required to remember visually presented stimuli (digits) participants recall was significantly disrupted by the auditory presence of material phonologically similar to the visual material. Consistent with this are the effects observed (Baddeley, Lewis & Vallar, 1984) when participants are told to repeat an irrelevant word or phrase (thus suppressing the activity of the articulatory rehearsal mechanism) whilst trying to retain material in memory.

The fact remains however that in this present set of investigations it is evident that children can successfully make judgments about the rhymes at the level of phonological complexity that this task requires. This suggests that in the with picture condition the demands made of working memory in the rhyme awareness task might be met without the involvement of the phonological loop. This could be accounted for by invoking the involvement of the central executive in short term storage, as suggested by Hitch, Halliday & Littler (1993), who indicated that articulatory suppression might induce greater use of the the central executive of working memory in tasks involving both temporary storage and another, concurrent, task. This is not to say, however, that the central executive is not also involved in the initial phoneme task, as evidenced (§6.1.2.3.2) by the significant prediction of initial phoneme scores by memory span scores. It seems likely, however, that the initial phoneme task (with pictures) does not suppress the activity of the phonological loop to the same extent as the rhyme awareness task.

6.2 Memory span and reading

In this part of the chapter the questions to be addressed concern the issue of whether the number or type of items that can be held in working memory is related to performance in word reading, and secondly whether memory skills predict performance in reading at a later stage of development .

In §6.2.1 the relationship between memory span (ie the number of items that can be held in memory) and performance in tests of word recognition and reading will be evaluated to determine if: a) memory span and reading are associated across the age range studied; b) if either memory span or reading is more clearly predictive of the other when reassessed twelve months later.

In §6.2.2 the effects of phonological similarity amongst items held in working memory will be examined in the context of performance in the measures of reading in order to evaluate if the type of item that can be held in memory has any effect on the development of reading. Again the longitudinal data will also be inspected to establish if there are developmental predictors of word reading.

6.2.1 <u>The study of the relationship between the size of memory span and reading</u>

There have been a number of studies (eg Byrne & Arnold, 1981; Holligan & Johnston, 1988; Johnston, Rugg & Scott, 1987; Rizzo, 1939; Spring, 1976), in which reduced memory span has been found to be associated with reading difficulties, although as Jorm (1983) noted, the relationship has not always proved to be a strong one. Ellis (1979) has also pointed out that a memory span deficiency has not been found in all groups of children with reading difficulties.

Hulme & Roodenrys (1995) offer cautions against treating short-term memory as a basic unitary function with causal implications for short-term memory deficits. In their view short-term memory difficulties may arise from a variety of sources, but favour explanations given in terms of language perception or processing disorders. They also suggest however that memory deficits might be a consequence rather than a cause of language difficulties. Ellis & Large (1988) and Gathercole, Willis & Baddeley (1991b) have also suggested that reading experience might facilitate the development of memory span. Jorm, Share, Maclean & Matthews (1986) however have found that children who became poor readers had had poor short-term memory skills before they entered school. Further support for a view that memory span development is not consequent on reading comes from a recent study by Avons & Hanna (1995) who reported findings suggesting that reading deficits cannot be the cause of poorer memory spans. Avons & Hanna (1995) and Hulme & Roodenrys (1995) concluded that findings are indicative of a developmental lag which may affect both memory span and reading ability.

In the investigations to be reported here (§6.2.1), therefore, the data gathered from children who are just learning to read will be examined firstly to see if a simple association exists between the size of a child's memory span and her or his ability to read. Secondly, using data from the longitudinal study, an attempt will be made to evaluate the two (reciprocal) possible directions of causality between reading and size of memory span.

In §6.2.2 a description will be offered of the effect on recall of phonological similarity between items and the underlying mechanisms within working memory that the evidence supports. In order to explain findings obtained here, however, some initial discussion of an aspect of the functions of the phonological loop are necessary.

In brief, evidence summarised by Baddeley, Lewis & Vallar (1984) showed that when participants in experiments were given visually presented stimuli that were either phonologically confusable or distinct, and required to attempt immediate oral recall of the stimuli, there was little difference between the number of items (confusable or distinct) that could be recalled when participants were required to simultaneously repeat an unconnected word or phrase. Without the simultaneous task, or when the confusable and distinct stimuli are presented auditorily, there were markedly more errors in recall of the confusable items than there were for the phonologically distinct items. The reason for these differing effects are thought to illustrate the distinct functions of the two subcomponents of the phonological loop. The phonological store is directly accessible to spoken material and is thought to be the location of the phonological similarity effect. Material in the phonological store is refreshed by the other subcomponent in which a process of articulatory rehearsal occurs. This articulatory rehearsal subcomponent, however, is also responsible for the phonological recoding of visually presented verbal material. Thus, if there is an explicit requirement for a word or phrase to be rehearsed, this is thought to prevent the recoding of visually presented material which is therefore denied access to the phonological store. Similarly, it was shown by Salamé & Baddeley (1982) that recall of visually presented items is significantly impaired by the simultaneous presence of some auditory material, particularly if that material is phonologically similar to the visual task materials. In the administration of the Carver test of word recognition the child must search for a visual match for an auditorily presented stimuli. Thus the test demands simultaneous rehearsal of an auditorily presented word whilst searching a visual array. The implications of this are discussed in the light of the findings from this investigation.

6.2.1.1 *Methodology*

The children involved in the investigations reported here are those forming the samples in the main cross-sectional study as described elsewhere.

The measure of memory span (MeS) has already been described in §6.1 and §3.3.3. The Carver test of Word Recognition and the BAS test of Word Reading have similarly been described in §3.3.6. The first of these measures of reading (Carver) is designed to test children's ability to select a printed word to match that spoken by the experimenter. Scores in this test may range from 1 to 10. The second measure of reading (BAS) is a direct standardised test of children's ability to read aloud single, unconnected, printed words. Scores in this test could range from 1 to 90.

6.2.1.2 *Results*

The mean scores achieved by each group of children in memory and reading are shown below in Table 6.13 (below).

Table 6.13 Mean (sd) scores in Memory Span (MeS), Word Recognition (Carver) and Word Reading (BAS) in '92 and '93 (n=15 for each group)

	'92	'93
MeS		
R	3.6 (0.91)	3.2 (1.15)
Y 1	4.07 (1.67)	4 (0.66)
Y 2	5.47 (1.06)	4.93 (1.39)
Carv		
R	2 (1.51)	1.73 (1.49)
Y 1	3.4 (2.61)	4.07 (2.34)
Y 2	6.6 (2.47)	7.47 (2.39)
BAS		
R	0 (0)	0 (0)
Y 1	1.53 (3.52)	5.73 (14.11)
Y 2	17.4 (17.3)	17.4 (19.44)

6.2.1.2.1 *Data Screening and Treatment*

As the data will also be analysed in a form consisting of the entire cohort of 45 children at each sampling in '92 and '93, as well as screening for non-normality of data by groups of 15 (see Appendix 2), the data for each sample of 45 has similarly been checked for kurtosis and skew (using the criteria described by Tabachnick and Fidell, 1989) in '92 and '93.

It was found that the memory span and word recognition (Carver test) data conformed to assumptions of normality in both '92 and '93. Phonological awareness scores in '92 and '93 also conformed to acceptable limits. The Word Reading (BAS test) data in '92 and '93 was found to have significant skew and kurtosis. This is almost certainly because very few of the younger children (none of the 5-year old children) achieved a score in this test. This data was accordingly transformed using $f(x)$: $\log(1 + x)$. Both skew and kurtosis of transformed data was found to lie well within acceptable limits. Further, the BAS scores obtained from children aged 7 (Y2) in '93 were found to be positively skewed. These scores have therefore been transformed by taking the square root of scores.

6.2.1.3 *Analysis of associations across age groups*

For the tests of reading changes with age have been reported in Chapter 4 where statistically significant increases in children's word recognition and reading over the age range studied are recorded.

It has also been demonstrated in §6.1.2.3 that the measure of MeS shows increases in memory span with age, although the change is only significant in comparison of 5- and 7-year-old performance. It is possible therefore that increases in both reading and memory span are associated. The correlations between memory, reading, nonverbal ability (Raven's matrices) and ages in the two samples of 45 5- to 7-year-old children are shown in Table 6.14 (below).

Table 6.14a: Pearson Correlation Coefficients for MeS, Reading, Raven's matrices and Age in '92. (n=45)

	MeS	Carv	BAS	Rav	Age
MeS	1				
Carv	0.522**	1			
log(1+BAS)	0.428**	0.686**	1		
Rav	0.251ns	0.541**	0.298*	1	
Age	0.533**	0.659**	0.556**	0.39**	1

*p<0.05;**p<0.01

Table 6.14b: Pearson Correlation Coefficients for MeS, Reading, Raven's matrices and Age in '93. (n=45)

	MeS	Carv	BAS	Rav	Age
MeS	1				
Carv	0.635**	1			
log(1+BAS)	0.551**	0.87**	1		
Rav	0.339*	0.474**	0.525**	1	
Age	0.575**	0.7621**	0.705**	0.578**	1

*p<0.05;**p<0.01

In order to determine if there was a significant, predictive, relationship between memory span and reading that was independent of age, two approaches have been adopted. In the first set of analyses, hierarchical regressions of reading scores onto Age, nonverbal ability (Raven's matrices) and MeS have been performed. Secondly coefficients of correlation within each age group have been examined.

The results of the hierarchical regressions are shown below in Table 6.15. Non-verbal ability (Rav) has been included to achieve statistical control for the effects of non-verbal abilities.

Table 6.15: Hierarchical regressions of Reading (Carver, BAS) scores onto Age, Ravens and Memory Span (n=45 in each regression)

	'92		'93	
	Adj R2	F-to-enter	Adj R2	F-to-enter
DV=Carv				
Age	0.421		0.571	
Rav	0.507	8.46**	0.563	0.17ns
MeS	0.531	3.22*	0.614	6.60**
DV=log(1+BAS)				
Age	0.294		0.486	
Rav	0.285	0.48ns	0.495	1.81ns
MeS	0.292	1.40ns	0.516	2.82ns

*p<0.05;**p<0.01

It seems therefore that once the effects due to age and nonverbal abilities have been taken into account word reading ability (BAS) is unlikely to be associated with memory span. Word recognition (Carver) however does seem to have a memory span component that is independent of age. The correlations between memory span and word recognition (Carv) scores for 5-, 6- and 7-year-old children in '92 and '93 have been calculated (Table 6.16) and show little in the way of specific age-related associations.

Table 6.16: Pearson Coefficients of Correlations between Memory Span and Word Recognition (Carver) test for R, Y1 and Y2 groups (n=30 in each case)

R	0.46*
Y 1	0.31ns
Y 2	0.22ns

*p<0.05

This table (6.16) in fact suggests that the association between memory span and word recognition decreases across age. This is further discussed below.

6.2.1.4 *Summary and discussion*

The evidence above suggests that there is evidence of a relationship between memory span and word recognition (Carver test) ability, and that this is age-specific. There is however no evidence of a relationship between word reading (BAS test) and memory span. A possible explanation for this difference lies in the contrasting nature of

the tests and in the different functions of the working memory model.
With respect to the relationship with working memory under discussion here the crucial factor for success in the Carver test would be the child's ability to retain in working memory a phonological representation of the word that was auditorily presented whilst concurrently processing the visually presented stimuli (printed words and non-words) and deciding which corresponds to the word held in working memory. According to the working memory model it is probable that the visually presented stimuli would ordinarily be phonologically coded by the articulatory rehearsal loop.

In contrast the BAS test (word reading) requires that the visual stimulus has to be phonologically encoded and some decision then made about whether this matches a word in the child's lexicon. In this case there is no simultaneous processing of auditory and visual stimuli.

The Carver test of word recognition can be seen as placing demands on both subcomponents of the phonological loop in the working memory model (Baddeley, 1986; Gathercole & Baddeley, 1993b). Because of the need for the child to retain a word in memory while performing a second task (searching the printed stimuli) the conditions are similar to those of articulatory suppression employed by workers examining rehearsal processes in memory (eg Baddeley, Lewis & Vallar, 1984), and unattended speech effects studied by Salamé & Baddeley (1982). In the work of Baddeley *et al* (1984) it had been found that articulatory rehearsal was impaired by articulatory suppression, and that phonological coding of visually presented material for entry to the phonological store can also be disrupted (Baddeley *et al*,1984; Levy, 1971; Salamé & Baddeley, 1982). It is therefore somewhat surprising that children are able to achieve success in the Carver test. The evidence of this current research (of increasing success in the Carver test, and of an association of Carver scores with memory span) therefore requires some careful explication, as follows, in order to address what could be a challenge to the working memory model (due to Baddeley, 1986, and others).

The views of Case, Kurland & Goldberg (1982), endorsed by Gathercole & Baddeley (1993a), are that increased efficiency of working memory processes underpins the developmental increase in memory span. Some support for this from the results of the present research has been presented above (§6.1.3.3.2). Case *et al* (1982) suggest that as a result storage space is freed up; Gathercole & Baddeley (1993a) hold that increased span is a manifestation of a reduced rate of decay of phonological representations. The second of these possibilities is thought to arise from increased efficiency in the articulatory rehearsal sub-component of the phonological loop. In the light of work undertaken by Hitch, Halliday & Littler (1989) which experimentally dissociated developmental changes in the central executive and phonological loop components of working memory, Gathercole & Baddeley (1993a) offered a reconciliation of the views of Case *et al* (1982) and their own views of the working memory model (Gathercole & Baddeley, *passim*). Gathercole & Baddeley (1993a) concluded that while changes in memory span with age may be largely due to increases in speed of articulatory rehearsal (ie there is increased efficiency within the phonological loop), there are also developmental improvements in the efficiency of central executive function which leads to greater availability of processing resources for storage and retrieval of memory items. The overall increases in verbal memory performance are, it is thought, the result of the combination of improvements in the functioning of both central executive and the articulatory process within the phonological loop. Hitch, Halliday & Littler (1993) also suggested that the involvement of the central executive of working memory in memory span might be more evidently necessary when tasks become too complex for the articulatory rehearsal loop alone. As an example of the level of complexity that require additional working memory resources Hitch *et al* (1993) cite Daneman & Carpenter's (1980) 'reading span' task. This task involved the temporary accumulation of verbal material in working memory while continuing to perform further reading or listening. It is possible that the Carver test is for children of the ages studied here of comparable complexity to the demands placed on the adults in Daneman & Carpenter's (1980) task.

Under the conditions imposed by the Carver test either greater processing efficiency or storage space would presumably mean that a child would have less difficulty retaining the auditorily presented target word whilst simultaneously scanning and attempting to phonologically code the visually presented words. Conversely the BAS Word Reading test places direct demands on the articulatory rehearsal component in which the printed word stimuli would be encoded into phonological representations. Since it appears that the auditory memory span measure (MeS) is not associated with performance in the BAS, but is associated with performance in the Carver test, this suggests that the test (MeS) is not a measure of the effectiveness of the articulatory rehearsal process. This dissociation of the effects of memory span between the two measures of reading therefore suggests that the measure of memory span may, according to Gathercole & Baddeley's (1993b) formulation of working memory and the speculations of Hitch *et al* (1993), therefore be associated with central executive function. This also accords with the explanation provided by Case *et al* (1982) that increasing memory span results from the increased availability of storage space. It is possible therefore that the apparent association between memory span and word recognition scores that was found to be statistically significant amongst 5-year-old children, but then decreases with age, is effectively a 'floor' effect. Thus it might be that young children in the early stages of learning to read require some minimum working memory capacity within the central executive when undertaking a task such as the Carver test. Above a minimum range of functioning other factors, such as lexical knowledge or phonological awareness, may become more salient.

6.2.1.5 *The longitudinal relationship between Memory and Reading*

The view of the apparent relationship between memory span and word recognition that has emerged above might also lead to a prediction that superior performance in memory at one stage would be associated with better word recognition at a later stage of development. A lack of longitudinal association would be neutral with respect to such a hypothesis, but a longitudinal association of superior word recognition being predictive of larger memory span at a later stage would contradict the conjecture. Accordingly the longitudinal data has been analysed using hierarchical regressions to test the validity of the opposing hypotheses.

In order to do this the longitudinal data available from 24 children who were followed up a year after the initial round of tests was checked for departures from normality evidenced by extremes of skew or kurtosis using the criteria suggested by Tabachnick & Fidell (1989). On this basis it was necessary to transform the scores obtained in the first round of tests (at T1) for Word Recognition (Carv1) and Memory Span (MeS1). Carv1 was found to be positively skewed and the square root transformation of scores was found to reduce the coefficient of skew to within acceptable limits. The MeS1 scores exhibited a significant degree of positive kurtosis which was successfully corrected when natural logarithms of the scores were taken. These transformed scores will be used in detailed analysis, below.

The means and standard deviations of the raw scores at T1 and, twelve months later at T2 are shown below.

Table 6.17: Mean (sd) of Age and raw scores for Memory Span (MeS) and Word Recognition (Carv) obtained at T1 and T2 (n=24)

	Mean	sd
Age1	63.25	6.24
MeS1	3.92	1.25
MeS2	4.63	1.25
Carv1	2.88	2.35
Carv2	5.71	3.09

Tests of the differences between children's scores at T1 and T2 in memory and word recognition were performed to establish if the differences are greater than might be expected by chance. In order to avoid any violations of the assumptions of normality underlying parametric t-tests, the Wilcoxon signed-rank test was used. For memory span this yields $z = -3.22$, $p<0.05$; and for word recognition $z = -4.00$; $p<0.01$. It seems therefore that there were significant increases in children's memory spans and word recognition over the twelve months between testing at T1 and T2.

In order to determine if memory span predicted word recognition a year later, or if it was the reciprocal relationship that was the better descriptor, hierarchical regressions were undertaken. The correlation coefficients for all variables (using transformed scores for MeS1 and Carv1) to be entered are shown in Table 6.18.

Table 6.18: Coefficients of correlation (Pearson) between test scores obtained at T1 and T2. (n=24)

	Age1	ln(MeS1)	MeS2	√Carv1
Age1	1			
log(MeS1)	0.399*	1		
MeS2	0.472*	0.746**	1	
√Carv1	0.479*	0.371ns	0.304ns	1
Carv2	0.612**	0.558**	0.514*	0.802**

*p<0.05;**p<0.01

In both hierarchical regressions Age at T1 was entered first to effect statistical control of differences in age. In the regression of word recognition at T2 the scores obtained from the Carver test at T1 were entered as the second IV to offset any initial advantage in reading. This variable was followed by the memory span scores at T1. A similar procedure was followed in the regression of memory span at T2 with MeS1 following Age and Carver scores as the final IV. The results are summarised in Table 6.19 below.

Table 6.19: Hierarchical regression of longitudinal data. (n=24)

	Adj-R2	F-to-enter
DV=Carv2		
Age1	0.346	
√Carv1	0.683	24.4**
log(MeS1)	0.722	3.94*
DV=MeS2		
Age1	0.187	
log(MeS1)	0.554	19.1*
√Carv1	0.535	0.12ns

*p<0.05;**p<0.01

This indicates that memory span is more likely to be predictive of later word recognition scores than word recognition scores are to be predictive of memory span a year later. This supports the view outlined above that memory span may be associated with word recognition and suggests that superior memory functioning is an antecedent of word recognition skills. In terms of the explanation offered above (§6.2.1.4) this result suggests that if the central executive of working memory is functioning efficiently then progress in word recognition, that is the process of learning to match spoken words to printed words, should proceed more rapidly.

In the following section the methodology is designed to assess the contribution to reading of another component of the working memory model, the phonological loop.

6.2.2 An investigation of the phonological similarity effect

So far in this part of the chapter it has been the question of whether the number of items that can be held in working memory affects the development of reading. In the following section the issue to be evaluated is whether the type of verbal material to be memorised has any significance. In view of the evidence now accumulated this may be taken to distinguish between central executive and phonological loop functions within working memory.

The effects of phonological similarity on recall have been widely investigated as being an indicator of the interaction of phonology and memory in reading. Hitch & Halliday (1983), Shankweiler, Liberman, Mark, Fowler, & Fischer (1979), and Siegel & Linder (1984) suggested that poorer readers are less disadvantaged by phonological similarity effects. In the methodologies of those studies all children were given confusable and non-confusable strings of the same length to recall.

Hall, Wilson, Humphreys, Tinzman, & Bowyer (1983) and Johnston, Rugg & Scott (1987) used a more rigorous approach in which some adjustment was made for individual children's memory spans. In Johnston *et al*'s (1987) study the strings to be recalled were of lengths set just within the maximum memory span that each individual achieved. Under these conditions it was found that for visually presented stimuli there was no significant association between reading ability and phonological similarity effects. It has also been shown by Levy (1971) and Baddeley, Lewis & Vallar (1984) that the phonological similarity effect disappears under conditions of articulatory suppression when visually presented material is used. When auditorily presented material is used however the phonological similarity effect persists even when articulatory suppression is imposed. According to the current formulation of the working memory model (Gathercole & Baddeley, 1993b) phonological similarity effects are a demonstration of the function of the phonological store subcomponent of the phonological loop. According to Gathercole & Baddeley (1993a) visually presented material is first coded into a phonological form by the articulatory rehearsal subcomponent before it can gain access to the phonological store. In this present study auditory presentation of items has been used to ensure direct access to the phonological short-term store. The present methodology should therefore avoid any possible direct interference from the articulatory rehearsal mechanism during perception. Following the example of Johnston *et al* (1987), who had used visually presented materials, the lengths of string to be recalled has been adjusted to lie within the memory span of each individual child.

The clear implication from the findings of Hall *et al* (1983) and Johnston *et al* (1987) is that Shankweiler *et al* (1979) and others had presented both good and poor readers with the same memory demands. It is now thought that the effects of phonological similarity on poor readers' recall were probably artefacts of floor effects. Both Hall *et al* (1983) and Johnston *et al* (1987) studied the phonological similarity effect in children aged 8-years who were poor readers. The possibility still remains therefore that with the methodology adopted by Johnston *et al* (1987), but with younger non-reading children and children without significant delays in reading, phonological similarity effects might have a differential impact. The children in this study were aged between 5- and 7-years, and all 5-year-old children showed no evidence of word reading ability.

If age or reading ability was a significant factor, as well as finding a significant difference between the ability to recall non-rhyming and rhyming strings an interaction between age-group and the similarity effect would be expected. This hypothesis is tested by requiring children aged 5-, 6- and 7-years to recall of alternate non-rhyming (dissimilar) and rhyming (similar) strings of letter names. Evidence of an interaction between condition (rhyming vs. dissimilar strings) and age-group would be consistent with the findings of Shankweiler, Liberman, Mark, Fowler and Fischer (1979) who found that poor readers were less significantly disabled by similarity effects than good readers. Alternatively, a finding of no interaction would be in line with the results of Johnston, Rugg and Scott (1987) who controlled for the differences in children's memory spans and found that reading ability and similarity effects did not interact. As in the work of Johnston, Rugg and Scott (1987) the strings to be recalled were of lengths that were set just within each child's memory span.

This methodology also affords a test of the suppositions of Baddeley & Lewis (1981) and Besner & Davelaar (1982) that an articulatory code rather than an acoustic code for verbal material is operational in working memory. Baddeley (1986) summarised the available evidence and adduced that phonological similarity effects were likely to be due to confusions within an articulatory code. Baddeley (1986), however, also proposed that the putative 'acoustic' code that might also be used for some verbal material would be derived from the perception of speech and might form a basis for some phonological comparisons such as judgments about rhyme. As has already been shown (see chapter 5), however, in this research there is no evidence to support an association between children's awareness of rhymes and their competence in speech perception. It was also shown there that for the sample of hearing impaired children (aged about 7-years) there was no relationship between their performance in the tests of speech perception and rhyme awareness. Thus, following from Conrad (1970) who found that amongst children who were profoundly deaf those who were rated as having the better speech were found to have significantly greater confusions between phonologically similar stimuli, the phonological similarity effect has also been investigated in the partially-hearing children studied here. A prediction to be tested in this section is, therefore, that the partially-hearing children will show a similar phonological similarity effect to the hearing peers because all these children were able to use speech and the use of speech productive mechanisms (the articulatory coding processes) are therefore assumed to be functioning. A failure to find a phonological similarity effect in the sample of partially-hearing children would be a challenge to the view that articulatory codes are necessary for working memory.

6.2.2.1 *Methodology*

Following the assessment of memory span (described in earlier sections) each child was required to recall alternating strings of non-rhyming and rhyming letter-name strings set at a length one unit less than the length of letter-name string at which both items were failed in the memory span test. Children were presented (again auditorily from prerecorded cassette tape with an adult male speaker) with alternate rhyming and non-rhyming strings of letters. The set of letters from which rhyming strings were randomly drawn was {B, C, D, G, P, T, V} and dissimilar sounding letter strings were, again randomly, drawn from the set {H, K, L, Q, R, S, W}. There were seven items for both conditions, and no letters were repeated within items. Letters were spoken at the rate of one per second with twice the string-length time between items. Children were asked to repeat each item immediately it had been played. If any child was slow or hesitant in responding the tape replay was halted to allow the child time to respond. Each child was given all fourteen items set at the length appropriate to their memory spans. Scores were the total number of strings correctly recalled in serial order within each condition. Scores may therefore range from 0 to 7 in both conditions.

6.2.2.2 *Results*

The mean recall scores obtained from all groups of children are shown in Table 6.20 which shows the mean number of similar and dissimilar items correctly recalled. For comparison the mean memory span score for each group is also given.

Table 6.20: Mean number of phonologically similar and dissimilar letter strings recalled by hearing children aged 5- (R), 6- (Y1) and 7-years-old (Y2) and partially-hearing (P-H) children aged 7-years. (n=15 for each group)

	R-Groups		Y1-Groups		Y2-Groups		P-H Group
	'92	'93	'92	'93	'92	'93	
Mean Similar	2.53	2.4	2.8	2.47	2.07	2.2	2
sd	2.3	2.35	1.82	1.96	2.49	2.37	2.04
Mean Dissimilar	4.87	3.73	5.8	4.33	4.47	4.47	5.8
sd	2.36	2.79	1.08	2.13	2.26	1.64	1.61
Mean Memory Span	3.6	3.2	4.1	4	5.5	4.9	4.3
sd	0.9	1.2	1.7	0.7	1.1	1.4	1

6.2.2.2.1 *Data screening and treatment*

The scores have also been inspected for non-normality. Coefficients of kurtosis and skew are shown in Appendix 2. These conform to reasonable limits as computed by procedures described by Tabachnick & Fidell (1989). F_{max} was also calculated and found to be within acceptable limits.

6.2.2.2.2 *Analysis*

To determine if there was any effect due to Group (age and hearing/hearing-impaired) on performance in the measures of phonological similarity an analysis of variance was conducted on the data summarised in Table 6.20. A mixed design anova was used with Group as a between subjects factor and Condition (number of similar and dissimilar items recalled in serial order) as the within subjects repeated measure. This showed a significant interaction [$F(6,98) = 2.92$, $p<0.05$] between Groups and

Condition (number of similar and dissimilar items recalled), and a significant main effect [$F(1,98) = 192.4$, $p<0.01$] for the effect of phonological similarity. There was however no significant main effect of groups [$F(6,98) = 0.73$].

This indicates that across the groups there was a differential in the ability to recall phonologically similar and dissimilar strings, and that overall phonologically similar strings were significantly harder to recall than dissimilar strings, for all children. In view of the predictions that have been made that poorer readers would be less affected by the phonological similarity effect, but that partially hearing children would be able to perform at levels comparable to their hearing peers, two further analyses are summarised below.

The first of these was undertaken to establish if, for the hearing children, there was any difference between age groups with respect to the phonological similarity effect. As age and reading are significantly correlated ($r=0.7$, $p<0.01$, for Carver test; $\rho=0.72$, $p<0.01$, for BAS[1]) an analysis of covariance might be thought appropriate. This is not necessary however in the light of the results of a mixed design anova performed on the combined (n=30) groups of hearing children. In this anova, with age Group as the between subjects variable and Condition (similar vs. dissimilar) as the within subjects repeated measure, the interaction between Groups and Condition [$F(2,87)=0.47$] was not significant. The main effect of Condition [$F(1,87)=98.1$, $p<0.01$] confirmed that phonologically similar items were harder to recall accurately than dissimilar items. There was however no difference between groups [$F(2,87)=0.16$, ns].

The lack of any association between reading ability and the phonological similarity effect across ages was confirmed by computing the ratio of the number of correctly recalled similar strings to the number of correctly recalled dissimilar strings and testing the rank correlations of this ratio with performance in the Carver and BAS tests. For the complete sample of 90 hearing children there were four cases in which the ratio could not be computed because of 0s. With corrections for tied values, however, the correlations found for the remaining 86 cases were not significant. For the correlation with the Carver test $\rho=-0.13$, and for the correlation with the BAS test $\rho=-0.08$. The corresponding values for the partially-hearing children were $\rho=0.14$ and $\rho=0.08$, again

[1] A rank order correlation is chosen here because of the shape of the distribution of BAS scores.

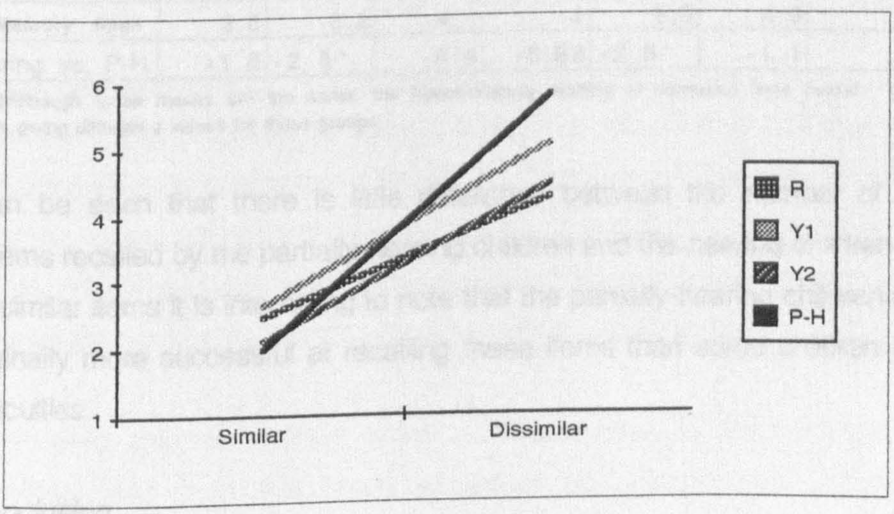
both are non-significant.

The second of these analyses was in the form of a comparison of the differences between the partially-hearing and hearing children in the recall of similar and dissimilar strings. It was thought that the calculation of a parameter for the ratio of the number of similar to dissimilar strings that were correctly recalled might be illustrative. This is shown in Table 6.21, and in Figure 6.2 where for ease of interpretation the hearing groups have been collapsed into one per age range - ie R, Y1, Y2, to contrast with the hearing-impaired group.

Table 6.21: The ratio of the number of similar to dissimilar strings recalled by children without hearing difficulties (R, Y1 and Y2 age groups) and Partially-Hearing (P-H) children (n=15 each group)

	R-Groups		Y1-Groups		Y2-Groups		P-H Group
	'92	'93	'92	'93	'92	'93	
Mean Similar	2.53	2.4	2.8	2.47	2.07	2.2	2
Mean Dissimilar	4.87	3.73	5.8	4.33	4.47	4.47	5.8
Sim:Dissimilar	1.92	1.55	2.07	1.75	2.16	2.03	2.9

Fig 6.2: Mean number of similar and dissimilar items recalled by hearing children (n=30 for each of R, Y1, Y2) and partially-hearing children (n=15)



The mean ratio (for all children) has also been computed and found to be 2.05 with a standard deviation of 0.43. This suggests that the partially-hearing children (ratio = 2.9) were somewhat more successful than other children at recalling dissimilar as opposed to similar sounding letter strings. Conversely the youngest children (R-groups) appear to less affected by phonological similarity in the items to be recalled.

To establish if there were any other significant differences between the recall of hearing and partially hearing children in the phonologically similar or distinct items Mann-Whitney (z) pairwise comparisons were made. These are shown in the following table. In this table, for comparison, the mean memory spans are given together with the results of tests of pairwise comparisons between hearing and partially-hearing children. As can be seen, in respect of memory spans the partially-hearing children obtained scores which are comparable with those of the normally hearing children aged 6-years.

Table 6.22: Mean numbers of phonologically similar and dissimilar items recalled and Mann-Whitney (z) tests of the difference between hearing groups (R, Y1, Y2) and the partially-hearing (P-H) group (n=15, each group)

	R-Groups		Y1-Groups		Y2-Groups		P-H Group
	'92	'93	'92	'93	'92	'93	
Mean Similar	2.53	2.4	2.8	2.47	2.07	2.2	2
z: Hearing vs. P-H	-0.64	-0.41	-1.35	-0.81	-0.24	-0.02	
Mean Dissimilar	4.87	3.73	5.8	4.33	4.47†	4.47†	5.8
z: Hearing vs. P-H	-0.98	-2.01*	-0.52	-1.9	-1.71	-2.23*	
Mean Memory Span	3.6	3.2	4.1	4	5.5	4.9	4.3
z: Hearing vs. P-H	-1.8	-2.8*	-0.4	-0.88	-2.6*	-1.1	

*p<0.05; †Although these means are the same, the Mann-Whitney statistic is computed from overall rank order information, giving different z values for these groups.

Thus it can be seen that there is little difference between the number of similar sounding items recalled by the partially-hearing children and the hearing children. In the case of dissimilar items it is interesting to note that the partially-hearing children appear to be marginally more successful at recalling these items than some children without hearing difficulties.

6.2.2.3 *Conclusion*

It can be seen that although the memory span performance of children was significantly different between age groups (see §6.1.2.3.1), once the number of items for recall is set within individual children's memory span they are undifferentiated in terms of the efficiency of recall and are generally able to recall roughly twice as many phonologically dissimilar as similar items. This parameter has been shown to hold for the partially-hearing children as well. A result that is critical with respect to the findings of Shankweiler *et al* (1979) and Siegel & Linder (1984) is that the 5-year-old non-reading children are essentially as affected by phonological similarity as older (7-year-old) children who are acquiring competence in reading.

This replicates the findings of Johnston, Rugg and Scott (1987) and Hall, Wilson, Humphreys, Tinzman & Bowyer (1983) who had also disconfirmed the findings of Shankweiler, Liberman, Mark, Fowler & Fischer (1979) and Siegel & Linder (1984) that phonological similarity effects differentiated good and poor readers. Johnston *et al* found a significant main effect of phonological similarity (with dissimilar items showing superior recall), no effect of age and no interactions between age and similarity, or between reading ability (grouped) and similarity. In the study reported here separate data for age and reading ability are available. It is evident that the youngest children (who were all effectively non-readers at the time of testing) were relatively no more or less affected by similarity effects than the oldest (and most successful in reading) children. For neither hearing nor partially-hearing children was a significant relationship found between performance in reading and the phonological similarity effect as shown by the ratio of phonologically similar to dissimilar strings correctly recalled.

If Salamé and Baddeley (1982) are right and that within the phonological store of the working memory model phonological representations are at risk of partial loss through interference from other phonological material, an implication of these findings is that young children (here as young as 5 years), or 'normal' non-readers, are proportionately no different from their older peers (who are readers) in terms of their susceptibility to interference induced decay in the phonological loop.

It was shown in Chapter 4 that there were differences between the partially-hearing and the hearing children in their levels of phonological awareness. The partially-hearing children did not achieve levels of awareness comparable to their chronological age match peers, but were comparable to the 6-year-old normally hearing children. This suggests that the partially-hearing children were able to form stable phonological representations and to make consistent judgments about phonological equivalence. In the case of the partially-hearing children it will also be recalled from Chapter 5 that their performance in rhyme awareness was not related to the consistency of their categorical speech perception. It may, therefore, be concluded that in line with the views of Baddeley (1986), Baddeley & Lewis (1981) and Besner & Davelaar (1982), an articulatory (as opposed to an acoustic) code for verbal material was operational in working memory for these children.

6.3 **Summary and conclusions**

In this chapter various aspects of the relationships between memory, phonological awareness and reading have been investigated.

It has been shown that performance in the measures of memory span and phonological awareness increased with age, and that taken overall there were significant bivariate correlations between the abilities of the children sampled on these measures. However there appeared to be no developmentally predictive relationship either way between memory span and phonological awareness.

Baddeley (1986) had suggested that working memory span might be the crucial factor in the phonological awareness tasks employed by Bradley & Bryant (1983), who had used phonological tasks similar to those used in this research, but without the pictures. In this present research whilst it seemed to be the case in the cross-sectional analysis that once the effects of age and non-verbal ability were partialled out (in hierarchical regressions) memory span was predictive of children's awareness of initial phonemes, it was also apparent in the longitudinal data that individual children's memory span (at T1) did not predict phonological awareness (of either rhyme or initial phonemes) at T2. It was also found that phonological awareness scores at T1 were not predictive of memory span scores at T2, but were associated with phonological awareness scores at T2. On this basis it would seem that there was some evidence in support of Baddeley's (1986) conjecture that children's performance in a phonological awareness task might be dependent on the children's scores in the test of memory span. However, memory span was not found to be consistently implicated in performance in the rhyme awareness test. Also, from the longitudinal data, there was no evidence that memory span was a determinant of the development of phonological awareness.

Thus it seems unlikely that memory span is crucial to performance in the phonological awareness tasks used here.

However, the possibility that there might be a memory component in a phonological awareness task was studied further by evaluating children's performance in tests of phonological awareness with and without the aid of pictures. In partial confirmation of MacLean, Bryant & Bradley's (1987) assumption that phonological awareness tasks imposed a memory burden on participants, in the case of rhyme awareness the presence of pictures was linked to a significant improvement in the awareness task. Performance in the test of awareness of initial phonemes was not affected by the presence (or absence) of pictures. Performance in both the phonological awareness tasks (without pictures) was also found to relate to performance in a measure of efficiency of recall of three word items (the word recall test). When pictures were present in the rhyme test however this association with word recall disappeared. The association between word recall and initial phoneme awareness was however found to be present in both conditions - ie with and without pictures. It was argued (in §6.1.4) that the evidence of this study indicated that rhyme and initial awareness tasks (with pictures) involved different components of the working memory model, and that for rhyme awareness the central executive was implicated in the short-term storage of items during phonological processing. The initial phoneme task however involved the phonological loop for short-term storage.

Performance in Word Recall, which was taken to be a measure of the efficiency of working memory processes, was found to contribute to performance in Memory Span in support of the predictions of Brady (1991) and Hitch, Halliday & Littler (1993) who had suggested that increased efficiency of processing would be associated with greater memory span.

Evidence from the investigation of the relationship between memory span and reading and the investigation of the phonological similarity effect provide further insights into the functioning of separable component of working memory. Thus it is possible to distinguish between functions of the subcomponents of the phonological loop and the central executive of the working memory model as described by Gathercole & Baddeley (1993a).

The articulatory rehearsal mechanism, which is evidenced here by the word recall test, is responsible for refreshing the contents of the phonological store. It also permits visually presented verbal material to be phonologically coded. Competition for the services of the articulatory rehearsal component, as may be seen in the Carver test of word recognition (but not the BAS test of word reading) and the test of awareness of rhyme with pictures, places complex demands on working memory. In the case of the Carver test it is suggested that these demands are met by involving the central executive in short-term storage. The involvement of the central executive is probably indicated here by the statistical relationship found between word recognition scores and the results obtained from the memory span test. In the rhyme test the pictures, which increase the level of performance, serve as an external aide-memoire. Rhyming stimuli otherwise tend to degrade or become confused in the phonological store significantly more rapidly than phonologically distinct stimuli. Working memory appears to manage the rhyme awareness task without pictures, but the addition of pictures seems to have the paradoxical effect of reducing the activity of the articulatory rehearsal subcomponent while increasing the overall level of performance in the task. It is suggested, following Hitch, Halliday & Littler (1993), that this may also indicate the activity of the central executive.

When the limits of working memory capacity (as indicated by the memory span ceiling for each child) were not exceeded, children's relative success at recalling rhyming and non-rhyming strings of letter names confirmed that all children found the rhyming items harder to recall than the non-rhyming ones. There was no differential effect of age or reading ability in this respect. Thus although younger children may be less capable of dealing with such material in working memory, there seems to be no additional evidence that they are proportionately more or less effective in their recall of phonologically similar or dissimilar stimuli. While this increases the doubts about the conclusions of Shankweiler *et al* (1979) that there exists a distinction between good and poor readers' ability in phonological similarity tasks, it strengthens the simple, but important point that some stimuli (phonologically similar, and hence confusable ones) are harder (by a factor of about 2) for all children to retain and recall. The results reported here complement the work of Johnston *et al* (1987) by confirming that there were no differential effects across ages and reading ability for the phonological similarity when auditory presentation was used. It further extends the finding of phonological similarity effects to younger children than had been studied before, and also adds some weight to the view that children a young as 5-years could be using articulatory coding in working memory.

The overall implications of work reported here are to suggest that memory is implicated in phonological tasks of the (simple) type employed here, but that the effects are subtle and to some extent obviated by the use of pictures. Similarly the relationship between memory and reading as demonstrated here suggests that the phonological similarity effect does not discriminate between children of different levels of competence in reading. Taken in conjunction with the work of Johnston *et al* (1987) it would seem that the differential effect of rhyming as opposed to non-rhyming stimuli does not, as had been suggested by Shankweiler *et al* (1979), indicate that younger, or less successful readers, have proportionately greater difficulty forming phonological representations. It is probable that younger children have less efficient memory processes. This could manifest itself as either smaller spans or by inferior performance in the type of phonological similarity tasks investigated by Shankweiler *et al* (1979).

Clearly a major weakness of the overall research paradigm adopted in this present work lies in the reliance on correlational study rather than experimental manipulation and control. It would therefore be of great interest to undertake further work with children both in an attempt to replicate the present findings with other and possibly clinically distinguishable samples, and to conduct experimental studies of some of the issues that have emerged here.

With regard to the phonological awareness tasks and the association with memory span it would be possible to investigate that relationship further by varying the numbers of phonologically comparable and distractor words within items. In contrast to the three word items used here, Bradley & Bryant's (1978, 1983) phonological measures contained four-word items. The number of words within items could therefore be varied and children's performance compared and related to data on their memory functions in order to establish, for instance, if memory span could impose a constraint on reliable performance in phonological tasks.

In terms of the model of working memory that has formed a major foundation for this chapter it would be of interest to establish if there is an articulatory rate effect (perhaps by using word length as a variable) within investigations of the phonological similarity effect. It would also be useful to include a delayed recall task so as to establish more clearly the relative rates of decay of similar and dissimilar stimuli within the articulatory rehearsal loop.

From an educational and clinical perspective an important group of children to be studied are those with significant difficulties in phonological awareness tasks who are now thought to comprise a large proportion of those with reading difficulties. Gathercole & Baddeley (1990) and Hulme & Roodenrys (1995) have also indicated that children with language difficulties may provide valuable information on the development of phonological memory. There is a growing need for assessment material which can be used to differentiate the needs of children. The work that has so far contributed to measures of phonological awareness in respect of reading difficulties (for example Gibbs & Miller, 1995) might now be complemented by further development of measures of working memory. Thus it would be helpful to compare other, and more sensitive, measures of span as Gathercole, Willis, Baddeley & Emslie (1994) for example have done and to relate evidence from such investigations to further extend our understanding of the relationship between phonological and memory processes.

Chapter Seven

Vocabulary, Phonological awareness and Reading

7.0 Overview

This chapter will present evidence of children's performance in a standardised test of vocabulary. The relationship between children's vocabulary and their phonological awareness will be explored in the context of changes in memory span. Given the evidence of age related increases in phonological awareness (reported in Chapter 4) two alternative proposals are considered:

1) Greater lexical knowledge facilitates the development of phonological awareness;

2) Heightened phonological awareness frees-up space for lexical processing.

The first of these proposals is found to be supported by the evidence available in the present study. In the light of that finding further investigation has been made of the developmental interaction between children's lexical knowledge, memory span and phonological awareness. In this respect a speculation that "less is more" (derived from Newport, 1990) is found to have some support in terms of the development of awareness of initial phonemes.

In the final section of this chapter the hypothesis that lexical knowledge was predictive of reading ability (Becker, 1979; Kleiman, 1975; Näslund & Schneider, 1991; Tunmer & Nesdale, 1985) is tested. The evidence is supportive of this hypothesis, with some indication that lexical knowledge may be dissociable from phonological awareness

7.1 Lexical knowledge and phonological awareness

7.1.1 Introduction

Children's vocabulary knowledge is, as Downing & Leong (1982) suggested, best understood within the context of the mental lexicon. The notion of the lexicon as an internal, mental concept was developed by Treisman (1960) and extended by Oldfield (1966). The lexicon was defined as an associative network of information. Items within the lexicon have phonological representations, and the strength of associations between items depends on the frequency of contingent activation.

Forster (1976) described the process of lexical access as analogous to looking up words in a printed dictionary. Thus in order to access an item in the internal lexicon the coded descriptions of candidate items would have to be compared with the code ascribed to the target word. This implies that the success, or otherwise, of a search through the lexicon will depend at least partly on the completeness of the lexicon and the accuracy of the coding and matching processes.

Aspects of the lexicon's phonological structure have been studied by Aitchison & Straf (1981), Brown & McNeill (1966), Fay & Cutler (1977), Koriat & Lieblich (1974), Rubin (1975) and Vihman (1981), amongst others. A conclusion arrived at by Vihman (1981) was that on first encountering a new word a child would interpret this with reference to preexisting and phonologically similar items in her/his lexicon. The most likely salient features in this connection were thought by Vihman (1981) to be syllabic stress or word-final sounds. In a comparison of the typical errors (malapropisms) made by children and adults, Aitchison & Straf (1981) found that adults tended to preserve the initial consonant of the correct word, whereas children were quite likely to have changed the initial sound while preserving the number of syllables and rhythmic pattern of the word. The salience of word-initial sounds in the adult lexicon was confirmed by Brown & McNeill (1966), Koriat & Lieblich (1974) and Rubin (1975) who observed that when trying to recall a word, on the tip-of-the-tongue, adults tended to recall words which shared the beginnings and, to a lesser extent, the endings of the target word. In reviewing the available evidence on developmental changes Aitchison (1994) concluded that from childhood there is a shift, with age, from lexical representations that are related to syllabic and/or rhythmic features to word-initial and -final features, with word-initial features being prominent in adulthood.

There is therefore a developmental relationship between lexical knowledge and phonology. As noted by Walley (1993), this relationship indicates that with vocabulary growth more fine-grained phonological units of representation may become necessary. This begs a question about whether phonology limits lexical size, or vice-versa. Dollaghan (1994) clearly suggested that children must have access to reasonably detailed phonological information in order to permit the growth of the lexicon.

It has however been suggested by Aslin & Smith (1988) and Walley (1988, 1993) that as more words are encountered, and therefore as the lexicon becomes larger, the child will need to add increasing phonological detail to lexical representations. This increasing phonological detail, they suggested, would enable the child to continue to differentiate between phonologically similar entries in the lexicon. Aitchison (1994) further suggested that as children learn to read, and are simultaneously acquiring a larger lexicon, there is a shift toward the more efficient adult strategy for storing and recalling words that uses word-initial sounds as the more important cue. It would be anticipated therefore that an association between vocabulary size and phonological skills might be found, and that over time the size of children's vocabulary predicts later awareness of initial phonemes. This possibility, and the reciprocal view that increasing phonological awareness facilitates the growth of the lexicon, is examined in §7.1.3.3.4.1.

An interesting complementary argument was put forward by Newport (1990) in discussing the maturational constraints on learning a hierarchically organised aspect of language. Newport (1990) reported that from studies of the acquisition of morphology in first and second language learning and from simulations she had conducted it seemed that there were advantages to begin learning at a young age. It appeared to be disadvantageous for a child to begin by storing whole words and most or all of their components of meaning and form. If, on the other hand due to "maturational constraints" (Newport, 1990, p22) learning started with exposure to a word and storage of only a limited number of its component features, the acquisition of knowledge about that aspect of the language was found to proceed more easily. In Newport's (1990) "Less is More" view (which she emphasised did not necessarily apply to all aspects of language learning) because of the restrictions on a child's perception and memory s/he would find it easier to perform certain linguistic analyses efficiently.

Newport (1990) did not discuss her proposals in terms of working memory components. In simulations which developed and extended Newport's (1990) speculations about initially constrained memory space, Elman (1993), however, considered the implications of "limited working memory" (*ibid*, p71) which it is possible to construe in terms of the central executive, as discussed in Chapter 6 (above). The work of Elman (1993) and Newport (1990) suggests that it would be appropriate to include a measure of processing space in the investigations reported here since it had been suggested by Elman (1993) and Newport (1990) that a network (simulating human learning) could make good progress in learning a task if in the initial phases of learning only a restricted subset of the full (adult) language is available for processing. Elman (1993) proposed that this restriction may be achieved by constraining the size of memory. These issues will be elaborated and explored in §7.2.2.2 (below).

In discussions of working memory and vocabulary there appears to be some controversy about the most appropriate measures of memory span. Gathercole, Willis, Emslie & Baddeley (1992) for instance used non-words as units in a measure of memory span. This type of measure has however been challenged by Snowling, Chiat & Hulme (1991) who suggested that the processes of phonological segmentation and assembly, and the issue of 'wordlikeness' which are all implicated in nonword repetition tasks are, in essence confounded variables. It is in Snowling *et al's* (1991) view, therefore, an oversimplification to interpret performance in nonword repetition as being simply a measure of 'memory'. Snowling *et al* (1991) offered an obverse argument to that of Gathercole, Willis, Emslie & Baddeley (1991,1992). The views of Snowling *et al* (1991) were that if children had better vocabulary knowledge they would be more likely to be able to cope with the totality of the demands of a nonword repetition test, including memory and phonological awareness.

In a prospective study of 5-year old children's ability to learn new words Michas & Henry (1994) overcame some of the methodological problems in Gathercole *et al*s (1992) investigations. Using a combination of Gathercole & Baddeley's (1989) non-word repetition test and a non-word memory span test with regression analysis Michas & Henry (1994) found evidence that 5-year-old children's phonological memory predicted their ability to learn new words. Michas & Henry (1994) addressed the points made by Snowling *et al* (1991) and in constructing the memory span test (from one-syllable non-words) considered that they had minimised, but not eliminated, the issues of phonological segmentation and articulation.

In this part of the present study it has, however, seemed more straightforward to continue to use the memory span measure that has been used throughout. This measure is thought to give some indication of central executive processes (§6.2.1.4). In examining the relationship between lexical knowledge (vocabulary) and memory span the number of items recalled in the memory span test will therefore be used as the simple indicator of processing space.

It has also been proposed above (§6.1.3.3.2) and by Brady (1991) that operational efficiency within constraints of memory span is an important factor in phonological processes. Gathercole & Baddeley (1993a) and Brady (1991) have suggested that increases in operational efficiency enhance available storage space. Brady's (1991) view was that memory is serviced by a system of limited capacity and that operations such as phonological encoding and retrieval become more efficient with experience. The proportion of operational resources that are required for short-term tasks may decrease with increased efficiency of processing, with a consequent increase in functional storage capacity. Increased storage space could be used for other purposes.

Gathercole & Baddeley (1993a) have suggested that in the light of findings by Hitch, Halliday & Littler (1989) increases in efficiency are likely to reflect central executive functioning. The central executive, it will be recalled, is believed to retrieve information from long-term memory, and to allocate material to the phonological loop. If, therefore, the central executive functions more efficiently, then a greater proportion of resources may be allocated to the storage and retrieval of memory items. The assumption here is that this subsumes the process of retrieval of lexical items from long-term memory.

In Chapter 5 it was shown that phonological awareness did not seem to derive clearly from perceptual knowledge of speech sounds. In this chapter it is thought to be important, therefore, to test an alternative view that linguistic knowledge might be a formative influence on phonological awareness. The children's scores in the test of vocabulary knowledge are first tested for age related increases and then to establish if increases in lexical knowledge were associated with increased phonological skills. As Michas & Henry (1994) also found that 'phonological memory' predicted the ability to learn words, in examining the effect of lexical knowledge on phonological awareness it has been thought appropriate to discriminate between the effects of memory and lexical knowledge. Therefore in this investigation the analyses will include both memory span and lexical knowledge as variables in regressions of phonological awareness.

Further tests of the relationship between lexical knowledge and phonological awareness are possible with the data available from the group of partially-hearing children. In §7.1.3.5 (below) comparisons are made between the partially-hearing children and the children with no hearing difficulties. The findings of Davis, Elfenbein, Schum & Bentler (1986) and Owrid (1970), indicate that children with partial-hearing would be likely to show poorer scores in tests of vocabulary knowledge than would be expected of children of their age. In the light of the findings of §4.3 (above) it has been possible to conduct a 'phonological age' match. In this comparison, as a further examination of the link between lexical knowledge and phonological awareness, the lexical knowledge of older children (the partially-hearing) with poor phonological awareness is compared with the lexical knowledge of younger (hearing) children with the same levels of phonological awareness.

In summary, in the first part of this chapter the main hypotheses to be examined are that lexical knowledge and phonological awareness are associated, with a shift from an association between lexical knowledge and awareness of rhymes to an association between lexical knowledge and initial phonemes.

7.1.2 Methodology

The data is drawn from the children involved in the main study. The measures used (described in more detail in Chapter 3) were those of nonverbal ability (Ravens matrices), phonological awareness (Rhyme and Initial Phoneme) and memory span that have been described earlier. Lexical knowledge (vocabulary size) was assessed using the British Picture Vocabulary Scale, short form (Dunn & Dunn, 1982).

7.1.3 Results

The means of raw scores (and standard deviations) obtained from each group are shown in Table 7.1.

Table 7.1: Means (and sd) of scores in Nonverbal ability (Rav), Phonological awareness (Rhy, IPh), Memory Span (MeS), Lexical Knowledge (BPVS) and Age for groups of children (n=15) aged 5-, 6-, and 7-years in '92 and '93, and combined groups (pooled scores, n=30)

	Rav	Rhy	IPh	MeS	BPVS	Age
R '92	15.5 (2.7)	4.9 (2.4)	3.9 (1.7)	3.6 (0.9)	10.9 (2.7)	58 (1.2)
R '93	12.3 (3.1)	4.5 (2.2)	3.7 (1.7)	3.2 (1.1)	8.7 (3.2)	56.5 (1.9)
R combined	13.9 (3.3)	4.67 (2.3)	3.8 (1.5)	3.4 (1.0)	9.83 (3.1)	57.3 (1.7)
Y1 '92	18.2 (4.2)	7 (1.6)	5.9 (2.0)	4.1 (1.7)	12.3 (2.7)	69.8 (1.6)
Y1 '93	15.9 (3.5)	6 (2.4)	5.3 (3.1)	4 (0.7)	10.5 (2.1)	69.8 (1.3)
Y1 combined	17.1 (4.0)	6.5 (2.1)	5.6 (2.6)	4.0 (1.2)	11.4 (2.6)	69.8 (1.4)
Y2 '92	19 (4.4)	6.9 (2.1)	6.9 (2.1)	5.5 (1.1)	13.6 (2.5)	81.9 (1.2)
Y2 '93	18.7 (5.3)	7.6 (1.6)	7.5 (2.1)	4.9 (1.4)	13.5 (3.5)	81.7 (1.7)
Y2 combined	18.9 (4.8)	7.27 (1.9)	7.2 (2.2)	5.2 (1.2)	13.5 (3.0)	81.8 (1.5)

7.1.3.1 *Data Screening and Treatment*

All variables in all groups were inspected for kurtosis and skew (see Appendix 2). Significant positive kurtosis and skew was found in the vocabulary scores obtained from 5-year old (R-group) children in '93. This variable was therefore transformed by taking natural logarithms of scores.

Although the combined Y1 (6-year-old) Memory span scores were found to have significant positive kurtosis (primarily due to the limited range of scores obtained from this group of children) it did not prove possible to effect a transformation of this variable that sufficiently reduces kurtosis without introducing other problems. This variable was therefore left untransformed. The scores for all other variables in all other groups were found to conform to reasonably normal distributions.

7.1.3.2 *Reliability*

Reliability coefficients for BPVS scores have been calculated using the Kuder-

Richardson formula cited by Anastasi (1968). These compare favourably with those obtained from the standardisation sample (Dunn & Dunn, 1982). The reliability coefficients obtained from the main study are shown below in Table 7.2.

Table 7.2: Reliability coefficients for BPVS scores

	r
R '92	0.82
R '93	0.87
Y1 '92	0.72
Y1 '93	0.63
Y2 '92	0.63
Y2 '93	0.81

7.1.3.3 *Analysis*

7.1.3.3.1 *Changes with age*

The differences in vocabulary knowledge between chidren of different ages were confirmed in each each sampling year by means of one-way anovas and post hoc Scheffé comparisons of pairs. The results of these analyses are shown in the following table (Table 7.3) which indicates that there were increases in lexical knowledge between children aged 5-years (R groups) and 7-years (Y2 groups).

Table 7.3: Analysis of between group changes (anova, post hoc Scheffé)

	Overall F	R vs. Y2	R vs. Y1	Y1 vs. Y2
BPVS '92 (n=15)	3.79*	3.79*	1.04ns	0.85ns
BPVS '93 (n=15)	9.60**	9.38*	1.26ns	3.77*
BPVS comb'd (n=30)	12.3**	12.2*	2.2ns	4.0*

*$p<0.05$; **$p<0.01$

The changes in BPVS scores between age groups are shown graphically below.

Fig 7.1a: BPVS changes with age for groups in '92

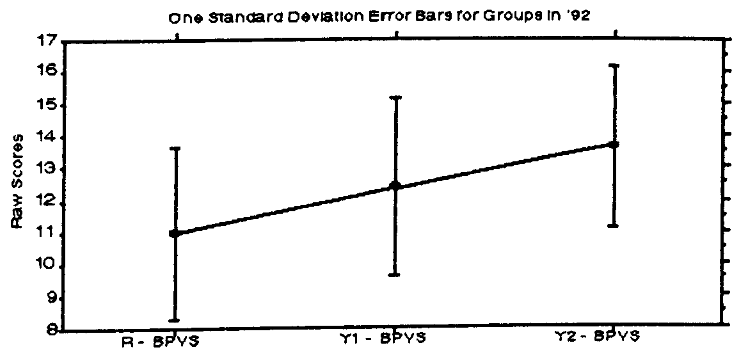


Fig 7.1b: BPVS changes with age for groups in '93

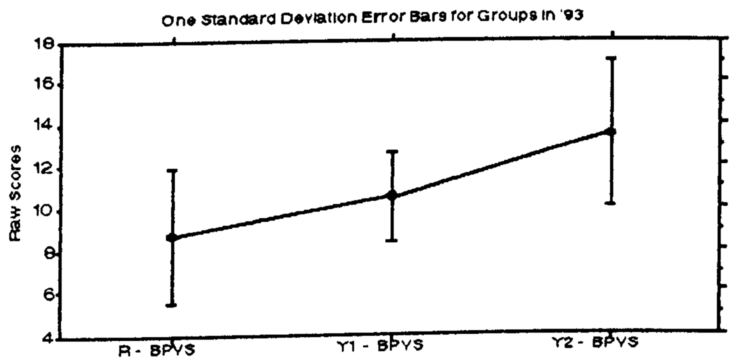
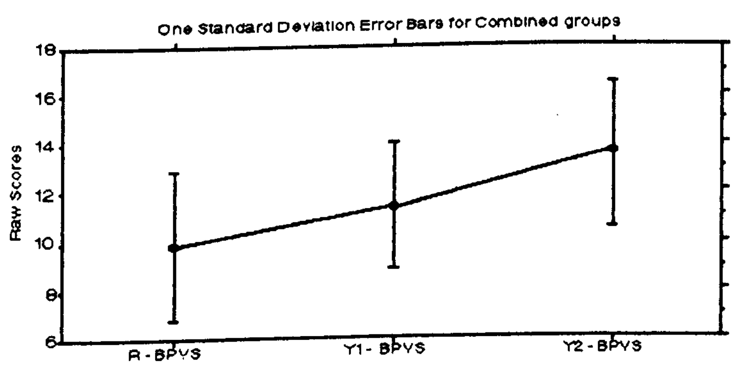


Fig 7.1c: BPVS changes with age for groups in '92 and '93 combined



7.1.3.3.2 *Associations between lexical knowledge and other variables*

In order to establish if there were associations between lexical knowledge and phonological awareness (as predicted by Dollaghan, 1994) Pearson correlations between variables were computed within the samples of 45 children, ie the total groups in '92 and '93. For these groups hierarchical regressions of phonological awareness scores onto lexical knowledge were subsequently performed with prior entry of Age, Raven's matrices (non-verbal ability) and memory span. The results of those analyses are shown in tables 7.5 and 7.6 below.

Table 7.4a: Correlation coefficients between Vocabulary (BPVS), Phonological awareness (Rhy, IPh), Memory Span (MeS), Nonverbal ability (Rav) and Age in '92 (n=45)

	BPVS	Rhy	IPh	MeS	Rav
BPVS	1				
Rhy	0.482**	1			
IPh	0.551**	0.738**	1		
MeS	0.237ns	0.29ns	0.484**	1	
Rav	0.394**	0.275ns	0.398**	0.251ns	1
Age	0.406**	0.359*	0.538**	0.533**	0.39**

*p<0.05;**p<0.01

Table 7.4b: Correlation coefficients between Vocabulary (BPVS), Phonological awareness (Rhy, IPh), Memory Span (MeS), Nonverbal ability (Rav) and Age in '93 (n=45)

	BPVS	Rhy	IPh	MeS	Rav
BPVS	1				
Rhy†	0.382**	1			
IPh†	0.623**	0.701**	1		
MeS	0.428**	0.498**	0.566**	1	
Rav	0.512**	0.37*	0.45*	0.339*	1
Age	0.567**	0.535**	0.585**	0.575**	0.578**

*p<0.05;**p<0.01; † These variables transformed - see §7.1.3.1

Table 7.5: Hierarchical regressions of phonological awareness (Rhy, IPh) onto lexical knowledge (BPVS scores) with prior control for Age, nonverbal ability (Rav) and memory span (MeS) for combined age groups (n=45) in '92 and '93

'92			'93	
DV=Rhy	Adj R2	F to enter	Adj R2	F to enter
Age	0.109		0.269	
Rav	0.11	1.07ns	0.258	0.33ns
MeS	0.101	0.58ns	0.298	3.40*
BPVS	0.205	6.35**	0.282	0.11ns
DV=IPh				
Age	0.273		0.327	
Rav	0.299	2.61ns	0.331	1.23ns
MeS	0.335	3.28*	0.398	5.69**
BPVS	0.429	7.76**	0.475	7.02**

*p<0.05;**p<0.01

The regression analyses indicate that once variance in phonological awareness scores due to variance in age, nonverbal ability and memory span was removed a significant contribution to phonological awareness was likely to have been made by lexical knowledge. For awareness of initial phonemes this association was replicated in both samples.

7.1.3.3.3 *The unique contribution of lexical knowledge to phonological awareness*

The next stage in the examination of the hypothesis that increased lexical knowledge might enhance or enforce increased phonological awareness was to repeat the above analyses by performing hierarchical regressions of Phonological awareness scores onto nonverbal reasoning (Ravens), Memory Span (to discount any variance due to size of processing space) and finally vocabulary scores (BPVS) obtained from each age group.

With this number of independent variables there would be barely enough cases in groups of 15 to satisfy the recommended minimum ratio of cases to variables for hierarchical regression (Tabachnick & Fidell, 1989). As spurious significance could result from having too many variables, a more statistically robust investigation, though without the benefits of replication was undertaken with the larger groups (n=30) formed by collapsing both groups at each age. The results of these analyses are presented below.

Pearson correlations between variables were first computed for variables within each age group. These are shown in the following tables.

Table 7.6a: Coefficients of correlation between 5-year-old (R-group) children's scores in Phonological awareness (Rhy, IPh), Memory Span (MeS), Vocabulary (BPVS), Nonverbal ability (Rav) and Age (combined group, n=30)

Comb'd	Rhy	IPh	MeS	BPVS	Rav
Rhy	1				
IPh	0.759**	1			
MeS	0.306ns	0.342ns	1		
BPVS	0.391*	0.505**	0.021ns	1	
Rav	0.124ns	0.01ns	0.123ns	0.471**	1
Age	0.006ns	0.207ns	0.569*	0.155ns	0.191ns

*p<0.05; **p<0.01

Table 7.6b: Coefficients of correlation between 6-year-old (Y1-group) children's scores in Phonological awareness (Rhy, IPh), Memory Span (MeS), Vocabulary (BPVS), Nonverbal ability (Rav) and Age (combined group, n=30)

Comb'd	Rhy	IPh	MeS	BPVS	Rav
Rhy	1				
IPh	0.486**	1			
MeS	0.1ns	0.228ns	1		
BPVS	0.166ns	0.475**	-0.004ns	1	
Rav	0.188ns	0.422*	0.069ns	0.453*	1
Age	0.024ns	0.167ns	-0.135ns	0.308ns	0.301ns

*p<0.05; **p<0.01

Table 7.6c: Coefficients of correlation between 7-year-old (Y2-group) children's scores in Phonological awareness (Rhy, IPh), Memory Span (MeS), Vocabulary (BPVS), Nonverbal ability (Rav) and Age (combined group, n=30)

Comb'd	Rhy	IPh	MeS	BPVS	Rav
Rhy	1				
IPh	0.781**	1			
MeS	0.255ns	0.438**	1		
BPVS	0.242ns	0.428*	0.341ns	1	
Rav	0.145ns	0.166ns	0.115ns	0.22ns	1
Age	-0.027ns	0.144ns	0.141ns	0.228ns	0.427*

*p<0.05; **p<0.01

Table 7.7: Regression of Phonological awareness (Rhy, IPh) onto lexical knowledge (BPVS), with prior control for nonverbal ability (Rav) and memory span (MeS) for combined (n=30) groups

	R		Y1		Y2	
DV=Rhy						
	Adj-R2	F-to-enter	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Rav	-0.02		0.001		-0.01	
MeS	0.035	2.59ns	-0.03	0.21ns	0.01	1.69ns
BPVS	0.167	5.29**	-0.06	0.24ns	-0.004	0.61ns
DV=IPh						
	Adj-R2	F-to-enter	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Rav	-0.04		0.148		-0.007	
MeS	0.053	3.62*	0.16	1.38ns	0.147	6.05**
BPVS	0.394	16.2**	0.247	4.12*	0.201	2.82ns

*p<0.05; **p<0.01

This analysis of the scores from the groups of 30 children indicates that increased lexical size may be associated with heightened levels of phonological awareness (both rhyme and initial phoneme) at age 5-years. No association between awareness of rhymes and lexical knowledge is apparent amongst the older children. It appeared that lexical knowledge predicted initial phoneme awareness scores in the group of 6-year-old children. However it also appears from the fading proportion of shared variance (Adjusted R^2) that the association between lexical knowledge and awareness of initial phonemes decreases with age. With respect to the apparently significant regression of IPh scores obtained from 5-year-old children (R group) it must be recalled that IPh scores obtained from these (youngest) children showed very low reliability coefficients (see Chapter 4). It is possible therefore that the apparent association between IPh scores and DVs is a consequence of measurement error. That an association between lexical knowledge and awareness of initial phonemes exists however seems reasonable given the additional finding of a statistical relationship in Y1.

It seems possible therefore that there is an association between phonological awareness (Rhyme) and lexical knowledge (BPVS) amongst the 5-year old children that is greater than might be expected by chance, and associations between lexical knowledge and phonological awareness (Initial Phonemes) in both 5- and 6-year-old children.

7.1.3.3.4 *The developmental order of precedence*

The nature of the question under investigation, however, also requires a developmental investigation in order to establish if, over time, vocabulary was associated with later levels of phonological awareness, or vice-versa. This could be explored within the present study using the data available on children tested on both occasions, separated by 12 months. This was done using a similar hierarchical regression technique but entering the earlier scores in phonological awareness as one of the independent variables. This procedure was adopted in order to remove the effect of the phonological variable before testing if any variance in lexical knowledge at Time 1 was associated with variance in phonological awareness at Time 2.

7.1.3.3.4.1 *Data screening and treatment*

With this number of variables however the risks of using too small a sample size were again encountered. The risk of entering a large number of variables in a regression is that all variance is apparently accounted for, and thus of obtaining a solution that completely predicts the DV. The data from the group of 24 children who were tested on both occasions has, therefore, been used again. This group consisted of 13 who were in the R (5-year old) group in 1992 (T1) and 11 children who were in the Y1 (6-year old) group in 1993 (T1). The data for this group is shown in tables below. Table 7.8 (below) shows means (and sds) for the children's scores in variables at T1 and at T2.

On inspection of coefficients of kurtosis and skew it was found that non-verbal ability and memory span at T1 both exhibited significant departures from normality. This was corrected by the use of the natural logarithm transformation of these two variables.

An anticipated weakness was not however encountered. It has been recognised (see Chapter 4) that scores in the test of initial phoneme awareness obtained from the two groups of 5-year old children (R groups) did not demonstrate reasonable levels of reliability. Unreliability is a measure of error variance, and unreliable variables may appear to be spuriously associated (Tabachnick & Fidell, 1989). The reliability coefficients (Kuder-Richardson, cited by Anastasi, 1968) for IPh for the children comprising this longitudinal survey were therefore computed. It was found that at T1 r_{11}=0.53, and at T2 r_{11}=0.79 which are of sufficient magnitude to justify confident inclusion of the variables in the ensuing analysis.

7.1.3.3.4.2 *Results and analysis*

Table 7.8: Mean (and sd) of raw scores in Nonverbal ability (Rav), Memory Span (MeS), Lexical Knowledge (BPVS), Phonological Awareness (Rhy, IPh) and Age for longitudinal group at T1 and T2. (n=24)

	T1	**T2**
	Mean(sd)	**Mean(sd)**
Rav	16.92 (4.00)	17.13 (4.64)
MeS	3.92 (1.25)	4.63 (1.25)
BPVS	11.58 (2.69)	11.71 (2.71)
Rhy	6.04 (2.37)	6.75 (2.4)
IPh	5.25 (2.13)	6.58 (2.83)
Age	63.25 (6.24)	75.3 (6.24)

It can be seen that within this longitudinal group there was no appreciable difference between scores in BPVS at T1 and T2. It is not possible therefore to make any inferences relating to changes in lexical knowledge over time within this group. The phonological awareness variables at T1 and T2 also do not show substantial differences over time. These non-significant differences clearly impose limitations on the possibility of valid inferences.

In order to provide statistical control for the heterogeneity of the children's ages in the regression Age should be entered in the regression. However for a group of 24 children the maximum number of variables that can be used without violating the variables:cases ratio as stipulated by Tabachnick & Fidell (1989) would be four. Therefore two sets of hierarchical regressions of phonological awareness variables were performed with either Age or Ravens matrices scores as the first IV to be entered. Bivariate correlation coefficients for the variables to be used are shown in Table 7.9, and the results of the hierarchical regressions of phonological awareness scores are shown in Table 7.10.

Table 7.9: Correlation coefficients for variables at T1 and T2

	1	2	3	4	5	6	7	8
1.Rhy1	1							
2.Rhy2	.721**	1						
3.IPh1	.678**	.71**	1					
4.IPh2	.711**	.714**	.653**	1				
5.ln(MeS1)	.413*	.327ns	.482*	.52**	1			
6.BPVS1	.379ns	.449*	.558**	.497*	-.076ns	1		
7.BPVS2	.293ns	.229ns	.653**	.505*	.481*	0.425*	.363ns	.354ns
8.ln(Rav1)	.294ns	.324ns	.477*	.304ns	.181ns	.64**	1	.4ns
9.Age1	.464*	.414*	.659**	.342ns	.394ns	.175ns	.4ns	1

*p<0.05; **p<0.01

Table 7.10a: Hierarchical regressions of rhyme awareness (Rhy2) at T2 onto lexical knowledge (BPVS1) at T1 with prior control for nonverbal ability (Rav1), or Age, preexisting phonological awareness (Rhy1) and memory span (MeS1) (n=24)

DV= Rhy 2		
	Adj-R2	F to enter
Rav 1†	0.071	
Rhy 1	0.492	19.2**
MeS 1†	0.469	0.1ns
BPVS 1	0.463	0.78ns
DV=Rhy 2		
	Adj-R2	F to enter
Age1	0.134	
Rhy 1	0.483	15.9**
MeS 1†	0.461	0.14ns
BPVS 1	0.472	1.43ns

**p<0.01; † transformed variables - see §7.1.3.3.4.1

Table 7.10b: Hierarchical regressions of initial phoneme awareness (IPh2) at T2 onto lexical knowledge (BPVS1) at T1 with prior control for nonverbal ability (Rav1), or Age, preexisting phonological awareness (IPh1) and memory span (MeS1) (n=24)

DV=IPh 2		
	Adj-R2	F to enter
Rav 1†	0.049	
IPh 1	0.372	12.32**
MeS 1†	0.409	2.34ns
BPVS 1	0.526	5.91**
DV=IPh 2		
	Adj-R2	F to enter
Age1	0.077	
IPh 1	0.387	12.14**
MeS 1†	0.432	2.65ns
BPVS 1	0.494	3.44*

*p<0.05; **p<0.01; † transformed variables - see §7.1.3.3.4.1

This suggests that phonological awareness at T1 was a significant predictor of phonological awareness at T2. However with respect to the issue of whether better lexical knowledge at T1 was associated with heightened phonological awareness at T2, (according to the views summarised by Aitchison, 1994) there appear to be differences between the relationship with the two measures of phonological awareness. Thus it is possible that lexical knowledge at T1 was predictive of awareness of Initial Phonemes at T2 when variance due to either age or non-verbal ability, and initial awareness scores had been discounted. It does not seem that there is a similar effect in relation to awareness of rhymes.

A test of the reciprocal causal hypothesis is also justified since the speculations of Dollaghan (1994) were that increasing lexical size would require greater phonological detail in order to support the differentiation of an increasing number of phonologically similar items in the lexicon. Thus it is possible that in order to achieve an increase in the size of the lexicon a child would first have to have adequate phonological skills to distinguish between items with phonologically similar representations. If this were to be the case it would be expected that phonological skills that exist at T1 would be significant predictors of lexical knowledge at T2.

The procedure adopted therefore was to regress vocabulary scores at T2 onto measures taken at T1, the critical, and last IV to be entered in the regression being phonological awareness scores. Clearly if any effect on later vocabulary scores were to be detected it would be necessary to have first eliminated the effects of earlier vocabulary knowledge (BPVS1). It is recognised that the actual data used does not have significantly different mean BPVS scores at T1 and T2. BPVS1 was nonetheless entered following non-verbal ability scores, or Age taken at T1. Memory span scores at T1 were also entered in an attempt to dissociate memory and phonological influences. Once again in order to preserve an acceptable ratio of variables:cases two sets of regressions have been undertaken. In the first Age is entered as the first IV, and in the second set of regressions Ravens matrices scores (transformed) was the first IV entered in the regression.

Table 7.11a: Hierarchical regression of Lexical knowledge (BPVS 2) onto phonological awareness scores (Rhy1 or IPh1) taken 12 months earlier with statistical control for preexisting nonverbal ability (Rav1), lexical knowledge (BPVS1) and memory span MeS1)

DV = BPVS2		
	Adj-R2	F-to-enter
Rav1†	0.024	
BPVS1	0.102	2.92ns
MeS1†	0.394	11.12**
4th IV to be entered either		
Rhy1	0.388	0.79ns
or		
IPh1	0.416	1.75ns

**p<0.01; † transformed variables - see §7.1.3.3.4.1

Table 7.11b: Hierarchical regression of Lexical knowledge (BPVS 2) onto phonological awareness scores (Rhy1 or IPh1) taken 12 months earlier with statistical control for Age, preexisting lexical knowledge (BPVS1) and memory span (MeS1)

DV = BPVS2		
	Adj-R2	F-to-enter
Age	0.086	
BPVS1	0.191	3.86*
MeS1†	0.372	7.07**
4th IV to be entered either		
Rhy1	0.372	0.98ns
or		
IPh1	0.395	1.76ns

*$p<0.05$;**$p<0.01$; † transformed variable - see §7.1.3.3.4.1

These results show that phonological awareness (of either type) did not make a significant contribution to vocabulary scores once the effects of earlier vocabulary knowledge and memory span had been taken into account. However it is evident that memory span at T1 was a significant developmental antecedent for later vocabulary scores. This point will be developed in §7.2 (below).

7.1.3.4 *Summary*

From the results of the regressions reported in Table 7.5 and 7.7 it seems that for the children who participated in these investigations knowledge of vocabulary may have been associated with phonological awareness. This was evident amongst children at the start of their formal education (aged approximately 5-years) where both rhyme and initial phoneme awareness appear to have been associated with vocabulary scores, and at age 6-years (after a year of formal education) when awareness of initial phonemes was found to be associated with vocabulary. This is in line with evidence summarised by Aitchison (1994), that there is a trend with age toward phonological representations in the lexicon that are increasingly strongly related to word-initial sounds.

Longitudinally it seems likely that children's knowledge of words at the ages of 5- or 6-years may be associated with higher levels of phonological awareness (of word-initial sounds) a year later. It can also be seen that the reciprocal route of causation suggested by Dollaghan (1994), that in order to achieve growth in the lexicon children would need to have reasonable phonological skills, was not supported by the evidence available here, in that phonological awareness at T1 was not associated with lexical knowledge at T2. On this basis it might be concluded that phonological awareness is not a necessary precursor of later lexical knowledge. However for methodological reasons due to the size and composition of the group a causal relationship in this direction cannot be confidently eliminated.

However, with respect to the suggestions of Aitchison (1994), Aslin & Smith (1988) and Walley (1993) that in response to the increasing need to distinguish between words children would develop greater phonological skills to discriminate between phonologically similar representations in the lexicon, it seems that for the children in this study lexical knowledge predicted later awareness of initial phonemes. This would imply that for these (hearing) children, as they encountered new words their phonological representations of words became clearer, and in particular they acquired greater skill in detecting differences between word-initial sounds.

A contrasting situation was however discovered on examining the data available from the group of partially hearing children who were studied.

7.1.3.5 *Partially hearing children, lexical knowledge and phonological awareness*

As was discussed in Chapter 1 the evidence of studies such as those carried out by Davis, Elfenbein, Schum & Bentler (1986) and Owrid (1970) suggests that hearing-impaired children do not develop lexical knowledge as well as children with no hearing difficulties.

It has already been shown in §4.3 (Table 4.26) that the group of children in this study with partial-hearing showed levels of phonological awareness below those found in normally hearing children of the same age. It is of interest therefore to see if the partially-hearing children who participated in this present research would also show depressed scores in the test of lexical knowledge, and how their lexical knowledge might relate to phonological awareness test scores.

Critically for the issues under investigation in this chapter, as can also be seen in

Table 7.13 (below), this group of partially-hearing children (aged 7-years) did show low scores in vocabulary as compared to children of their own age who had no hearing difficulties, but also performed significantly less well in this measure of vocabulary than the children (aged 6-years) with no hearing difficulties who had similar levels of phonological awareness.

This observation affords a further test of the findings (above) that lexical knowledge was associated with the development of phonological awareness. Accordingly the data obtained from the 15, 7-year old partially-hearing children was analysed in the same way that was used above (§7.1.3.3.3), using hierarchical regression of phonological awareness scores onto non-verbal ability (Raven's matrices), memory span and finally vocabulary (BPVS) scores. It was not necessary to enter age as a variable since the group was homogeneous in this respect. The means (and sds) are shown in Table 7.12 and correlations of variables in Table 7.14. In Table 7.13 the partially-hearing children's scores in phonological awareness (Rhy, IPh), memory span (MeS), lexical knowledge (BPVS), nonverbal abilities (Rav) and Age are compared with the groups of hearing children aged 5-, 6- and 7-years.

7.1.3.5.1 *Data screening*

The data from the partially-hearing children was inspected for kurtosis and skew and for all variables found to lie within reasonable limits of normality.

7.1.3.5.2 *Results and analysis*

Table 7.12: Descriptive statistics for Partially-Hearing sample of 7-year-old children (n=15)

	Mean	sd
Rhy	6.2	1.6
IPh	6.2	2.4
MeS	4.33	1.05
BPVS	9.67	2.38
Rav	17.07	3.41
Age	82.7	4.83

Table 7.13: Means (sd) and Mann-Whitney comparisons (z) for 15 partially-hearing (P-H) and 30 normally hearing children

	Rhy	IPh	MeS	BPVS	Rav	Age
P-H n=15	6.2 (1.6)	6.2 (2.4)	4.3 (1.1)	9.67 (2.4)	17.07 (3.4)	82.7 (4.8)
Y2 hearing n=30	7.3 (1.9)	7.2 (2.2)	5.2 (1.2)	13.5 (3.0)	18.9 (4.8)	81.8 (1.5)
Y1 hearing n=30	6.5 (2.1)	5.6 (2.6)	4.0 (1.2)	11.4 (2.6)	17.1 (4.0)	69.8 (1.4)
R hearing n=30	4.7 (2.3)	3.8 (1.5)	3.4 (1.0)	9.8 (3.1)	13.9 (3.3)	52.3 (1.7)
z: P-H vs. Y2	-2.03*	-1.40ns	-2.18*	-3.69**	-1.22ns	1.13ns
z: P-H vs. Y1	-.67ns	-.78ns	-.75ns	-1.93*	-.09ns	-5.43**
z: P-H vs. R	-2.47*	-3.29**	-2.55**	-.12ns	-2.68**	-5.45**

*p<0.05; **p<0.01

From this it can be seen that the hearing-impaired children's performance in the measures of phonological awareness and memory was comparable to the performance of the 30 normally hearing children aged 6 years. The non-verbal ability scores for the P-H group are close to those of the unimpaired 6-year old child, but also statistically not significantly different from the 7-year old hearing children. The P-H children's lexical knowledge (BPVS) is however closest to the scores of the 5-year old hearing children.

Table 7.14: Coefficients of correlation. Hearing-Impaired sample (n=15)

P-H: n=15	Rhy	IPh	MeS	BPVS	Rav
Rhy	1				
IPh	-.381ns	1			
MeS	.0ns	.427ns	1		
BPVS	.484ns	.376ns	.335ns	1	
Rav	-.158ns	-.142ns	-.527*	.1ns	1
Age	.237ns	.165ns	-.024ns	.197ns	-.194ns

*p<0.05

Table 7.15: Hierarchical regression of Phonological Awareness onto Ravens, Memory Span and Vocabulary scores for Partially hearing group (n=15)

DV=Rhy		
	Adj-R2	F-to-enter
Rav	-0.05	
MeS	-0.126	0.12ns
BPVS	0.253	7.1**
DV=IPh		
	Adj-R2	F-to-enter
Rav	-0.055	
MeS	0.058	2.56ns
BPVS	0.037	.75ns

**p<0.01

7.1.3.5.3 *Conclusion*

It appears that lexical knowledge was predictive of these partially-hearing children's awareness of rhyme, but not of their awareness of Initial Phonemes. It could be anticipated that initial consonants, which typically have acoustic parameters with higher frequencies than vowels, should be found to be harder to discriminate than rhyme sounds (which typically have lower frequency vocalic nuclei) by many children with impaired hearing. It will be recalled that these partially-hearing children typically showed 'ski-slope' audiometric profiles (for details see Chapter 3 and Appendix 3). Thus they would be likely as a group to have greater difficulty with perception of consonants than vowels. In general their categorical speech perception (see Chapter 4) was found to be significantly poorer than other children of their age.

The fact that these partially-hearing children's lexicons were found to be more closely related to their awareness of rhymes than to their awareness of initial phonemes therefore might be due to the greater ease of perception of the vocalic nuclei of rhymes. For the partially-hearing children initial phonemes might also not have such stable or well established phonological representations as would be expected at their chronological age.

However it will be recalled that for children without hearing difficulties (Table 7.7) it appeared that for 5-year-old children there was an association between rhyme awareness and lexical knowledge. As has already been noted the partially-hearing children who participated in this research were found to have lexical knowledge comparable to the hearing children aged 5-years. Therefore it may be that, as noted by Vihman (1981), the lexicon at a 5-year-old age equivalent level is in some way structured on phonological representations associated with children's awareness of syllables and the sounds at the end of words- ie rhymes.

7.1.4 Conclusion

Overall it has been demonstrated that there were significant increases in lexical knowledge across ages in the hearing sample, as should be expected with such a standardised measure. The increases in vocabulary across age groups was found to make a significant contribution to phonological awareness scores. On more detailed examination of the scores from children at each age it was found that it was only amongst 5-year-old children that there was an association between lexical knowledge and awareness of rhymes, but that there was an apparently stronger association between lexical knowledge and awareness of initial phonemes that was significantly evident at age 5- and 6-years.

In Table 7.13 it can be seen that the 7-year old partially-hearing children were functioning in the test of Rhyme awareness at similar levels to the Y1 (6-year old) hearing children. In terms of lexical knowledge, however, the partially-hearing children did not achieve scores comparable to the 6-year old children without hearing difficulties, but were more like 5-year old children without hearing difficulties. Thus it is possible to make a comparison of older children (who have poorer phonological skills than another group of children of the same age) with younger children (who have comparable phonological skills) and it can be seen that the older group of children have even poorer lexical knowledge than the younger children. This 'phonological age' match adds some confirmation to the view that lexical knowledge is important in acquiring phonological awareness.

It appears that lexical knowledge at a certain stage is likely to be particularly associated with children's awareness of rhymes. It may be recalled that Vihman (1981) suggested that syllabic stress and word-endings were more likely than word-initial sounds to be salient phonological features in a child's lexicon.

An overall conclusion that might be offered at this stage is that the lexicons of the youngest children in this study had some structural phonological associations that were more likely to depend on rhyme features. Developmentally, however, it would seem that the demands of increasing the size of the lexicon was more likely to facilitate increased awareness of word-initial phonemes. It is possible that this could arise because for children without hearing difficulties word-initial sounds have great acoustic and temporal salience, as discussed by Walley (1993). These children's experience with new word items for lexical storage might have been closely linked to the temporally, acoustically and phonologically initial cues. However the children's word recognition processes may, as Aitchison (1994) suggests, be related to the start of formal instruction in reading. In this respect it is notable that for the 5-year-old children in this study lexical knowledge was associated with awareness of both rhyme and initial phonemes. Rhyme awareness was not associated with lexical knowledge at age 6- or 7-years and, over the space of a year, awareness of initial phonemes was predicted by lexical knowledge at the beginning of the year, suggesting that children with the largest lexicons at the start of the year were most likely to have developed higher scores in terms of awareness of initial phonemes. It also seems likely that in their instruction in reading children will be required to attend to stressed items (and word-initial sounds are stressed by many teachers of reading), and, Gleitman & Wanner (1982) note, there is evidence that suggests that children are more sensitive to stressed components, and learn these cues more rapidly than unstressed cues.

There are also issues (not fully explored in this thesis) to do with children's increasing ability to segment and manipulate the constituent sounds within words. Thus it is conceivable that the association between lexical knowledge and awareness of rhymes is a residue of earlier developmental stages. As Locke (1988) discussed, there is a stage (put conservatively at between 3 to 4 years) when a child begins to separate meaning from form and begins to handle words as physical entities.

Evidence of a different kind, but none-the-less pointing in a similar direction, comes from a study by Vihman & Miller (1988) in which infants' vocalisations were analysed. In that study it seems that during an early stage of communicational development (4 to

15 word utterances) there was a clear shift from a higher proportion of utterances containing no true consonants to a higher proportion of utterances which contained consonants.

However in terms of word recognition processes there may also be a tension between the temporal salience of word-initial sounds and the acoustic salience of syllables and their vocalic nuclei. Thus, as discussed by Jusczyk (1986), words that share common initial phonemes would be expected to be placed close to each other in the lexicon but because of the burgeoning number of words that would share that common initial phoneme a pressure would exist to further segment perceptual units. The evidence of this study (see also chapter 4) suggests that perceptual and phonological development might have proceeded in the opposite order in the children who were involved in this study. Thus it seems here that awareness of rhymes preceded awareness of initial phonemes. In terms of the relationship with lexical knowledge it also seems from examination of the hearing and partially-hearing children's scores that at around the age of 5-years lexical representations are associated with phonological information at the level of the rhyme, whereas with age there is a shift toward associations between lexical knowledge and phonological information at the more precisely segmented level of the initial phoneme. This order of development would also follow from the views of Vihman (1981) who suggested that syllabic stress and word-final sounds, in young children, had greater lexical salience than word-initial sounds.

7.2 The relationship between memory, lexical knowledge and phonological awareness

The analyses reported in this section are designed to consider how memory and lexical knowledge might inter-relate to enhance the development of phonological awareness.

7.2.1 Introduction

As already noted in Chapter 6 it appears that memory may make a significant contribution to performance in the measures of phonological awareness. From the analysis reported earlier in this chapter (Table 7.7) it is evident that for the 5-year-old children memory span and vocabulary were both implicated in performance in the test of Initial Phoneme awareness. The first part of this section will consider this relationship, and that between memory, vocabulary and rhyme awareness, in more detail. The second part relates to restrictions of memory span and the possible advantages this might confer on a child learning about words and phonology.

As indicated by Brady (1991) and Gathercole & Baddeley (1993a) encoding and retrieval operations within memory become more efficient with age. The work on phonological awareness reviewed by Fowler (1991) showed that measures in that domain are indicative of children's encoding skills. In Chapter 6 it was proposed that the measure of memory span gave some indication of the efficiency of the central executive of the working memory model. It is also thought (see Gathercole & Baddeley (1993a) that the central executive is functional in transfer and retrieval operations with respect to long-term storage, such as the lexicon.

In a previous section (§7.1.3) it was shown, in support of the conjectures of Aitchison (1994), Aslin & Smith (1988) and Walley (1993), that increased lexical knowledge seemed to promote greater awareness of word-initial sounds in order that children can distinguish between increasing numbers of lexical items. Gathercole & Baddeley (1993a) reviewed evidence which supported the idea that aspects of working memory may have a significant role in the acquisition of vocabulary, and, see Table 7.11, evidence has been presented in this study in support of that conjecture. Gathercole & Baddeley (1993a) also drew attention to evidence that indicates that the contribution of memory to the acquisition of vocabulary is most important at around the age of 5-years, and that there seems to be a change in the nature of vocabulary learning after that age.

On the basis of the following argument it is also possible that an interaction might be found between the role of increasing lexical knowledge, phonological skills and memory. Increasing memory span is, as indicated by Gathercole & Baddeley (1993a), associated with increased lexical knowledge, particularly at around age 5-years, and increased lexical knowledge facilitates the development of certain phonological skills (Aitchison, 1994, and others). In Chapter 6 the relationship between aspects of memory and phonological awareness was also discussed, with some evidence (see §6.1.2.3.2) presented in support of views put forward by Fowler (1988), Gathercole, Willis & Baddeley (1991b) and Mann & Liberman (1984) that memory and phonological awareness might be associated. It is therefore proposed that it might be possible to detect an interaction between vocabulary and memory span in the prediction of phonological skills.

One possibility, on the basis of what has been found so far in respect of the increasing salience of word-initial sounds within the lexicon (Aitchison,1994; Aslin & Smith,1988; and Walley,1993), is that it would be more likely, if this interaction exists, for it to be found in regressions of initial phoneme awareness than in regressions of rhyme awareness. On the other hand, Gathercole, Willis & Baddeley (1991b) have reported that at age 5-years there was a significant relationship between memory span and awareness of rhymes. Gathercole & Baddeley (1993a) also indicated that at around 5-years memory played a significant role in the development of vocabulary. On the basis of this latter evidence an alternative prediction would be for the interaction between memory span and lexical knowledge to be more likely in younger children, and in relation to rhyme awareness. These two alternatives are evaluated in the following section.

7.2.2 <u>Analyses</u>

7.2.2.1 *Do memory span and lexical knowledge interact ?*

In order to investigate this possibility amongst the groups of children aged 5-, 6-, and 7-years, hierarchical regressions were planned following the procedure outlined by Cohen & Cohen (1983) and Jaccard, Turrisi & Wan (1990) for treatment of interaction terms in regression analysis. In order to check if memory span and lexical knowledge interacted in predicting either of the measures of phonological awareness, the measure of phonological awareness (Rhyme or Initial Phonemes) was regressed onto non-verbal ability scores, vocabulary scores (BPVS), memory span (MeS), followed by the interaction of memory span and vocabulary scores formed by the product MeS x BPVS.

The descriptive statistics (means, standard deviations and correlation matrices) for the data from each group (of 30) children aged 5-, 6-, and 7-years are shown below in Table 7.16. As before the data was screened for skew and kurtosis and the distributions of scores was found to conform to reasonable limits in all cases.

Table 7.16a: Means (and standard deviations) for 5-, 6- and 7-year-old children's scores in Rhyme awareness (Rhy), Initial Phoneme awareness (IPh), Vocabulary (BPVS), memory span (MeS), interaction of vocabulary and memory span (BPVS x MeS), non-verbal ability (Rav), and age. (n=30)

	Rhy	IPh	BPVS	MeS	BPVS x MeS	Rav	Age
R-group	4.7 (2.3)	3.8 (1.5)	3.4 (1.0)	9.8 (3.1)	33.5 (15.3)	13.9 (3.3)	52.3 (1.7)
Y1-group	6.5 (2.1)	5.6 (2.6)	4.0 (1.2)	11.4 (2.6)	46.0 (17.2)	17.1 (4.0)	69.8 (1.4)
Y2-group	7.3 (1.9)	7.2 (2.2)	5.2 (1.2)	13.5 (3.0)	71.6 (25.3)	18.9 (4.8)	81.8 (1.5)

Table 7.16b: Correlation Coefficients for 5-year-old (R-group) children scores in Rhyme awareness (Rhy), Initial Phoneme awareness (IPh), Vocabulary (BPVS), memory span (MeS), interaction of vocabulary and memory span (BPVS x MeS), and non-verbal ability (Rav)

	1	2	3	4	5	6
1. Rhy	1					
2. IPh	0.759**	1				
3. BPVS	0.391*	0.505**	1			
4. MeS	0.306ns	0.342ns	0.021ns	1		
5. BPVS x MeS	0.536**	0.612**	0.66**	0.728**	1	
6. Rav	0.124ns	0.01ns	0.472**	0.123ns	0.423*	1

** $p<0.01$; * $p<0.05$

Table 7.16c: Correlation Coefficients for 6-year-old (Y1-group) children scores in Rhyme awareness (Rhy), Initial Phoneme awareness (IPh), Vocabulary (BPVS), memory span (MeS), interaction of vocabulary and memory span (BPVS x MeS), and non-verbal ability (Rav)

	1	2	3	4	5	6
1. Rhy	1					
2. IPh	0.486**	1				
3. BPVS	0.166ns	0.475**	1			
4. MeS	0.1ns	0.228ns	-0.004ns	1		
5. BPVS x MeS	0.179ns	0.486**	0.686**	0.707**	1	
6. Rav	0.188ns	0.422*	0.453*	0.069ns	0.377*	1

** $p<0.01$; * $p<0.05$

Table 7.16d: Correlation Coefficients for 5-year-old (R-group) children scores in Rhyme awareness (Rhy), Initial Phoneme awareness (IPh), Vocabulary (BPVS), memory span (MeS), interaction of vocabulary and memory span (BPVS x MeS), and non-verbal ability (Rav)

	1	2	3	4	5	6
1. Rhy	1					
2. IPh	0.781**	1				
3. BPVS	0.242ns	0.428*	1			
4. MeS	0.255ns	0.438*	0.341ns	1		
5. BPVS x MeS	0.325ns	0.514**	0.773**	0.85**	1	
6. Rav	0.145ns	0.166ns	0.22ns	0.115ns	0.184ns	1

** p<0.01; * p<0.05

It can be seen that there are large coefficients of correlation between the interaction term and memory span and vocabulary scores, as might be partially expected given that the interaction term is the simple product of each of these variables. Mason & Perreault (1991) suggest that collinearity (that is significant correlation between two or more predictor variables) in multiple regression may lead to an increased likelihood of Type 2 errors. In the following regressions (Table 7.17), therefore, the possibility of failing to reject the null hypothesis (ie that there is, in fact, a significant predictive effect of the interaction term) must be recognised. From the results of Mason & Perreault's (1991) analysis it is clear that there is greatest chance of error with small sample size (eg n=30), low overall R^2(<0.25) and high collinearity (r>0.8). As can be seen these are conditions that pertain in the analysis of scores in the Y2 group.

Table 7.17: Hierarchical regressions of phonological awareness (Rhyme, Initial Phonemes) onto nonverbal ability (Rav), vocabulary scores (BPVS), memory span (MeS) and the interaction of vocabulary and memory span (BPVS x MeS). (n=30)

	R		Y1		Y2	
DV=Rhy						
	Adj-R2	F-to-enter	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Rav	-0.02		0.001		-0.014	
BPVS	0.095	4.56*	-0.027	0.23ns	-0.002	1.34ns
MeS	0.167	3.33*	-0.058	0.23ns	-0.004	0.93ns
BPVS x MeS	0.238	3.43*	-0.096	0.08ns	0.006	1.27ns
DV=IPh						
	Adj-R2	F-to-enter	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Rav	-0.036		0.148		-0.007	
BPVS	0.271	12.8**	0.226	3.81*	0.129	5.36**
MeS	0.394	6.48**	0.247	1.74ns	0.201	3.44*
BPVS x MeS	0.431	2.68ns	0.219	0.07ns	0.176	0.23ns

*p<0.05; **p<0.01

From inspection of the table it seems that the interaction of vocabulary and memory span was statistically significant (accounting for an additional 7.1% of variance) in the regression of Rhyme awareness in the 5-year-old group. However, although not being detected as statistically significant in the regression of Initial phoneme awareness in this same group, the interaction term did account for another 3.7% of variance. In the regressions of scores for each of the other two groups, as summarised in the table, the interaction term clearly does not add any substantial variance to the model. In these analyses because of the size of the effect (of the BPVS x MeS terms) it seems unlikely (*pace* Mason & Perreault, 1991) that there is a risk of failing to detect a significant predictor. It seems likely, therefore, that the interaction of vocabulary and memory span (ie that there might be a synergic effect of superior memory span on the association between vocabulary knowledge and phonological awareness) is only plausible for the data from the youngest children in this study, and most specifically in the regression of rhyme awareness . This is in line with the findings of Gathercole & Baddeley (1993a) that memory span was most closely associated with vocabulary growth at around the age of 5-years. It is however possible, though not fully confirmed, that an interaction might also exist for the 5-year-old children in the regression of initial phoneme awareness as would be predicted by Aitchison (1994), Aslin & Smith (1988), and Walley (1993).

It was however possible to approach the issue of the inter-relationship of memory and vocabulary in the prediction of phonological awareness in another way by considering if either memory span or vocabulary scores acted as a 'mediator variable' (Cohen & Cohen, 1983) by obscuring the relationship of the other variable in the prediction of dependent variable scores.

In order to establish if there was such a relationship between memory span, vocabulary and phonological awareness the hierarchical regressions were re-examined with attention to the order in which IVs are entered. In Table 7.7, for example, MeS was entered ahead of BPVS in the regressions. The rationale for that order of IVs was to have discounted any effect due to processing space before testing if lexical knowledge was associated with phonological awareness. To investigate the possibility of 'mediation' Table 7.18 (below) shows the effect of reversing the order of entry of the variables MeS and BPVS in regressions of phonological awareness.

Table 7.18: Regression of Phonological awareness for combined (n=30) groups

	R		Y1		Y2	
DV=Rhy						
	Adj-R2	**F-to-enter**	**Adj-R2**	**F-to-enter**	**Adj-R2**	**F-to-enter**
Rav	-0.02		0.001		-0.014	
enter next						
MeS	0.035	2.59ns	-0.03	0.21ns	0.01	1.69ns
BPVS	0.167	5.29**	-0.06	0.24ns	-0.004	0.61ns
or						
BPVS	0.095	4.56*	-0.027	0.23ns	0	1.34ns
MeS	0.167	3.33*	-0.058	0.23ns	-0.004	0.93ns
DV=IPh						
	Adj-R2	**F-to-enter**	**Adj-R2**	**F-to-enter**	**Adj-R2**	**F-to-enter**
Rav	-0.04		0.148		-0.007	
enter next						
MeS	0.053	3.62*	0.16	1.38ns	0.147	6.05**
BPVS	0.394	16.2**	0.247	4.12*	0.201	2.82ns
or						
BPVS	0.271	12.8**	0.226	3.81*	0.129	5.36*
MeS	0.394	6.48**	0.247	1.74ns	0.201	3.44*

*p<0.05; **p<0.01

The interpretation of these analyses is dependent on examination of both Table 7.16 and Table 7.18.

For the youngest (5-year-old) R-group children it is evident that the bivariate correlation (Table 7.16b) between memory span and vocabulary scores was very low. It is unlikely therefore that either of these variables is 'mediating' the effect of the other in relation to phonological awareness. In terms of any significant association between either of these variables and phonological awareness, it could not, therefore, be concluded that the association was partially consequent on the inter-relationship of memory span and lexical knowledge. Thus since from Table 7.16 and Table 7.18 it appears that vocabulary scores were significantly associated with awareness of rhymes, this effect is almost certainly independent of the effects of memory. However, although the bivariate correlation between memory span scores and rhyme awareness scores was not significant, once the variance in phonological awareness associated with vocabulary scores had been removed, it emerged that there was a significant amount of variance shared by memory span and awareness of rhyme, indicating that the independent effect of memory span on awareness of rhyme could be overshadowed by the effect of lexical knowledge on awareness of rhyme. It has, however, already been shown (Table 7.17) that lexical knowledge and memory span interact in the prediction of awareness of rhyme, demonstrating that the effects of the two IVs are probably synergic in relation to these children's awareness of rhyme.

It does, however, seem that once variance shared by both lexical knowledge and awareness of initial phonemes was removed, there was still a significant proportion of variance shared by memory span and awareness of initial phonemes. In this case there was not a significant interaction between lexical knowledge and memory span, and it may be concluded that lexical knowledge and memory span both exert significant, but independent, effects on awareness of initial phonemes.

Turning next to the 6-year-old (Y1-group), again the bivariate correlation between vocabulary and memory span scores can be seen to be very small. (It is again unlikely therefore that mediator effects need to be considered.) There is also a non-significant correlation between memory span and either type of phonological awareness. Vocabulary scores do not seem to be associated with awareness of rhyme, but are significantly associated with awareness of initial phonemes. In Table 7.18 it is also evident that once the variance that is common to both lexical knowledge and awareness of initial phonemes had been removed, the amount of variance shared by memory span and phonological awareness did not appear to increase significantly. It seems most probable therefore that, for the children in this study, of the two potential predictor variables, lexical knowledge and memory span, only lexical knowledge might be thought to have any significant association with awareness of initial phonemes at this age.

In considering the effects of memory and vocabulary on phonological awareness for the 7-year-old children (Y2 group) it should be recognised that whilst the bivariate correlation between memory span and vocabulary scores is not statistically significant (Table 7.16d) it approaches the critical value (which is 0.361 for this size group). The possibility of mediator effects should therefore be considered. There is, however, clearly no significant relationship between either lexical knowledge, memory span, or their interaction (Table 7.17), with awareness of rhymes, at this age. Table 7.17 also shows that the interaction of vocabulary and memory was not a significant predictor of awareness of initial phonemes either. On comparing the effects of order of entry of vocabulary and memory span in the regression of initial phoneme awareness scores for these children (Table 7.18) it can be seen that when memory span is entered first it accounts for approximately 15% of the variance, and that vocabulary scores only add another (non-significant) 5.4%. When vocabulary scores are entered first, however, approximately 13% of the variance appears to be shared with initial phoneme scores, and memory span scores contribute a further, and statistically significant, 7.2%. This suggests that once children's knowledge of vocabulary is put to one side it becomes more apparent that size of memory span scores and performance in phonological awareness tasks were associated in their own right.

7.2.2.1.1 *Conclusion*

It seems therefore that memory and vocabulary scores did interact in the prediction of awareness of rhyme scores in the cross-sectional analysis of the data from the 5-year-old children. It is also possible that there was an interaction in the prediction of initial phoneme scores for these children, although the result does not quite achieve a level of statistical significance. The interaction between memory and lexical knowledge might arise if memory span is both a measure of the efficiency of transfer (by the central executive in the working memory model) to and from the lexicon (as postulated by Gathercole & Baddeley, 1993), and a measure of the efficiency of operation of phonological processing within working memory (Brady, 1991). Thus children's performance in the phonological awareness task might be eased by having a larger reservoir of words with easier access, and greater facility in maintaining phonological representations. Words might therefore be more readily recognised, and, as indicated by Aitchison (1994), rhyming features might, at the age of 5-years, be more prominent aspects of words that are to be recognised. Thus words within the phonological test might be most efficiently recognised and compared most easily by children with good lexical knowledge and memory processes.

It seems unlikely however that any synergy between lexical knowledge and memory processes exists in the cognitive abilities of the older children studied. It also seems unlikely that lexical knowledge was associated with awareness of rhymes for either the 6- or 7-year-old children.

For the oldest (7-year-old) children it seems more likely that while both memory and vocabulary are significantly associated with awareness of initial phonemes they make dissociable contributions to performance in the test of awareness of initial phonemes. The emergence of a significant association between lexical knowledge and awareness of initial phonemes would be expected from the conclusions of Aitchison (1994).

Since it seems that at the start of these children's education there was an interaction between lexical knowledge and memory in the prediction of phonological awareness at the same age, but that, as expected, with age lexical knowledge was only associated with awareness of initial phonemes, in the following section the longitudinal relationship between lexical knowledge, memory and the development of phonological awareness is explored. In particular the conjecture that, somewhat paradoxically, an initially restricted memory span might be advantageous.

7.2.2.2 *Does initial size of memory span affect the development of phonological awareness ?*

Work carried out by Newport (1990) and Elman (1993) suggested that under some conditions aspects of language (morphology and grammar, respectively) may be acquired more efficiently when memory is restricted.

The work of Elman (1993) showed that in simulations carried out on neural networks the network could process complex sentences provided the network had 'learned' grammatical regularities during a training programme. If training was attempted with the full 'adult' language and an unrestricted memory span, the network was unable to acquire any learning of rules underpinning the grammatical regularities, and was thus unsuccessful at processing novel and complex sentences. 'Learning' could, however, occur in one of two ways. If the network was exposed to a carefully controlled incremental series of increasingly complex sentences learning took place and the network was subsequently able to process novel sentences. If, however, the network was exposed to the full corpus of 'adult' language but, Elman (1993, p78) argues, more realistically in comparison to human development, with a gradually increasing 'memory span', learning was initially slower than in the incremental task scenario. In this scenario ultimately the network was, however, as effective at processing novel sentences as in the incremental task simulations.

It is important to note two features of these simulations. One is that in the increasing memory span simulations the learning system is not 'static' but is developing in the face of a fully formed complex domain of language. This is not to say that the changes in 'memory span' are caused by the nature of the tasks, but that in interaction with the task to be learned (the regularities of a grammar in Elman's simulations) the increases in memory span appear to facilitate successful learning. The second feature is that the domain in which learning takes place is hierarchically organised. Thus the successful learning of simple rules provides the necessary basis for learning rules which can be applied to more complex data.

Both Elman (1993) and Newport (1990) took as their starting points for their investigations the observation that, at least in the field of first language learning, the greatest rate of learning occurs in childhood - at the same time that there is the greatest rate of organic (ie neural) development.

Newport (1990) reported studies into the acquisition of morphology of a language (American Sign Language) in children and adults, and in second language learners. From these two lines of investigation, the convergent results confirmed that language learning is most successful in the least mature learners.

Newport (1990) put forward the view, supported by the evidence of her studies into language acquisition and mathematical simulations, that the differences in the success rate of learning lay in the ways adults and children perceived and stored complex linguistic stimuli. Thus, Newport (*op cit*, p 24) argued, if children are only able to perceive some component parts of complex stimuli, they may 'be in a better position to locate the components' than adults who perceive and store the totality of the stimuli. Specifically, in terms of morphology Newport suggested (p24) that 'The learner must find, in the linguistic input data, the particular components of word forms which map consistently onto components of meaning.'

The acquisition of phonological awareness might be considered comparable to the acquisition of morphology in that children are learning sound-meaning mappings, and there is an hierarchical progression from awareness of rhyme to awareness of initial phonemes. From the work of Newport (1990) and Elman (1993) it is therefore possible to consider how the size of vocabulary and memory span might interact in predicting the growth in phonological awareness. (This is clearly a different relationship than that described in the previous section, §7.2.2.1, in which the interaction between memory span and vocabulary was considered in relation to phonological awareness at the same age.)

Thus if a child has a sizable lexicon it is likely (Aitchison, 1994) that there are clusters of similar sounding words in that lexicon. If the child also has a restricted memory span it would be able to hold in mind a smaller subset of items from the lexicon than a child with a less restricted memory span. Within the restricted subset it would, according to the logic of Newport's (1990) findings, be easier for the child to locate the components which comprise meaning-sound pairs. Given the evidence and suggestions reviewed by Aitchison (1994) that older children and adults have stronger associations between word-initial sounds and items in their lexicons, and that the time when children learn to read (ie between ages 5- to 7-years) might be a period when associations between lexical items and initial sounds might be learned, it is proposed that children with larger vocabularies and smaller memory spans would be more likely to develop awareness of initial phonemes than children with smaller lexicons or larger memory span.

Investigation of the speculation derived from Elman *op cit* and Newport *op cit* was accomplished by means of a statistical exploration of the possible interactional effect between memory and vocabulary on phonology. The hypothesis is that children with smaller initial memory spans would more easily have learned associations between lexical items and in doing so would (following the suggestions of Dollaghan (1994) and the evidence of §7.1.3.3.4) have necessarily acquired phonological discriminational ability. In order to study the synergistic effect of smaller memory span a derived variable has been computed. This is the multiplicative reciprocal of MeS. Children with smaller memory spans would generate larger values of 1/MeS, and conversely those with larger MeS scores would have had smaller 1/MeS values. In the interaction term (BPVS x 1/MeS) that was formed (following the procedures outlined by Cohen & Cohen, 1983; Jaccard, Turrusi & Wan, 1990) therefore the children with the smallest memory span scores would have generated the largest values of the interaction term.

The alternative hypothesis, outlined above, is that memory span and lexical knowledge together facilitate phonological awareness. The corresponding interaction term used to test for this effect is BPVS x MeS.

Within the developmental data available in this study it might be possible to observe the effect of an initially restricted memory span. This would be evident within regressions of phonological scores at T2 onto scores (including the interaction term) obtained a year earlier at T1. Some problems with the longitudinal data that have been gathered have already been discussed, and are still relevant cautions that prevent a full evaluation of the issue. However the measure IPh provided statistically significant differences between mean scores at T1 and T2 and the difference between administrations of Rhy yielded means whose difference approached conventional thresholds of significance ($t = 1.95$, $p=0.06$). On this basis it should be possible to observe if changes in phonological awareness were associated with either of the interaction terms.

The descriptive statistics for the relevant derived variable (1/MeS) obtained from the data at T1 and T2 are shown in the following table.

Table 7.19: Mean (sd) for the reciprocal of memory span (1/MeS) derived from longitudinal sample (n=24; T2 - T1 = 12 months)

1/MeS	Mean	sd
T1	0.282	0.097
T2	0.23	0.056
T1 vs. T2	t=3.74**	

**p<0.01

The interactional variable that was used is the product BPVS 1 x 1/MeS1. The descriptive statistics for this variable are given in the following table. The table also shows the statistics for the alternative interaction term, BPVS1 x MeS1.

Table 7.20: Mean (sd) for interaction terms formed from memory span, MeS, or its reciprocal, 1/MeS, and vocabulary score, BPVS, MeS x BPVS; 1/MeS x BPVS, derived from longitudinal sample at T1 (n=24)

	Mean	sd
BPVS1 x MeS1	45.125	17.24
BPVS1 x 1/MeS1	39.375	23.03

All the data was screened for deviations from normality. In the process it was found that the variable 1/MeS1 was moderately positively skewed. The data for that variable was, therefore, transformed using the square-root of scores to achieve reasonable conformity to a normal distribution. This transformed variable [1/√(MeS1)] was used in ensuing analyses. All other variables were found to have coefficients of kurtosis and skew that were within acceptable limits.

The matrices of bivariate correlations for variables in the proposed regressions are shown in the following tables. (It will be recalled from §7.2.1.1 that MeS1 was transformed by the use of natural logarithms to reduce the effects of positive skew and kurtosis, hence the entry of that term in Tables 7.22 and 7.24.)

Table 7.21: Correlations of Phonological awareness (Rhy, IPh) at T1 and T2, Lexical Knowledge at T1 (BPVS1), memory span at T1 (transformed: 1/√MeS1) and Age1 at T1 (n=24)

	1	2	3	4	5	6	7	8
1.Rhy1	1							
2.Rhy2	0.721**	1						
3.IPh1	0.678**	0.71**	1					
4.IPh2	0.711**	0.714**	0.653**	1				
5.BPVS1	0.379ns	0.449*	0.558**	0.497*	1			
6.1/√MeS1	-0.45*	-0.235ns	-0.497*	-0.528**	0.029ns	1		
7.BPVS1x1/MeS1	0.418*	0.475*	0.307ns	0.552**	0.459*	-0.115ns	1	
8.Age1	0.464*	0.414*	0.659**	0.342ns	0.175ns	-.386ns	0.118ns	1

*p<0.05;**p<0.01

Table 7.22: Correlations of Phonological awareness (Rhy, IPh) at T1 and T2, Lexical Knowledge at T1 (BPVS1), memory span at T1 (transformed: lnMeS1) and Age1 at T1 (n=24)

	1	2	3	4	5	6	7	8
Rhy1	1							
Rhy2	0.721**	1						
IPh1	0.678**	0.71**	1					
IPh2	0.711**	0.714**	0.653**	1				
BPVS1	0.379ns	0.449*	0.558**	0.497*	1			
ln(MeS1)	0.448*	0.293ns	0.515**	0.546**	-0.037ns	1		
BPVS x MeS1	0.532**	0.486*	0.751**	0.71**	0.646**	0.724**	1	
8.Age1	0.464*	0.414*	0.659**	0.342ns	0.175ns	0.399ns	0.436*	1

*p<0.05;**p<0.01

In accordance with the procedure outlined by Cohen & Cohen (1983) the main variables were entered in advance of the interaction term in hierarchical regression. In the analysis of this longitudinal data phonological awareness at T1 was again entered first to remove from consideration the effects of initial levels of awareness. The results were as follows.

Table 7.23: Results of hierarchical regressions of phonological awareness (Rhy2, IPh2) at T2 onto preexisting phonological awareness (Rhy1, IPh1), memory span (transformed: 1/√MeS1), lexical knowledge (BPVS1) and interaction term BPVS1 x 1/MeS1 (n=24)

DV = Rhy 2		
	Adj-R2	F-to-enter
Age1	0.134	
Rhy 1	0.483	15.9**
1/√MeS1	0.466	0.36ns
BPVS 1	0.474	1.3ns
BPVS1 x 1/MeS1	0.471	0.88ns
DV = IPh 2		
	Adj-R2	F-to-enter
Age1	0.077	
IPh 1	0.387	12.14**
1/√MeS1	0.429	2.53ns
BPVS 1	0.485	3.21ns
BPVS1 x 1/MeS1	0.566	4.52*

*p<0.05;**p<0.01

Table 7.24: Results of hierarchical regressions of phonological awareness at T2 onto BPVS1 x MeS1 interaction for longitudinal group (n=24)

DV = Rhy 2		
	Adj-R2	F-to-enter
Age1	0.134	
Rhy1	0.483	15.86**
lnMeS1	0.461	0.14ns
BPVS1	0.472	1.43ns
BPVS1xMeS1	0.443	0.01ns
DV = IPh 2	Adj-R2	F-to-enter
Age1	0.077	
IPh1	0.387	12.14**
lnMeS1	0.432	2.65ns
BPVS1	0.494	3.44*
BPVS1xMeS1	0.52	2.04ns

*p<0.05

7.2.3 Conclusion

These results indicate that, as predicted, children's later awareness of initial phonemes may be developmentally predicted by an interaction between their scores, obtained a year earlier, in the test of vocabulary and the reciprocal of their memory span. This suggests that an initially smaller memory span (generating the larger values of 1/MeS) in interaction with lexical knowledge conferred some advantage in acquiring awareness of initial phonemes. There does not however seem to have been a comparable effect with respect to the children's acquisition of greater awareness of rhymes.

This finding provides some support for the simulations and conjectures of Elman (1993) and Newport (1990). The simulations conducted by Elman (1993) and Newport (1990) demonstrated that if a network that was set the task of learning about language could only hold a limited part of the possible set of information, but could operate efficiently, then learning about connections or rules within the domain would be established relatively quickly. Contrariwise larger chunks of information would take longer to process and, with few initial rules to guide choices of connections, learning would be slower.

The indications from these results are that if children's processing space (the central executive of working memory) is in some way constrained or limited in size (and developmentally it seems that the younger children in this study had smaller memory spans than older children, see §6.1.2.3), then, in conjunction with greater lexical knowledge, awareness of word-initial sounds was, over the space of a year, acquired more easily. Further replication with other groups, and some other methodologies would be essential to substantiate this result.

7.3 The relationship between lexical knowledge and reading

7.3.1 Introduction

It seems intuitively appealing to hold that as children learn to read they would be helped by already having had aural and oral experience of the words they read so that they already 'know' the word and its meaning. Evidence in support of this view is available from a variety of sources.

Becker (1979) for instance found word frequency effects in children's visual word recognition. It has also been found (Vellutino & Scanlon, 1985) that children with reading difficulties had smaller vocabularies than children of the same age who did not have reading difficulties. Tunmer & Nesdale (1985) in studying the relationship between phonological awareness and reading used a measure of vocabulary (the PPVT (Dunn & Dunn, 1981) from which the BPVS - used in this study - was derived) as a control for verbal ability. In fixed order regressions of reading scores the vocabulary scores were found to make a significant contribution to the variance in reading. Other studies have reported associations between vocabulary and performance in reading tests in partially-hearing children (Davis, Elfenbein, Schum & Bentler, 1986; Owrid, 1970). Davis *et al* (1986) also found that the partially-hearing children's PPVT scores were significantly below the norms for the test.

In studies of adult readers, Kleiman (1975) demonstrated that during reading the meaning of words was accessed from the lexicon prior to phonological recoding. Barron (1986) however concluded that in the early stages of reading development neither direct or indirect access (that is via phonological coding) to the lexicon is predominant. Seymour & Elder (1986) in a study of children who had been taught to read without phonological processing found that the children's errors in reading were largely visual substitutions within the set of words that they had been taught, but also that semantic factors had some influence over which word was selected.

Seymour & Elder's (1986) work is of relevance to the findings to be discussed in this section, and in particular the evidence that is available from the partially-hearing children. Seymour & Elder (1986) proposed the use of the term '*logographic lexicon*' to cover a rudimentary process of word recognition without letter-sound conversions. This process was, in Seymour & Elder's (1986) account, linked to the earliest stages in the models of reading that had been developed by Frith (1985) and Marsh, Friedman, Welch & Desberg (1981). These stage models (to be discussed in Chapter 8) proposed that in the earliest stages of learning to read children pass through a phase, termed *logographic* by Frith (1985), in which they learn to recognise whole words on sight.

Thus overall it seems that knowledge of words and their meanings is likely to be associated with word reading ability. It is of interest therefore to establish if, for the children who participated in this study, there were significant associations between lexical knowledge and reading scores, and if there was any difference between the performance of the partially-hearing children and the children without hearing difficulties in the test of vocabulary.

Given the findings of Seymour & Elder (1986) and others, and the finding established earlier in this chapter that lexical knowledge and phonological awareness were associated, it was hoped to establish what effects on word reading lexical knowledge might have that were separable from the effects of phonological awareness. In this present research however it was not intended to enter into a detailed exploration of the relative importance of phonological coding in lexical access and the sequential order of phonological processing and lexical access. Rather it was intended to simply evaluate, as part of the process of exploring influences on phonological awareness, what effect lexical knowledge (vocabulary) might have on phonological awareness.

7.3.2 Methodology

The data available from the children in the main cross-sectional and longitudinal samples was analysed to establish the contribution of lexical knowledge to the children's reading. Since the interest was to establish the contribution of lexical knowledge that was independent of phonological awareness, the phonological awareness variables were also included in the analyses as statistical controls. As part of the examination of the causal influences of lexical knowledge the data from the partially-hearing children was examined since, as shown in §7.1.3.3.6, the partially-hearing children were found to have significantly poorer vocabulary scores than would have been generally expected amongst children of that age.

7.3.2.1 *Data screening and treatment*

The data (summarised in Table 7.25) for groups of 45 children in each sampling cohort of children without hearing difficulties in '92 and '93 was examined for departures from normality.

Table 7.25: Means (sd) of Age, Nonverbal ability (Rav), Lexical Knowledge (BPVS), Phonological awareness (Rhy, IPh), Word Recognition (Carv) and Word Reading (BAS) obtained from hearing children in '92 and '93 aged 5 - 7 years (n=45 each group), and partially-hearing children (P-H) aged 7-years (n=15)

	'92 (n=45)	'93 (n=45)	P-H (n=15)
Age (months)	69.9 (9.9)	69.3 (10.5)	82.7 (4.8)
Rav	17.6 (4.0)	15.7 (4.8)	17.1 (3.4)
BPVS	12.3 (2.8)	10.9 (3.5)	9.7 (2.4)
Rhy	6.3 (2.3)	6.0 (2.4)	6.2 (1.6)
IPh	5.6 (2.3)	5.5 (2.8)	6.2 (2.4)
Carv	4.0 (2.9)	4.4 (3.2)	6.1 (2.7)
BAS	6.3 (12.7)	7.7 (15.4)	20.2 (18.0)

For these children it was found that the vocabulary (BPVS), phonological awareness and word recognition (Carver test) data conformed to assumptions of normality both in '92 and in '93. The Word Reading (BAS test) data in '92 and '93 was found to have significant skew and kurtosis. This is almost certainly because very few of the younger children (none of the 5-year old children) achieved a score in this test. This data was accordingly transformed using f(x): log(1 + x). Both skew and kurtosis of transformed data was found to lie within acceptable limits. For children in the Y2 group in '93 BAS scores were found to require a transformation (the square root) to counteract a significant positive skew.

The data from the partially-hearing children was similarly tested and all variables were found to have coefficients of skew and kurtosis within acceptable limits.

7.3.2.2 *Analyses*

7.3.2.2.1 *Is lexical knowledge (vocabulary) associated with word reading ?*

Hierarchical regressions of reading scores onto lexical knowledge were undertaken with prior entry of age and non-verbal ability. The results are summarised in the following Table 7.27 below. Table 7.26 shows the bivariate correlation coefficients.

Table 7.26a: Correlation coefficients for Age, Nonverbal ability (Rav), Lexical Knowledge (BPVS), Phonological awareness (Rhy, IPh), Word Recognition (Carv) and Word Reading (transformed scores: log(1+BAS)) in '92 (n=45)

	1	2	3	4	5	6	7
1.Age	1						
2.Rav	0.39**	1					
3.BPVS	0.406**	0.394**	1				
4.Rhy	0.359*	0.275ns	0.482**	1			
5.IPh	0.538**	0.398**	0.551**	0.738*	1		
6.Carv	0.659**	0.541**	0.612**	0.508**	0.717**	1	
7.log(1+BAS)	0.703**	0.499**	0.53**	0.393**	0.633**	0.858**	1

*p<0.05;**p<0.01

Table 7.26b: Correlation coefficients for Age, Nonverbal ability (Rav), Lexical Knowledge (BPVS), Phonological awareness (Rhy, IPh), Word Recognition (Carv) and Word Reading (transformed scores: log(1+BAS)) in '93 (n=45)

	1	2	3	4	5	6	7
1.Age	1						
2.Rav	0.578**	1					
3.BPVS	0.567**	0.512**	1				
4.Rhy	0.535**	0.37*	0.382*	1			
5.IPht	0.585**	0.45**	0.623**	0.701**	1		
6.Carv	0.762**	0.474**	0.56**	0.644**	0.75**	1	
7.log(1+BAS)	0.705**	0.525**	0.624**	0.659**	0.756**	0.87**	1

*p<0.05;**p<0.01

Table 7.26c: Correlation coefficients for Age, Nonverbal ability (Rav), Lexical Knowledge (BPVS), Phonological awareness (Rhy, IPh), Word Recognition (Carv) and Word Reading (BAS) for scores obtained from partially-hearing children (n=15)

	1	2	3	4	5	6	7
1.Age	1						
2.Rav	-0.194ns	1					
3.BPVS	0.197ns	0.1ns	1				
4.Rhy	0.237ns	-0.158ns	0.484*	1			
5.IPh	0.165ns	-0.142ns	0.376ns	-0.381ns	1		
6.Carv	0.239ns	0.412ns	0.672**	0.288ns	0.357ns	1	
7.BAS	0.474ns	0.099ns	0.613**	0.372ns	0.226ns	0.644**	1

*p<0.05;**p<0.01

Table 7.27a: Regression of Reading (Carver, word recognition; BAS, word reading, transformed scores) scores onto lexical knowledge (BPVS) with controls for Age and non-verbal ability (Rav). ('92 and '93 hearing samples; n=45 in each group)

'92			'93	
DV=Carv	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Age	0.421		0.571	
Rav	0.507	8.45**	0.563	0.17ns
BPVS	0.593	9.92**	0.576	2.32ns
DV=log(1+BAS)				
Age	0.483		0.486	
Rav	0.533	5.63**	0.495	1.81ns
BPVS	0.567	4.35**	0.546	5.65**

**p<0.01

Table 7.25b: Regression of Reading (Carver, word recognition; BAS, word reading) scores onto lexical knowledge (BPVS) with controls for Age and non-verbal ability (Rav). (n=15, partially-hearing samples)

DV=Carv	Adj-R2	F-to-enter
Age	-0.015	
Rav	0.155	3.62ns
BPVS	0.502	9.34**
DV=BAS		
Age	0.165	
Rav	0.14	0.61ns
BPVS	0.389	5.91*

*$p<0.05$;**$p<0.01$

These results indicate that vocabulary scores were predictive of reading scores for both the hearing and the partially-hearing children in this study.

7.3.2.2.2 *Are the effects on word reading of lexical knowledge and phonological awareness dissociable ?*

Given the results of chapter 4 (where the relationship between phonological awareness and reading was confirmed) and the results reported earlier in this chapter (§7.1.3.3.2) where it was shown that lexical knowledge had been predictive of phonological awareness, it was reasonable to enquire if the effects of phonological awareness and lexical knowledge were statistically dissociable. A second series of regression analyses of the data obtained in '92 and '93 were therefore performed in which phonological awareness was entered into the regression ahead of lexical knowledge. The results of these analyses are reported in Table 7.28.

Table 7.28a: Hierarchical regression of Word Recognition (Carv) and Word Reading (BAS) onto lexical knowledge (BPVS) with statistical control for non-verbal ability (Rav) and phonological awareness (Rhy, IPh) (n=45)

'92			'93	
DV=Carv	Adj-R2	F to enter	Adj-R2	F to enter
Age	0.421		0.571	
Rav	0.507	8.46**	0.563	0.17ns
then				
Rhy	0.559	5.99**	0.635	9.24**
BPVS	0.606	5.83**	0.642	1.89ns
or				
IPh	0.639	16.4**	0.702	20.57**
BPVS	0.663	3.92**	0.649	0.003ns
DV=log(1+BAS)				
Age	0.483		0.486	
Rav	0.533	5.63**	0.495	1.81ns
then				
Rhy	0.535	1.23ns	0.594	11.20**
BPVS	0.558	3.13*	0.633	5.42**
or				
IPh	0.589	6.71**	0.659	21.17**
BPVS	0.594	1.52ns	0.658	0.87ns

*p<0.05;**p<0.01

Table 7.28b: Hierarchical regression of Word Recognition (Carv) and Word Reading (BAS) onto lexical knowledge (BPVS) with statistical control for non-verbal ability (Rav) and phonological awareness (Rhy, IPh) for partially-hearing children (n=15)

In this analysis Age was not entered as a predictor variable since to do so would be to use too great a number of variables in violation of the cases:variables ratio indicated by Tabachnick & Fidell (1989). The group is in any event homogeneous w.r.t age.

DV=Carv	Adj-R2	F to enter
Rav	0.106	
then		
Rhy	0.181	2.19ns
BPVS	0.458	7.13**
or		
IPh	0.237	3.23ns
BPVS	0.499	7.26**
DV=BAS		
Rav	-0.07	
then		
Rhy	0.025	2.22ns
BPVS	0.22	4.00*
or		
IPh	-0.087	0.76ns
BPVS	0.207	5.46*

*p<0.05;**p<0.01

This second series of regressions suggests that for the children without hearing difficulties there was some evidence of separable contributions to reading from phonological awareness and lexical knowledge. It is notable that awareness of initial phonemes is consistently associated with word recognition (Carv) and word reading (BAS) scores.

In the sample of partially-hearing children however scores in reading were not predicted by phonological awareness, but were associated with lexical knowledge after the variance due to phonological awareness had been entered in the regressions. This suggests that the partially-hearing children were not using phonological strategies in their reading (either word recognition, or word reading) but were likely to be using lexical knowledge.

This was confirmed by an examination of the relative strengths in phonological awareness, lexical knowledge and reading in partially-hearing and children without any hearing loss. In the Table 7.29 (below) it can be seen that whilst the partially-hearing children's reading was comparable to children of the same age without hearing difficulties, their lexical knowledge and phonological awareness was significantly poorer than same-age hearing peers. The partially-hearing children's phonological awareness was comparable to that evidenced by the children without hearing difficulties in Y1, but their vocabulary scores were comparable to children without hearing loss aged 5-years.

Table 7.29: Mean (and sd) of scores in Rhyme, IPh, BPVS, Carv and BAS obtained from Hearing-Impaired (n=15) and Hearing children (n=30 for each age group) with Mann-Whitney test (z) for differences between Hearing and Partially-Hearing (P-H) children

	P-H (n=15)	Hearing n=30		
Age group:	**Y 2**	**Y 2**	**Y 1**	**R**
Mean Rhyme	6.2	7.28	6.5	4.67
sd	1.61	1.89	2.08	2.28
z: H vs P-H		-2.03*	-.671ns	-2.47*
Mean IPh	6.2	7.2	5.6	3.8
sd	2.4	2.2	2.6	1.5
z: H vs P-H		-1.40ns	-.78ns	-3.29**
Mean BPVS	9.7	13.5	11.4	9.8
sd	2.4	3	2.6	3.1
z: H vs P-H		-3.69**	-1.93ns	-.12ns
Mean Carv	6.1	7	3.7	1.9
sd	2.7	2.4	2.5	1.5
z: H vs P-H		-1.17ns	-2.54*	-4.33**
Mean BAS	20.2	17.4	3.6	0
sd	18	18.1	10.3	0
z: H vs P-H		-.61ns	-3.74**	

*p<0.05;**p<0.01

In the light of the results presented above and the particularly large contribution of age to Carver scores in '93 (see Table 7.26 a) it was important also to establish if within the samples of children without hearing difficulties there were any age-specific associations between phonological awareness, lexical knowledge and reading. This was achieved in a similar manner to that used for the complete samples in '92 and '93.

Table 7.30 shows the means (sd) for scores for each group of 30 children in each of the 5-year-old (R), 6-year-old (Y1) and 7-year-old (Y2) combined groups. The data for these groups was checked for violations of normality (see Appendix 2). For the Y1 group there were only 8 children who achieved a score in the BAS test of word reading, and none of the R-group children scored in this test. BAS scores have therefore not been used in the following analyses of these groups. In the Y2 group BAS were found to have significant skew. This variable was transformed by taking the square-root of scores.

Table 7.30: Means (and sd) of Age, Nonverbal Ability (Rav), Lexical Knowledge (BPVS), Phonological Awareness (Rhy, IPh), Word Recognition (Carv) and Word Reading (BAS) scores obtained for children aged approximately 5-, 6-, and 7-years (n=30 for each group)

	R group	Y1 group	Y2 group
Age (months)	57.3 (1.7)	69.8 (1.4)	81.8 (1.50
Rav	13.9 (3.3)	17.1 (4.0)	18.9 (4.8)
BPVS	9.8 (3.1)	11.4 (2.6)	13.5 (3.0)
Rhy	4.7 (2.3)	6.5 (2.1)	7.3 (1.9)
IPh	3.8 (1.5)	5.6 (2.6)	7.2 (2.2)
Carv	1.9 (1.5)	3.7 (2.5)	7.0 (2.4)
BAS	0 (0)	3.6 (10.3)	17.4 (18.1)

The Pearson coefficients of the correlations between variables are shown in Table 7.31, and the regressions of reading scores are summarised in Table 7.32.

Table 7.31a: Coefficients of Correlation of Age, Nonverbal ability (Rav), Lexical Knowledge (BPVS), Phonological awareness (Rhy, IPh), and Word Recognition (Carv) scores for R-group

	Age	Rav	BPVS	Rhy	IPh	Carv
Age	1					
Rav	0.191ns	1				
BPVS	0.155ns	0.472**	1			
Rhy	0.006ns	0.124ns	0.391*	1		
IPh	0.207ns	0.01ns	0.505**	0.759**	1	
Carv	0.108ns	-0.186ns	0.167ns	0.426*	0.518**	1

*p<0.05;**p<0.01

Table 7.31b: Coefficients of Correlation of Age, Nonverbal ability (Rav), Lexical Knowledge (BPVS), Phonological awareness (Rhy, IPh), and Word Recognition (Carv) scores for Y1-group (n=30)

	Age	Ravens	BPVS	Rhy	IPh	Carv
Age	1					
Rav	0.301ns	1				
BPVS	0.308ns	0.453**	1			
Rhy	0.024ns	0.188ns	0.166ns	1		
IPh	0.167ns	0.422*	0.475**	0.486**	1	
Carv	0.164ns	0.27ns	0.417*	0.451**	0.603**	1

*p<0.05;**p<0.01

Table 7.31c: Coefficients of Correlation of Age, Nonverbal ability (Rav), Lexical Knowledge (BPVS), Phonological awareness (Rhy, IPh), Word Recognition (Carv) and Word Reading (BAS) scores for Y2-group (n=30)

	Age	Rav	BPVS	Rhy	IPh	Carv	√BAS
Age	1						
Rav	0.427*	1					
BPVS	0.228ns	0.22ns	1				
Rhy	-0.027ns	0.145ns	0.242ns	1			
IPh	0.144ns	0.166ns	0.428*	0.781**	1		
Carv	0.324ns	0.461**	0.444*	0.456**	0.611**	1	
√BAS	0.214ns	0.469**	0.535**	0.554**	0.586**	0.721**	1

*p<0.05;**p<0.01

Table 7.32a: Regressions of Carver (word recognition) scores onto phonological awareness (Rhy or IPh) and lexical knowledge (BPVS) (n=30 for each group)

	R		Y1		Y2	
DV=Carv						
	Adj-R2	F-to-enter	Adj-R2	F-to-enter	Adj-R2	F-to-enter
Rav	0		0.04		0.185	
then						
Rhy	0.183	7.27**	0.183	5.89**	0.32	6.59**
BPVS	0.17	0.563ns	0.247	3.32*	0.377	3.44*
or						
IPh	0.253	10.48**	0.317	12.4**	0.47	16.1**
BPVS	0.224	0.00ns	0.316	0.95ns	0.472	1.12ns

*p<0.05;**p<0.01

Table 7.32b: Regressions of BAS (word reading, transformed) scores onto phonological awareness (Rhy or IPh) and lexical knowledge (BPVS) for Y2 group (n=30)

DV=√BAS		
	Adj-R2	F-to-enter
Rav	0.192	
then		
Rhy	0.421	12.1**
BPVS	0.531	7.3**
or		
IPh	0.448	14.0**
BPVS	0.499	3.76*

*p<0.05;**p<0.01

It can be seen that following the entry of the phonological variable, lexical knowledge did not appear to have any predictive value for the youngest children's word recognition scores. The children in Y1 and Y2 however showed that following rhyme awareness, lexical knowledge (BPVS) made a significant unique contribution to the variance in word recognition. A comparable effect was not however evident following the entry of initial phoneme awareness scores in the regression. With respect to word reading, in the Y2 group, lexical knowledge scores were significantly associated once the effects due to phonological awareness (of either variety) had been removed.

The latter set of relationships (in the Y2 group) would seem to have a straightforward explanation in terms of the the overall benefits to children's reading from greater knowledge of the existence and meaning of words, and corresponds to the findings of Becker (1979), who reported word frequency effects in children's word recognition, and Tunmer & Nesdale (1985), who found a significant association between vocabulary and word reading scores.

It is evident that in the regressions of word recognition (Carver test) scores initial phoneme awareness scores contribute rather more variance than rhyme awareness scores. It is possible that this is because children with a better ability to detect the initial sounds of a word will be more able to use that sort of information in selecting the correct response in the Carver test. Awareness of rhymes, on the other hand, may be an indicator of phonological awareness which does not provide such obvious clues in the word recognition test.

Lexical knowledge is, however, also useful to 6- and 7-year-old children in the word recognition (Carver) test, as evidenced by the significant amount of variance that lexical knowledge scores account for following rhyme awareness. Following entry of initial phoneme awareness scores, however, it is notable that lexical knowledge does not make a significant contribution to word recognition scores, suggesting that there is substantial commonality in the relationship of initial phoneme awareness and lexical knowledge with word recognition. This might be expected from the significant correlation between initial phoneme awareness and lexical knowledge reported in Table 7.31. It will also be recalled from Tables 7.7 and 7.18 (above) that in this study, for 5- and 6-year-old children, lexical knowledge appeared to make a more substantial contribution to awareness of initial phonemes than to awareness of rhymes. Thus in the regressions reported in Table 7.32 it is possible that awareness of initial phonemes may subsume lexical knowledge as a predictor of word recognition scores.

In the prediction of word reading scores (Table 7.32b) it appears that both phonological awareness and lexical knowledge are significant. This might be expected since in the BAS test words have to be decoded from print into speech. This clearly involves phonological skills (implicated in letter-sound conversion), but also, presumably, knowledge of words that might match the sound pattern that is assembled from print. Children who have better phonological skills might be thought to be more able to form accurate and reliable acoustic representations of graphemes, which, with better knowledge of vocabulary they could match to real words.

However, as is evident from the sample of partially-hearing children, when phonological awareness is not associated with reading lexical knowledge may be found to make a larger contribution to word recognition than is the case for children without hearing difficulties of the same age (see Tables 7.28 and 7.32a).

Given the earlier discussion (§7.1) of the longitudinal relationship between phonological awareness and lexical knowledge, of interest also is the longitudinal relationship between phonological awareness and lexical knowledge at one age and reading ability at a later age. This is explored in the following section.

7.3.2.2.3 *Are the developmental effects of lexical knowledge and phonological awareness dissociable ?*

To establish if there were separate developmental contributions from phonological awareness and lexical knowledge to word reading, the data from the 24 children seen in '92 (T1) and again in '93 (T2) were analysed using hierarchical regressions of reading scores onto age, nonverbal ability, preexisting reading scores, phonological awareness and vocabulary scores. It is recognised that five independent variables and 24 cases was in breach of the minimum ratio of variables:cases (1:5) recommended by Tabachnick & Fidell (1989), but the analysis was performed on the understanding that any significant predictions might be due to overfitting of variables. The means and standard deviations of scores for these children are shown in Table 7.33, and the bivariate correlations between variables are shown in Table 7.34. The results of the hierarchical regressions are summarised in Table 7.35.

Table 7.33: Means (sd) of Age, Nonverbal ability (Rav), Phonological awareness (Rhy, IPh), Lexical Knowledge (BPVS), Word Recognition (Carv) and Word Reading (BAS) scores obtained from children seen at T1 and T2 (T2 - T1 = 12 months; n=24)

	T 1	*T 2*
	Mean (sd)	**Mean (sd)**
Age	63.3 (6.2)	75.3 (6.2)
Rav	16.9 (4.0)	17.1 (4.6)
Rhy	6.0 (2.4)	6.8 (2.4)
IPh	5.3 (2.1)	6.6 (2.8)
BPVS	11.6 (2.7)	11.7 (2.7)
Carv	2.9 (2.3)	5.7 (3.1)
BAS	8.2 (3.0)	12.2 (19.2)

It is evident (as has been discussed in earlier chapters) that several of the proposed predictor variables did not show significant differences between scores at T1 and T2. The differences between outcome variables (ie reading scores at T1 and T2) have been confirmed by Mann-Whitney tests of the differences. For Carver scores $z=-3.2$ ($p<0.01$) and for BAS $z=-3.4$ ($p<0.01$).

7.3.2.2.3.1 *Data screening and treatment*

This data was again screened for departures from normality. As a result it was found necessary to transform some variables to achieve reasonable conformity to assumptions of normal distributions. Ravens matrices scores at T1 showed significant positive skew and kurtosis and which were transformed by taking natural logarithms;

and the moderate skew and kurtosis of Carver (word recognition) scores at T1 was transformed by the use of the square-root of scores. These transformed variables were used in the following analyses. However it was evident that too few children achieved any score in word reading (BAS) scores at T1 and T2 to allow any regression analyses with control for word reading at T1. In this event the regression was undertaken but without the entry of any reading control scores at T1.

7.3.2.2.3.2 *Results and Analysis*

Table 7.34: Coefficients of Correlation of Age, and Nonverbal ability (transformed scores: LnRav), Phonological awareness (Rhy, IPh), Lexical Knowledge (BPVS) and Word Reading (BAS) scores at T1, and Word Recognition (Carv) scores at T1 and T2 (n=24)

	1	2	3	4	5	6	7	8
1.Age	1							
2.LnRav	0.40ns	1						
3.Rhy1	0.46*	0.29ns	1					
4.IPh1	0.66**	0.44*	0.68**	1				
5.BPVS1	0.17ns	0.63**	0.38ns	0.56**	1			
6.√Carv1	0.48*	0.43*	0.58**	0.79**	0.71**	1		
7.Carv2	0.61**	0.40ns	0.64**	0.89**	0.55**	0.80**	1	
8.BAS2†	0.52**	0.37ns	0.66**	0.88**	0.53**	0.73**	0.87**	1

*p<0.05;**p<0.01;†transformed as Ln(1+BAS2)

Table 7.35: Hierarchical regressions of word recognition scores (Carv) at T2 onto phonological and lexical developmental antecedents (n=24)

DV=Carv2			DV=Ln(1+BAS2)		
	Adj-R2	F-to-enter		Adj-R2	F-to-enter
Age	0.346		Age	0.241	
LnRav	0.347	1.03ns	lnRav	0.236	0.87ns
√Carv1	0.667	21.2**	Rhy1	0.432	8.25**
Rhy1	0.678	1.67ns	BPVS1	0.507	4.03*
BPVS1	0.663	0.17ns			
or			or		
IPh1	0.784	11.90**	IPh1	0.74	41.8**
BPVS1	0.772	0.00ns	BPVS1	0.728	0.12ns

*p<0.05;**p<0.01

This analysis indicates that for the children who participated in the longitudinal study lexical knowledge (vocabulary scores) at T1 was not indicative of performance in the tests of reading twelve months later, except in so far as the regression of word reading (transformed scores) suggests that rhyme awareness and lexical knowledge scores at T1 were separately predictive of word reading twelve months later.

7.3.4 Conclusion

In this section the relationship between lexical knowledge, phonological awareness and word reading has been evaluated. It has been found that for the children in the study without hearing difficulties there was an association between their lexical knowledge and word reading as might be expected (Becker, 1979; Kleiman, 1975; Näslund & Schneider, 1991; Tunmer & Nesdale, 1985). On further inspection, it was found that the effects of lexical knowledge were statistically dissociable from the effects of phonological awareness in some groups. However there was no consistent replicated dissociation when the entire samples of children aged 5- to 7-years were analysed. When age specific effects were tested there was evidence that at age 6- and 7-years lexical knowledge had a separable effect on word recognition (Carver test) after rhyme awareness, but not following awareness of initial phonemes. To some extent this might be attributed to the evidence (elaborated in §7.1.3.3.5) that vocabulary scores make a substantial contribution to the variance in initial phoneme scores at certain ages. It has been further suggested above (§7.3.2.2.2) that in the regressions of word recognition scores awareness of initial phonemes may subsume the contribution of lexical knowledge scores. Thus, since in the Carver test the task for children is to match an orally presented word to one of several visually presented words, it may be that word-initial phonemes are clues to word recognition that over-ride any possible contribution that vocabulary knowledge might make. The salience of rhyme awareness as a strategy is, however, complemented by knowledge of the words.

With respect to performance in the word reading test (BAS) there was only adequate data for the purposes of the proposed regressional analyses in the Y2 group. Here the evidence was more straightforward, and suggests that there might be effects on reading due to lexical knowledge that were quite distinct from the effects of phonological awareness. Thus it was clear that, in the regressions, whether either rhyme or initial phoneme awareness had been entered (and both made significant unique contributions to reading) lexical knowledge accounted for a further significant proportion of the overall variance in reading scores. Thus performance in this test (BAS) is facilitated by phonological awareness and, separately, lexical knowledge. That finding does not, however, deny the possibility of vocabulary scores acting as a proxy for initial phoneme awareness scores (ie another aspect of phonological awareness) in the regression of reading involving rhyme as a predictor variable.

Longitudinally the evidence is not at all clear. This is partly due to the nature of the data available from the children tested on both occasions (twelve months apart). These data, as has already been noted, did not always significantly differentiate between children's performance at T1 and T2. Thus while there are substantial differences between children's performance in reading at T1 and T2, the proposed predictor variables do not all show clearly different mean scores at T1 and T2. It is also the case that too few children were able to achieve any score in the test of word reading (BAS) at T1 to permit an entry of that variable as a control for word reading performance at T2.

In the Carver test word recognition scores at T2 were predicted by the children's awareness of initial phonemes a year earlier, but not by awareness of rhyme or by lexical knowledge. In the analysis of word reading (BAS) at T2, however, both rhyme awareness and lexical knowledge made significant and dissociated contributions to later word reading. It was not found that a similar dissociation existed for awareness of initial phonemes and lexical knowledge since lexical knowledge at T1 did not make any contribution further to that made at T1 by initial phoneme awareness.

It may cautiously be concluded that the development of word reading, ie actively converting printed stimuli into vocalised words, is facilitated by aspects of phonological awareness and lexical knowledge. Thus the informal observations that children sub-vocalise while reading might be a manifestation of their use of phonological cues in trying to locate the word in their lexical store. The lack of dissociated contributions to word reading from initial phoneme awareness and lexical knowledge might again be because the initial phoneme awareness scores subsume any contribution from vocabulary scores to reading.

In the sample of partially hearing children who were investigated there was no evidence that their awareness of phonological segments (either initial phonemes or rhymes) made any contribution to their performance in reading. Their lexical knowledge, however, was significantly associated with their reading scores. Since these partially-hearing children achieved scores in both tests of reading that were not significantly different from the children of the same age with no hearing difficulties, it may be concluded that the aspects of reading assessed by these reading tests do not necessarily depend on phonological awareness.

7.4 Summary and discussion

This chapter has been devoted to an examination of the relationship between lexical knowledge (vocabulary), memory and phonological awareness in the context of word reading.

7.4.1

It has been shown that for the hearing children in the study greater lexical knowledge might be associated with better phonological awareness. This was most clearly the case for the awareness of rhyme in 5-year old children and for the awareness of initial phonemes in children aged 5- and 6-years. Developmentally the evidence suggests that for children aged 5- and 6-years at the outset of the study their initial lexical knowledge enabled them to become better at identifying initial phonemes. There did not, however, seem to be a similar facilitative developmental effect on the awareness of rhymes.

The concurrent predictive effect of lexical knowledge on rhyme awareness was also found in the case of the sample of hearing-impaired children aged 7 years. These hearing-impaired children were found to have phonological skills comparable to the normally hearing children aged 6, and lexical knowledge comparable to the hearing children aged 5-years. It was suggested that the 'phonological match' showing significantly poorer lexical knowledge in the older, but phonologically 'younger' children, was further confirmation of an association between lexical knowledge and phonological awareness.

It is interesting to speculate on these findings and to consider why lexical knowledge might be differently related to the two aspects of phonological awareness. In her study of children's speech errors in relation to lexical knowledge and phonology Vihman (1981) found that for the oldest children in the study (aged 5+ years) more errors (50%) were associated with words sharing the same final segment than errors (40%) associated with words sharing the same initial segment. Vihman (1981) suggested that her findings confirmed a view that for children word-final segments are lexically more salient than word-initial sounds. Studies of adults cited by Vihman (1981) on the other hand suggest that word-initial sounds and orthography are significant influences on the storage of words in the lexicon. This may be, as noted by Vihman (1981) and Aitchison (1972), because instructional processes and indexation of words are dominated by initial sounds and letters, so knowledge of these features becomes increasingly important. Thus the developmental effect found here that initial phoneme awareness might be predicted by earlier lexical knowledge is possibly not a direct cause and effect relation, but a relationship at least mediated by instruction and environmental factors.

The combined evidence of the investigations also give clear indications, however, that it is more likely that increases in lexical knowledge enhance phonological awareness than the converse possibility. That this may be the case may be inferred from

a) the findings summarised above that, both concurrently and longitudinally, lexical knowledge predicted phonological awareness;

b) the findings that the hearing-impaired children, who had poorer lexical knowledge than their chronologically matched hearing peers, also had poorer lexical knowledge than hearing children who had similar levels of phonological awareness;

c) the finding of no relationship between phonological awareness at T1 and lexical knowledge a year later at T2.

This conclusion corroborates the findings of Maclean, Bryant & Bradley (1987) who found significant correlations between children's vocabulary scores (BPVS) taken at the start of their study (at age 3-years 4 months) and their phonological awareness at later stages (up to 4-years 7 months). It also seems possible that in MacLean *et al*'s study greater knowledge of nursery rhymes was associated with larger vocabulary scores, and vocabulary and phonological awareness scores were highly associated with the children's parents' levels of education.

Overall the view taken here, in support of the conjectures of Dollaghan (1994), is that greater lexical knowledge facilitates the development of greater phonological skills. The evidence here suggests that with a larger number of lexical entries, with an increased probability of phonological similarity between entries, superior phonological skills are acquired in discriminating between entries. This view could be tested in experimental and training studies using groups of children with and without phonological difficulties, and in further developmental studies of children with hearing impairments. It would be of interest also to attempt some further differentiation between the effects of increasing lexical knowledge on rhyme and initial phoneme awareness.

7.4.2

The second issue to be investigated in this chapter was the relationship between memory, lexical knowledge and phonological awareness. Gathercole & Baddeley (1993a, and *passim*) had revealed an association between 'phonological working memory' and vocabulary. Näslund & Schneider (1991) had also found a predictive effect of memory span on phonological awareness. It had also been suggested by Elman (1993) and Newport (1990) that there might be initial advantages in having a restricted memory processing space when learning some aspects of language. It was of interest, therefore to study the combined effects of memory and lexical knowledge on phonological awareness.

The principle findings here are that there appeared to be relationships between memory span, lexical knowledge and phonological awareness which varied with age. Concurrently there were effects of lexical knowledge and memory span on phonological awareness. The effects of memory span and lexical knowledge were found to interact in the prediction of awareness of rhyme for the 5-year-old children. In the prediction of initial phonemes it was found that at ages 5- and 7-years memory span and lexical knowledge appeared to have made dissociable contributions.

This picture of the concurrent relationships has to be reconciled with the longitudinal evidence that there was an interaction between the reciprocal of memory span (which is proposed to be a indicator of the effects of a restricted memory span) and lexical knowledge in the acquisition of greater awareness of initial phonemes.

The simplest reconciliation of this evidence comes from the view that the developmental analysis is about change and learning, whereas the cross-sectional view is about how children's cognitive processes inter-relate at anyone time. Gathercole, Willis, Emslie & Baddeley (1992) suggested that children with good phonological memory produced memory traces that were phonologically discriminable and persistent in working memory. As a consequence, there was greater chance that for such children the memory traces could become long-term phonological representations in the lexicon. The concurrent data described above seem to give a complementary view. Thus at a certain stage in their phonological development children's phonological awareness draws on their ability to compare phonological representations. Those with greater lexical knowledge will be more likely to have developed the necessary skills to discriminate between lexical items that have phonologically similar representations (Dollaghan, 1994). Children who also have superior memory skills will be able to maintain more items in working memory whilst making the phonological comparisons that are demanded within those tasks. The interaction between memory span and lexical knowledge in predicting awareness of rhyme at age 5-years occurs, it has been suggested, because memory span may be representative of the efficiency of transfer to and from the lexicon, a process thought to implicate the central executive of working memory, and may also represent efficiency of phonological processing within working memory.

On the other hand when it comes to learning about the associations between lexical items and their phonological features, it seems that over time it is an advantage to have an initially smaller processing space. The reasons developed by Elman (1993) and Newport (1990) to explain this suggested that within a smaller processing space it is easier to learn aspects of a language's associative regularities successfully. In comparison with Newport's (1990) studies of how children learn form-meaning associations, in this study it is claimed that children's acquisition of sound-meaning associations might be supported by a similar mechanism. Thus within a restricted subset of the available (adult) language, ie that held within smaller memory spans, it is suggested that children would find it easier to locate the most reliable sound-meaning pairs. Consistent with the views summarised by Aitchison (1994) and the findings of Newport (1990), it has been found that children with smaller memory spans when data was first gathered had, a year later, been more successful at learning the associations between word-initial sounds and lexical items.

7.4.3

The final section of the chapter presented an evaluation of the relationship between lexical knowledge, phonological awareness and reading.

It was shown that an apparent association between vocabulary scores and reading might, in the case of children without any hearing difficulties but not for partially hearing children, be substantially modified when phonological awareness was included in the analysis. It is not unambiguously clear whether or not lexical knowledge and aspects of phonological awareness made separable contributions. There is some indication that rhyme and vocabulary made separate unique contributions to word recognition scores at age 6- and 7-years, and to word reading scores at age 7-years. In the group of oldest children who were beginning to show clear evidence of word reading (as opposed to being able to recognise a printed word when it is spoken) it seems likely that lexical knowledge and phonological awareness were dissociated.

As has been discussed above (§7.3.4), however, there was not, unfortunately any reliable longitudinal evidence to substantiate the separateness of phonological awareness and lexical knowledge. Lexical knowledge can, however, be seen to have made a distinct and separate contribution to the development of children's reading in the group of partially-hearing children. These children showed levels of phonological awareness comparable to children a year younger, and their scores in the test of vocabulary were comparable to children 2-years younger. Their performance in both measures of reading was, however, close to their normally-hearing chronological age peers. In the regressional analyses it was lexical knowledge, not phonological awareness, that offered the best prediction of reading. Phonological awareness, in fact, did not appear to play any part in predicting the reading or word recognition scores of the partially-hearing children.

7.4.4

Overall, therefore, this chapter has suggested that lexical knowledge contributes to phonological awareness. Either indirectly (through phonological awareness), or directly (independently of phonological awareness), lexical knowledge may facilitate word reading.

Clearly further work involving larger and randomly selected groups of children would be required to substantiate these claims. The suggestions made in this chapter would be refuted if a group with poor vocabulary scores were found to have word and non-word reading abilities comparable to children with age-appropriate lexical knowledge. Certainly the conjectures should also be tested in groups of children with developmental language difficulties.

As regards the reading of the partially-hearing children some better explanation for their reasonable performance in the tests of reading should be sought. It would be very interesting to follow a group of similarly impaired children over time to see if their increasing lexical knowledge generated phonological awareness. On the basis of the present evidence, however, it is hard to reconcile that developmental causal mechanism with the finding that the partially-hearing children's phonological awareness was comparable to children aged 6-years whereas their lexical knowledge was comparable to that found in the 5-year old sample.

Chapter Eight

Models of Word Reading

8.0 Overview

In the context of a review of theories of the development of reading some predictions which may be tested within the data available from this study will be outlined and tested in this chapter (§8.1). The relative importance of awareness of Phonological Awareness, Memory Span and Lexical Knowledge will be related (in §8.2) to word-recognition and word-reading abilities in the samples of hearing and hearing-impaired children who form the basis of this study.

The chapter concludes (§8.3) with a discussion of the implications of the work reported in this thesis.

8.1 Existing models of word reading and evidence available within this study

8.1.1 Introduction

A variety of approaches to understanding and modelling the development of word reading have been used by researchers in this field. Rack, Hulme & Snowling (1993) have remarked that many theorists have not attempted to formulate descriptions of gradual improvement from a starting point of non-reading but have rather proposed development progressing in 'stages'. An aim of this part of the study is to see if it is possible to reconcile the data from the present study with a 'staged' description. This section will therefore firstly outline 'stage' models of reading development, the 'dual-route' model of skilled reading, and 'interactive' models of proposed cognitive structures which may be significant to the development of reading, before proceeding to an examination of the fit of the available data to these theoretical models.

8.1.1.1 *'Stage' models*

Of the stage models which have been proposed those of Frith (1985) and Marsh, Friedman, Welch & Desberg (1981) have been amongst the most influential. Each is described below briefly.

8.1.1.1.1 *Marsh et al's (1981) model*

In the model described by Marsh *et al* (1981), children are required to recognise a small number of words by sight by 'rote association between an unsynthesized visual stimulus and an unanalysed oral response' (*ibid*, p201). At this stage of developing reading, Marsh *et al* propose that a child is likely to attempt to predict a word from the context. In the second stage of Marsh *et al's* model, however, visual features are used to discriminate between words, and initial letters may be used to guess an unfamiliar word. An ability to decode words begins to become apparent in the third stage of the model, and emerges, Marsh *et al* proposed, in response to environmental and cognitive factors. Since, in environmental terms the child encounters a rapidly increasing number of words in reading, Marsh *et al* suggested there was a need for children to learn a strategy which would enable them to overcome the potentially impossible memory load of a large volume of whole words. Fortunately the child has, according to this account, gained the cognitive ability to attend to both a word's phonemes and its meaning and these are skills which form the basis of the strategy used at this stage. Marsh *et al* (1981) stated that by the time a child entered the fourth, and final stage of their model (in middle childhood) s/he would be able to demonstrate use the use of analogies, as well decoding phonemes on the basis of information about the phonemic context, in order to read unfamiliar words.

8.1.1.1.2 *Frith's (1985) model*

In Frith's (1985) formulation of her 3-phase model, which she acknowledged was a modification of Marsh *et al* (1981) described above, the child's first words will be read 'logographically', that is on the basis of the distinctive visual or contextual features. In this phase, Frith stated, phonological factors play a secondary role, and words are pronounced *after* they have been recognised. Frith (*op cit*, p307) held that children will, during this logographic phase, utilise their 'basic (and impressive) memory skills... when starting to learn to read... allowing a sizable sight vocabulary to develop.' Recognition of the constituent sounds in words (utilising the child's phonological awareness) becomes a strategy in the second, 'alphabetic', phase of this model. Frith *op cit* suggested that prompts to alphabetic reading arose through experience in learning to spell words. In the final stage of learning to read, children are thought to begin to convert words into orthographic units without phonology. These orthographic units would, Frith stated, be internally represented as abstract letter strings. Frith (*op cit*, p306) distinguished between the logographic and orthographic phases of her model by holding that the latter is 'analytic in a systematic way and by being non-visual.' The orthographic phase is distinct from the alphabetic phase, because it operates with bigger units and is non-phonological.

In both Marsh *et al's* (1981) and Frith's (1985) models in the earliest stages phonological skills are not supposed to be relevant. Phonological skills are posited to play a crucial, but transitory, role at later stages. Other work (eg Bradley & Bryant, 1983; Hatcher, Hulme & Ellis, 1994) has however demonstrated that phonological awareness may have a more continuous role, and that there is a need to link it to other strategies and knowledge, including knowledge about words learned in reading.

8.1.1.1.3 *Seymour & MacGregor's (1984) model.*

Seymour & MacGregor (1984) had earlier developed a model in which phonological and semantic 'processors' were proposed, and held to predate acquisition of reading. At least three different types of lexicon (phonological, logographic and orthographic) are suggested as constituents of this model.

In the first stage of Seymour & MacGregor's (1984) model, as in Marsh *et al's* (1981) and Frith's (1985) models, the beginning reader acquires a small 'sight-word' vocabulary. However, unlike the previous models, specific mechanisms are proposed, via a 'logographic' lexicon, 'to attach these... to preexisting entries in a phonological lexicon and semantic memory system' (*ibid*, p46). In the second stage of Seymour & MacGregor's model, the 'alphabetic' stage, children begin using an 'alphabetic' lexicon to learn the association between individual graphemes and phonemic entries in the phonological lexicon. Seymour & MacGregor *op cit* stipulated, as a prerequisite of the emergence of the alphabetic stage, that children must be able to segment spoken language at the level of the phoneme. The final, 'orthographic' stage, of Seymour & MacGregor's model, emerges when children are able to take account of the 'relations between spelling and meaning' (*ibid* p 48). Seymour & MacGregor (1984) referred to the 'orthographic' lexicon, which begins to emerge at this stage in the form of an upgrade of the alphabetic lexicon, as being 'a general purpose system for translating from print to pronunciation or from phonology to writing' (*ibid* p48).

Although Seymour & MacGregor's (1984) model is more complex than those of Marsh *et al* (1981) and Frith (1985), and despite Seymour & MacGregor's (1984) case study details from a group of developmental dyslexics (aged 11 to 25 years), in which the various 'lexicons' that are proposed support a differentiation of sub-types of dyslexia, it is not clear that the distinctions proposed are necessary for an adequate understanding of the normal development of reading. Three sources of evidence in fact suggest that it would perhaps seem more parsimonious in the context of the normal development of word reading to consider only the functioning of *a* lexicon in which entries have phonological labels. Firstly the evidence relating to the lexicon and phonology (reviewed in Chapter 7). Secondly the widely accepted findings (see Snowling (1996) and Chapter 4 above) that the acquisition of phonological processes underlies the development of reading. And lastly the description of the relation between the logographic, alphabetic, and orthographic, lexicons and the phonological lexicon given by Seymour & MacGregor's (1984). This possibility is further discussed below.

8.1.1..2 *'Dual-route' models*

In contrast to the 'stage' models which provide descriptions of the development of children's reading, the 'dual-route' theories of reading (Coltheart, 1978; Humphreys & Evett, 1985) were originally put forward as models of skilled adult reading. The essentials of these models may be stated simply. The 'direct' route proceeds from a printed word to the lexicon where the word's meaning is accessed without any requirement for phonological representations. Following this, the phonological representation of the word is activated. The alternative, and strictly independent 'indirect' route, involves prelexical formation (or assembly) of the word's phonological representation. This phonological representation then provides access to the lexicon. Some commentators (eg Stuart & Coltheart, 1988) have suggested that children in the early stages of reading development can show evidence of the use of either route. Other writers (eg Barron, 1986; Rack, Hulme & Snowling, 1993) have suggested that although surface behaviours might indicate otherwise, the models can be described more parsimoniously as the outcome of a single mechanism. Barron's (1986) view was that according to the 'dual-route' model phonological representations could not be assembled with any reference to lexical knowledge. This seems to deny the evidence (Reitsma, 1983; Waters, Seidenberg & Bruck, 1984) discussed in Chapter 7 that lexical knowledge does influence the assembly of phonological representations in the process of word reading.

8.1.1.3 *'Interactive' models*

Barron (1986) suggested that an alternative single process model might exist in which orthographic and phonological processing interacts within the lexicon. Adams (1990) and Adams & Bruck (1993), building on the work of Seidenberg & McClelland (1989), similarly describe an interactional model in which orthographic and phonological processors correspond with each other and a 'meaning processor'. Hulme, Snowling & Quinlan (1991) were critical of the Seidenberg & McClelland (1989) model, and suggested that a psychologically more plausible view of early reading development would take account of the phonological representations, within a lexical store with direct connections to an orthographic store, which are well established by the time children begin to learn to read. Snowling *et al* (1991) were not however able to elaborate the details of how the model might operate.

In the more detailed model described by Barron (1986) however it was proposed that in the process of reading children would use lexical knowledge to help in the segmentation of words, the application of letter-sound correspondences (the GPC rules proposed by Venezky (1970) and Wijk (1966)) and in assembling phonological representations. Thus, for example, it might be thought that lexical knowledge would be involved in the decision not to segment *ph* in *telephone*, and in the decision to separate the *p* and the *h* in *shepherd* (Henderson, 1982). Barron (1986) proposed that GPC rules might be accommodated within a 'lexical' model of reading by contributing 'a set of procedures for segmenting, sequencing and retaining one level of orthographic units within an interactive system of developing lexical knowledge.' (*ibid* p115). Barron (*op cit*) indicated that such a model could accommodate data from developing, as well as skilled, readers, but did not provide any account of observable developmental changes in strategy.

8.1.2 <u>Testable Predictions</u>

In this section conjectures are proposed which derive from some of the above models and may be tested within the data from the children who participated in this study.

8.1.2.1 *Marsh's theory*

In Marsh *et al's* accounts (Marsh,Friedman, Welch & Desberg, 1981; Marsh, Friedman, Desberg & Saterdahl, 1981) it is evident that phonological awareness was not considered to play a part in children's earliest (stage 1) 'rote associations' between visual stimuli and their oral responses. At this stage children are, according to Marsh *et al*, reading words as logograms, and are not using any 'decoding' strategies, but rely heavily on semantic and syntactic contexts to aid their 'linguistic guesses'. Since, on this basis, phonological skills are not necessary,

> associations between phonological awareness and early word recognition or word reading ability would not be expected,

though clearly both could be associated if each is similarly affected by a third factor. If a semantic factor is an important determinant at this stage there might be evidence of an association between lexical knowledge and word recognition.

In the second and third stages of Marsh *et al*'s model, however, phonological awareness might be expected to be related to word reading and recognition. In the second stage, which was predicted by Marsh *et al* to be evident by second grade (ie age 7 years), children are thought to be using some initial letter cues to guess unfamiliar words. It might be expected therefore that children with greater ability to identify initial phonemes would be relatively more successful at matching printed stimuli to the spoken equivalents. In the present study therefore,

> the performance of children who are becoming proficient at both word recognition and reading would be expected to be associated with their performance in the test of awareness of initial phonemes. In terms of Marsh *et al*'s chronology, this should be observable in the 7-year-old (Y2) children in this study.

In the third stage, awareness of phonemes and lexical knowledge would be important factors relating to reading ability, since Marsh *et al* postulated that at this stage children would be cognitively able to begin attending to both a word's sound and meaning. Since Marsh *et al* indicated that this strategy is unlikely to emerge before the age of 8-years, this association might only be expected to be found amongst the oldest and most proficient children in this study.

Overall therefore, if Marsh's model is supported by the evidence of this study, it should be possible to discriminate between those children who had minimal word reading ability which would not be associated with abilities in the tests of phonological awareness, as opposed to the most competent readers in the study, amongst whom word reading abilities should be closely associated with both phonological awareness (particularly awareness of initial phonemes) and lexical knowledge. Marsh *et al's* model might be challenged by either:

a) evidence of an association between phonological awareness and word reading at the earliest stage;

or,

b) no evidence that both lexical knowledge and awareness of initial phonemes was associated with reading at a later stage when the ability to decode unfamiliar words was evident.

8.1.2.2 *Frith's theory*

In a similar manner evidence from this study in support of Frith's (1985) model would consist of differing patterns of association between variables at each of three stages in the development of reading.

In the first, and earliest stage of reading, according to Frith's model phonological assembly of a word should occur *after* a word had been recognised. In the Carver test of word recognition, phonological assembly is not necessarily entailed since children are not required to make a verbal response. It might be anticipated therefore that

no association between word recognition and phonological awareness would be necessary.

Frith's theory does, however, imply an association between word recognition and lexical knowledge at this stage.

In the second phase of Frith's model, recognition of constituent sounds within words is held to be a strategy.

Thus phonological awareness would be predicted to be associated with word recognition,

and, since Frith (1985, p306) explicitly referred to children's 'knowledge and use of individual phonemes and graphemes and their correspondences', it may be anticipated that

children's reading at this stage would be particularly associated with performance in the test of awareness of initial phonemes.

In the final phase of her model however, Frith (1985) claimed that children would use non-phonological strategies to analyse words into orthographic units. Snowling & Frith

(1981) had found that by a reading age of about 7 years children were using orthographic cues more than phonological cues. In this study therefore

> an association between reading and phonological awareness might not be expected in children with a reading age of at least 7 years.

The existence of such an association is not ruled out by Frith's theory, but although Frith (1985, p306) suggested that children may "fall back" on earlier strategies, she also claimed that once the orthographic strategy has become established, previous strategies would be less accessible. Since Frith claimed that, at this stage, orthographic units would be likely to coincide with units of meaning, an association between reading ability and lexical knowledge might be expected. A radical prediction that would be consistent with Frith's theory therefore would be that

> for the most advanced readers in this study, their word reading ability would not be associated with phonological awareness but would be associated with lexical knowledge.

Frith's theory of this stage would be challenged by

> evidence of a significant association between phonological awareness and reading, with no association between reading and lexical knowledge or between phonological awareness and lexical knowledge.

8.1.2.3 *Seymour & MacGregor's theory*

It seems, from Seymour & MacGregor's (1984) account that at all three proposed stages, lexical knowledge and phonological awareness should be associated with reading.

In the first, 'logographic' stage (see also Seymour & Elder,1986) however, phonology plays a subsidiary role, as in Frith's (1985) model, and is described in terms of the 'phonological lexicon' against which visual forms of words may be matched (*op cit*, p46). The conceptualisation of a 'phonological lexicon' with a role in word recognition at this stage therefore implies that

> lexical knowledge would be associated with phonological awareness and, that lexical knowledge would be associated with word recognition.

It would not however be expected that

> phonological awareness would be found to be associated with word recognition once the effects of lexical knowledge (which, as has been demonstrated in the previous chapter, have a phonological component) have been taken into account.

In the second stage of Seymour & MacGregor's (1984) model, a stated prerequisite (*op cit* p 48) is that children should have the ability to segment spoken language at the level of the phoneme. It is also explicitly predicted (*op cit* p 47) that knowledge of individual graphemes and their speech sounds would be correlated at this stage and linked to representations in the 'alphabetic' lexicon. Since this lexicon is described by Seymour & MacGregor (1984) in terms of a system for the recognition of graphemes, whose elements are aligned with phonemic categories in the phonological lexicon, it might be expected therefore that

> both awareness of initial phonemes and lexical knowledge would be associated with reading in the second stage of this model.

In the final 'orthographic' stage of development outlined in Seymour & MacGregor's (1984) model the 'orthographic lexicon' is held to be an upgrade of the 'alphabetic' lexicon, and is a system for 'translating from print to pronunciation or from phonology to writing' (*ibid* p 48). In Seymour & MacGregor's description, this lexicon contains an alignment of phonological and semantic lexicons. An association between performance in measures of phonological awareness and lexical knowledge and performance in reading might thus be expected at this stage.

> In the present study the association of phonological awareness and lexical knowledge should be evident in relation to both word reading and word recognition tasks.

In the case of word reading (BAS test), children are required to decode a printed stimulus. As this involves 'translating from print to pronunciation', at this stage of Seymour & MacGregor's model the orthographic lexicon would entail the use of both phonological skills and lexical knowledge. The word recognition task (Carver test) could be considered to involve translating from 'phonology to writing' because in this task children have to match an auditory (spoken) stimulus with orthographic information. Children whose lexical knowledge and phonological skills are both good would be advantaged in this task, according to Seymour & MacGregor's formulation, by virtue of having clearly delineated mappings of both phonological and orthographic segments onto semantic addresses.

8.1.2.4 *Barron's theory*

As outlined by Barron (1986) word recognition in early reading develops as a result of the influence of lexical knowledge on the formation of phonological representations.

Barron also suggested that children learn to segment printed words into two types of unit: 1) letter-sound units (most likely consonants) and 2) letter cluster-sound units (which correspond to the final part of syllables) which would be used particularly in the application of analogies (Goswami, 1986; Treiman, 1985a) within reading. The indications from Goswami (1986) and Treiman (1985a) are that younger, less proficient readers are less likely to use initial letter-sound units than more experienced readers. Thus Barron's theory would, in the terms of the present study, predict

> a relationship between phonological awareness and lexical knowledge that changed from one in which awareness of rhyme was a correlate of lexical knowledge and word recognition amongst the youngest and less experienced readers, to one in which awareness of initial phonemes and lexical knowledge would be closely associated with reading in the older and more proficient readers.

8.1.2.5 *Summary*

The predictions which can be made from the theories outlined above and tested within the data available in this present study involve differences in the relationship between aspects of phonological awareness, lexical knowledge and word recognition and reading.

The 'stage' theories of Marsh *et al* (1981) and Frith (1985) do not implicate lexical knowledge except in the final stage of Marsh *et al*'s model. In contrast, the model outlined by Seymour & MacGregor (1984) and the interactive model of Barron (1986) both entail an inter-relationship of phonological awareness and lexical knowledge.

8.1.3 <u>Testing the predictions derived from theories</u>

In order to test the predictions derived from the 'stage' theories outlined above the entire data set (from 90 children) was partitioned into three groups on the basis of the children's performance in the Carver test of word recognition. In this way three groups of readers at three different 'stages' of proficiency in reading may be examined.

The Carver test (described in §3.3.6.1) provides a measure of children's ability to match printed words to spoken stimuli. Over the entire group of 90 children performance in this measure correlates very highly with performance in the BAS test of word reading (Spearman $\rho=0.82$, $p<0.01$).

8.1.3.1 *Partitioning the sample*

It was intended that the three groups should represent children who: a) had yet to demonstrate any proficiency; b) were becoming proficient; and c) had achieved proficiency in reading which might be compared with Snowling & Frith's (1981) criterion for 'orthographic' strategies at a reading age of 7 years. The data was therefore partitioned on the basis of Carver test scores of: a) a score of 2 or less (ie highly likely to have achieved a score by chance - $p \approx 0.5$); b) a score in the range 3 - 5; c) a score of 6 or more (unlikely to be achieved by chance - $p<0.01$) . On this basis it was found that there were exactly 30 children in each of the three groups. The characteristics of the three groups are shown in Table 8.1 (below).

Table 8.1: Means (sd) for three groups (partitioned by performance in Carver test) of children in word recognition (Carver), Chronological age (in months), nonverbal ability (Ravens matrices), phonological awareness (Rhyme / Initial Phoneme) lexical knowledge (BPVS) and word reading (BAS)

	Group 1	Group 2	Group 3
Carver	1.07 (.69)	3.57 (.63)	8.0 (1.4)
Age	62 (7.5)	67.3 (8.3)	79.5 (4.9)
Ravens	14.8 (3.2)	15.5 (3.8)	19.5 (5.0)
Rhyme	4.6 (2.0)	6.1 (2.2)	7.7 (1.8)
Initial Phoneme	3.7 (1.3)	5.1 (2.4)	7.8 (1.8)
BPVS	9.9 (2.7)	10.7 (2.9)	14.2 (2.6)
BAS	-	0.67 (1.7)	20.4 (18.1)

The mean BAS raw score of 20.4 obtained by children in group 3 has a reading age equivalent to 6.5 years (Elliot, Murray & Pearson, 1983). The children in this group with at least a raw score of 20 may therefore be considered as being near to entering the 'orthographic' stage in Frith's (1985) and Snowling & Frith's (1981) terminology.

Inspection of the coefficients of kurtosis and skew for this data revealed a moderate negative skew for the phonological awareness scores in Group 3. This was alleviated for the purposes of subsequent analysis by reflecting and taking the square root (ie $f(x)=\sqrt{(10-x)}$) for awareness of Rhymes in Group 3, and by reflecting and taking natural logarithms (ie $f(x)=\ln(10-x)$) in the case of awareness of Initial Phonemes in Group 3. Word Reading (BAS) scores were also clearly not normally distributed. For the purposes of correlational analysis however, since Spearman correlations by ranks were calculated, untransformed data was used.

That there were differences by scores in word recognition, nonverbal ability, lexical knowledge and age across the three groups was confirmed by means of one way analyses of variance and post-hoc Scheffé pairwise tests. For the Carver test scores $F=369.9$ ($p<0.01$) with significant differences between groups 1&2, 1&3, and 2&3; for Ravens $F=11.7$ ($p<0.01$) with significant differences found between Groups 1&3, and between groups 2&3; for BPVS $F=21.2$ ($p<0.01$) with significant differences between groups 1&3 and 2&3; and for Age $F=48.4$ ($p<0.01$), with significant differences between groups 1&2, 1&3, and 2&3.

It is evident therefore that the three groups do differentiate between different levels of reading ability, and also that the groups represent different ages of children. It should be noted that children in groups 1 &3, and 2 & 3 showed different levels of non-verbal ability. This would be expected since the Raven's matrices scores are raw scores which should show age-related increases. However the possibility that different levels of performance in the groups are due to nonverbal ability will be addressed below (see table 8.3).

Differences between the three groups' performance in each measures of phonological awareness was confirmed by means of Kruskal-Wallis one-way analyses of variance by ranks. For awareness of Rhymes $KW=27.4$ ($p<0.01$); for awareness of Initial Phonemes $KW=39.0$ ($p<0.01$). Pairwise comparisons were also undertaken using Mann-Whitney tests which indicated significant differences for all pairs of groups.

In order to establish if the three groups are differentiable by the effects of phonological awareness or lexical knowledge, over and above the effects of nonverbal ability three analyses of covariance were undertaken. Nonverbal ability (Ravens matrices scores) was entered as the covariate, with scores in either measure of phonological awareness (transformed as above for all three groups) or lexical knowledge (BPVS scores) as the dependent variable. Correlations between variables (using transformed scores) are shown in Table 8.2. The F-ratios are reported in Table 8.3.

Table 8.2: Pearson coefficients of correlation between variables in entire data set (n=90).

	1	2	3	4	5	6	7
1. Carver	1						
2. Age	0.71**	1					
3. Ravens	0.48**	0.49**	1				
4. Rhy	0.57**	0.45**	0.33**	1			
5. IPh	0.73**	0.56**	0.42**	0.72**	1		
6. BPVS	0.55**	0.49**	0.49**	0.42**	0.59**	1	
7. BAS†	0.87**	0.70**	0.49**	0.53**	0.70**	0.55**	1

**p<0.01; †BAS scores transformed as log(1+BAS)

Table 8.3: F-ratios for between groups analyses of covariance with Ravens matrices (nonverbal ability) scores as covariate.

DV:	Rhyme	Initial Phoneme	BPVS
F(2,86)	18.3**	24.9**	10.9**

**p<0.01

On the basis of these analyses it is safe to conclude that there are differences between the three group's awareness of rhymes and initial phonemes, and between the group's mean lexical knowledge over and above the differences in nonverbal ability between groups.

8.1.3.2 *Analysis*

8.1.3.2.1 *Tests of predictions of Marsh et al's (1981) and Frith's (1985)stage models*

In order to test if there were specific stages when phonological awareness was associated with reading ability, as was predicted from Marsh *et al*'s (1981) and Frith's (1985) models, simple bivariate (Spearman) correlations between phonological awareness variables and word recognition and between lexical knowledge (BPVS) and word recognition were calculated for each group. These are shown in Table 8.4 (below).

Table 8.4: Spearman rank correlations between Phonological awareness (Rhyme/Initial Phoneme), BPVS and Word Recognition (Carver) in Groups 1,2 & 3 or Word reading (BAS) in Group 3

	Group 1	Group 2	Group 3
Carver x			
Rhyme	0.03 ns	0.16 ns	0.39*
Initial Phoneme	0.21 ns	0.33 ns	0.51**
BPVS	0.02ns	0.06ns	0.14ns
BAS x			
Rhyme	-	†0.13 ns	0.49**
Initial Phoneme	-	†0.39*	0.23 ns

*p<0.05; **p<0.01; †to be treated with caution since there are only 5 non-zero BAS scores in Group 2.

These results indicate that for children in Groups 1 & 2 (ie those whose Carver scores might have occurred by chance) there was a) no significant association between word recognition and either type of phonological awareness, as might be predicted by both Marsh *et al* (1981) and Frith (1985); but b) no association between lexical knowledge and word recognition, which seems to contradict the predictions derived from the two theoretical models. The finding of some association between phonological awareness and word recognition / reading in Group 3 is also in line with Frith's model if these children are held to be still at a stage of consistently using orthographic strategies.

It was indicated in §8.1.2.1 that the model of Marsh *et al* (1981) would predict that the most competent readers would show associated skills in awareness of Initial Phonemes, Lexical Knowledge and reading. Accordingly the correlations between the relevant variables in Group 3 have been computed and are shown in Table 8.5.

Table 8.5: Spearman rank correlation coefficients for awareness of Initial Phonemes (IPh), Lexical knowledge (BPVS), Word recognition (Carver) and Word reading (BAS) in Group 3 (n=30)

	IPh	BPVS	Carver
IPh			
BPVS	0.13 ns		
Carver	0.51**	0.14 ns	
BAS	0.23 ns	0.21 ns	0.44*

*p<0.05;**p<0.01

This does not indicate that for the more proficient readers in this study there is a simple correlation between vocabulary size and either measure of reading.

Since Snowling & Frith (1981) had suggested that the 'orthographic' strategy that characterises stage 3 of Frith's (1985) model would not be established in children with reading ages of less than 7 years, a further partitioning of the data was performed in order to establish if, within the sample of children who had participated in this study, there was evidence to support the conjectures derived from Marsh *et al* (1981) and Frith (1985) relating to performance in the 'orthographic' stage.

The BAS scores were therefore re-examined in order to construct a group of children with mean reading-age equivalents of 7-years. In the manual for administration of the BAS test (Elliot, Murray & Pearson, 1983) a reading age of 7-years corresponds to a raw-score of 35 for the subtest (A) that was used in this study. The procedure that was adopted was to successively delete from the data set the children whose BAS scores maintained a mean BAS score below 35. Thus the first children to be deleted had BAS raw scores of 12. Children with higher scores were progressively deleted until the mean raw-score lay above 35. The resulting data set (now consisting of 11 children, mean scores shown in Table 8.6) was examined for associations between phonological awareness, lexical knowledge and reading, using Spearman rank correlations. The results of this analysis are shown in Table 8.7.

Table 8.6: Mean (sd) scores for awareness of Initial Phonemes (IPh), Lexical knowledge (BPVS), Word recognition (Carver) and Word reading (BAS) for the group with mean BAS reading age equivalent greater than 7 years. (n=11)

Rhy	IPh	BPVS	Carver	BAS
8.4 (1.5)	8.4 (1.0)	14.8 (2.3)	8.8 (1.1)	39.2 (17.2)

Table 8.7: Spearman rank correlation coefficients for awareness of Initial Phonemes (IPh), Lexical knowledge (BPVS), Word recognition (Carver) and Word reading (BAS) for the group with mean BAS reading age equivalent greater than 7 years. (n=11)

	Rhy	IPh	BPVS	Carver
Rhy				
IPh	0.47 ns			
BPVS	-.33 ns	-.38 ns		
Carver	0.29 ns	0.74*	-.37 ns	
BAS	0.35 ns	0.15 ns	0.36 ns	-0.03 ns

*p<0.05

In support of both Marsh *et al* (1981) and Frith (1985) who conjectured that children able to use an 'orthographic' strategy would not utilise phonological skills, this analysis does not show any association between phonological awareness and word reading as measured by the BAS test. This finding is not however reconcilable with the evidence of an association between word recognition (Carver test) and awareness of initial phonemes. This association is suggestive that what Frith (1985) termed 'alphabetic' strategies might still persist in relation to the word recognition task. Also, contrary to the prediction derived from Marsh *et al* (1981), there is no evidence that these children's performance in reading or word recognition was associated with their lexical knowledge.

8.1.3.2.1.1 *Conclusion*

The above analyses of data available from children grouped according to their proficiency in word recognition shows that for the least proficient readers' word recognition ability did not appear to be associated with awareness of either rhymes or initial phonemes. The more proficient readers did, however, show skills in phonological awareness that were associated with their proficiency in word recognition and word reading. This is in agreement with the general predictions that were made on the basis of the 'stage' models of the development of reading due to Marsh *et al* (1981) and Frith (1985). However it was in Group 3 that associations between phonology and reading were found which might indicate that the children in this group were in fact at stage 2 of Frith's model. This group did not however show any association between Word Reading scores and awareness of initial phonemes as was predicted for Stage 2.

When, in line with the findings of Snowling & Frith (1981), the group of children with a mean reading age of 7-years was examined the association between word reading and phonological awareness was not greater than might be expected by chance. This is supportive of the idea that the children in the most advanced phase of Frith's (1985) model would not be characterised by the use phonological strategies. There is, however, some evidence that these competent readers' awareness of initial phonemes was associated with their performance in the word recognition task. This suggests that the 'alphabetic' strategy was still relevant to this task for the children at this stage of development. Further, there is no evidence that these children's performance in word reading or word recognition was associated with lexical knowledge. Since lexical knowledge and awareness of initial phonemes were not significantly associated it may also be concluded that there is no indirect association of lexical knowledge and word recognition mediated by awareness of initial phonemes.

The absence of evidence of any association between these children's lexical knowledge and their performance in either reading task is contrary to the predictions which arose from Marsh *et al* (1981), who suggested that in the latter stages of development children would show the ability to attend to both a word's sound and its meaning.

Clearly the methodology of the present study is not sufficient to determine if children were actually using a given strategy whilst reading, but this evidence does suggest that skills in the domains of phonology and lexical knowledge are not necessarily associated with each other or with performance in the reading of the most competent readers in this study.

8.1.3.2.2 *Tests of predictions of Seymour & MacGregor's model*

In the above description of Seymour & MacGregor's (1984) account of stages in the development of reading (§8.1.2.3) both lexical knowledge and phonological awareness were postulated to be associated with reading tasks in some degree at all stages. Although, from the previous section (§8.1.3.2.1) it seems unlikely that such associations may be found, the following table (8.8) is provided to show the bivariate (Spearman) correlations between phonological awareness variables, lexical knowledge and reading tasks in each of the three groups whose summary data was provided in Table 8.1 (above).

Table 8.8: Spearman rank correlations between phonological awareness (Rhyme, Initial Phoneme), lexical knowledge (BPVS), word recognition (Carver) and word reading (BAS) in each of three groups partitioned on the basis of performance in the Carver test (n=30 for each group)

	Rhy	IPh	BPVS	Carv
Group 1				
Rhy	1			
IPh	0.75**	1		
BPVS	0.17 ns	0.33 ns	1	
Carv	0.03 ns	0.21 ns	0.02 ns	1
BAS	-	-	-	-
Group 2				
Rhy	1			
IPh	0.40*	1		
BPVS	0.27 ns	0.46*	1	
Carv	0.16 ns	0.33 ns	0.06 ns	1
BAS†	0.13 ns	0.39*	0.17 ns	0.38*
Group 3				
Rhy	1			
IPh	0.66**	1		
BPVS	0.04 ns	0.13 ns	1	
Carv	0.39*	0.51**	0.14ns	1
BAS	0.49*	0.23ns	0.21ns	0.44*

*p<0.05; **p<0.01; † to be treated with caution since there are only 5 non-zero BAS scores in Group 2.

On the basis of this analysis it does not seem likely that the conjectures derived from Seymour & MacGregor's (1984) can be fully upheld by the data from this study.

Seymour & MacGregor (1984) also indicated that in the first stage of reading the 'logographic lexicon' would be a critical component which could discriminate between the visual forms of a small number of "sight words" and match these to entries in the 'phonological lexicon'. It was therefore proposed in §8.1.2.3 that phonological awareness would not be associated with visual word recognition (Carver test) once the effects of lexical knowledge had been taken into account. In Table 8.7 it can be seen that neither BPVS scores nor phonological awareness (neither rhyme nor initial phoneme awareness) was associated with Carver scores in Group 1. There is no evidence here therefore in support of stage 1 of Seymour & MacGregor's (1984) model.

At stage 2, the 'alphabetic', it was suggested (in §8.1.2.3) that awareness of initial phonemes would be linked to lexical knowledge and reading. In Table 8.8 it can be seen that awareness of Initial Phoneme scores was correlated with both BPVS scores and BAS scores, but that BPVS scores were not correlated with BAS scores. This suggests that awareness of Initial Phonemes is aligned with lexical knowledge, and that awareness of Initial Phonemes is associated with word reading ability, but that lexical knowledge is not associated with word reading. Whilst this conflicts with one possible view of Seymour & MacGregor's (1984) model in which all three postulated lexicons are closely inter-related, Seymour & MacGregor in fact outline the processing assumptions of their model as separating orthographic and semantic processes, with the phonological processor as an intermediary. Within the orthographic processor visually presented letter strings are segmented into units which may be recognised within the orthographic lexicon. The alignment of the orthographic lexicon with the phonological processor is thought to allow for the pronunciation of words located in the lexicon. In this model once elements of the orthographic lexicon have been assigned to phonological categories there may be reference to the semantic processor. This cross-reference is not however necessary before the 'word' is spoken. On this basis the present data may be seen to be consistent with Seymour & MacGregor's (1984) model in that the visual stimulus of individual words in the BAS test are subject to orthographic analysis, which is aligned to awareness of phonemes. The phonological categories which are activated by this orthographic input are associated with semantic entries (assessed here by the BPVS scores). There is, however, no evidence of likely direct facilitation of visual processing by the size or quality of the lexical data represented by BPVS scores. Clearly, though, these inferences must be regarded as highly speculative since there were only 5 non-zero BAS scores to be related to performance in other measures.

A characteristic of the third, and final, 'orthographic', stage of Seymour & MacGregor's (1984) model of reading, which is held to be an upgrade of the the 'alphabetic' stage, it has been suggested, would be more fluent translation of print to speech. In §8.1.2.3 it was suggested that this would be evidenced by further associations between phonological awareness, lexical knowledge and reading. Again, as can be seen in Table 8.8, in Group 3 there is no evidence that lexical knowledge (BPVS scores) was associated with either measure of reading or phonological awareness, although phonological awareness scores were associated with aspects of reading. It is possible that this lack of association in the 'orthographic' stage between lexical knowledge and reading is a consequence of low reading age (Snowling and Frith, 1981). However with reference to Table 8.7 (above), where the associations within the group of children with a mean reading age of 7 years are reported, it can be seen there that none of the coefficients of interest are greater than might be expected by chance. It may thus be concluded that for the group of children in this study with most advanced skills in reading it is unlikely that they conformed to the predictions derived for stage 3 of Seymour & MacGregor's model.

8.1.3.2.2.1 *Conclusion*

Overall it does not seem that the data available from this study is supportive of the conjectures derived from Seymour & MacGregor (1984). An interpretation of the analysis of the data in Group 2 (children who were becoming proficient in word recognition) is compatible with the description of Stage 2 - the 'alphabetic' stage - in Seymour & MacGregor's (1984) model, but there is no evidence which supports the descriptions of Stages 1 or 3.

8.1.3.2.3 *Tests of predictions of Interactive models*

In contrast to the models of the development of reading that have been examined so far, Barron's (1986) formulation does not make reference to distinct phases, and, in concluding in favour of a 'single process lexical model' (*ibid* p93), may be a simpler description of possible mechanisms which address the issue of how readers learn to access the meaning of printed words.

On the basis of the predictions outlined in §8.1.2.4 that for younger, less proficient readers word recognition skills would be more likely to be associated with rhyme and lexical knowledge, whereas for older more proficient readers reading would be more closely associated with awareness of initial phonemes and lexical knowledge, it was decided for the purposes of this investigation to partition the full data set in age groups and to compare the youngest (5-year-old, R-group) and oldest (7-year-old, Y2-group) children. This partition yielded two groups each comprising 30 children. The data for this partitioning are summarised in Table 8.9.

Table 8.9: Means (sd) of age (in months), non-verbal ability (Rav), awareness of Rhymes (Rhy), awareness of Initial Phonemes (IPh), lexical knowledge (BPVS), word recognition (Carv), and word reading (BAS) in two groups of 30 children

	Age	Rav	Rhy	IPh	BPVS	Carv	BAS
R-Gp	57.3 (1.7)	13.9 (3.3)	4.7 (2.3)	3.8 (1.5)	9.8 (3.1)	1.9 (1.5)	O
Y2-Gp	81.8 (1.5)	18.9 (4.8)	7.3 (1.9)	7.2 (2.2)	13.5 (3.0)	7.0 (2.4)	17.4 (18.1)
Z†	-6.7**	-3.7**	-4.1**	-5.0**	-4.1**	-6.0**	-6.2**

**p<0.01; †z-test statistic for Mann-Whitney test of differences between groups.

The coefficients of kurtosis and skew were checked for the data for each variable in each group and, with the exception of BAS scores in Y2, were all found to lie within acceptable limits. By taking natural logarithms of (1+BAS) in Y2 scores the high positive coefficients of skew and kurtosis were reduced to lie within acceptable limits.

Differences between raw scores for variables in the two groups were tested by use of the Mann-Whitney test, and, as can be seen on Table 8.9, all differences were found to be significantly greater than might be expected by chance.

The Spearman rank correlations between variables in each group are reported in Table 8.10.

Table 8.10(a) Coefficients of Spearman rank correlations between variables for R-group (5-year-old) children (n=30)

	Age	Rav	Rhy	IPh	BPVS
Age					
Rav	0.2 ns				
Rhy	0.02 ns	0.20 ns			
IPh	0.20 ns	0.05 ns	0.79**		
BPVS	0.18 ns	0.55**	0.47**	0.48**	
Carv	0.14 ns	-.07 ns	0.30 ns	0.45*	0.18 ns

*p<0.05; **p<0.01

Table 8.10(b): Coefficients of Spearman rank correlations between variables for Y2-group (7-year-old) children (n=30)

	Age	Rav	Rhy	IPh	BPVS	Carv
Age						
Rav	0.47**					
Rhy	-.05 ns	0.14 ns				
IPh	0.10 ns	0.12 ns	0.78**			
BPVS	0.24 ns	0.20 ns	0.24 ns	0.41*		
Carv	0.38*	0.41*	0.50**	0.63**	0.38*	
BAS	0.21 ns	0.45*	0.60**	0.51**	0.48**	0.65**

*p<0.05;**p<0.01

Since, in the analysis of the 7-year-old children, it became apparent that both Age and non-verbal ability (Rav) were associated with other variables partial correlations were calculated with variance due to Age and Ravens matrices removed. The salient results of this are reported in Table 8.11.

Table 8.11: Coefficients of partial correlation (effects of age and non-verbal ability removed) for group of 7-year-old children (n=30)

	Rhy	IPh	BPVS
Rhy			
IPh	0.775**		
BPVS	0.226ns	0.4*	
Carv	0.467**	0.617*	0.376*
BAS	0.582**	0.66**	0.479**

*p<0.05;**p<0.01

From this analysis (Table 8.10a) it is possible to conclude that when the sample is partitioned by age rather than level of functioning the youngest children in this study showed an awareness of rhymes and initial phonemes which was associated with their lexical knowledge. These children's awareness of initial phonemes was also related to their performance in the test of word recognition. Their lexical knowledge was not, however, associated with their abilities in the test of word recognition.

The oldest children, on the other hand, did not show levels of awareness of rhyme which were associated with their lexical knowledge (see Table 8.11). Awareness of initial phonemes was associated with lexical knowledge. Performance in both measures of reading were associated with both measures of phonological awareness and with lexical knowledge.

8.1.3.2.3.1 *Conclusion*

From the above analysis it may be concluded that Barron's (1986) proposals are partially supported by the data from this study in that the oldest children's lexical knowledge was associated with both their awareness of initial phonemes and their reading and word recognition skills, whereas their awareness of rhymes was not associated with lexical knowledge. Awareness of rhymes was however associated with lexical knowledge in the group of 5-year-old children. In this respect an aspect of the relationship between phonological awareness and lexical knowledge did change with age in line with Barron's (1986) theory. The data in this study for the 5-year old children (beginning readers) does not however conform to Barron's model, since lexical knowledge was not found to be associated with word recognition in this group. It therefore seems that on the basis of an age-based partition of the data there is closer agreement between the data and Barron's theoretical model for older children in this study. However when the data is explored on the basis of different levels of functioning (the analytic strategy adopted in preceding sections) no awareness between lexical knowledge and awareness of initial phonemes was found.

8.1.4 Summary and discussion

Analysis of the extent to which the data available from this study conforms to predictions from existing models of reading and its development suggests that none of the theories reviewed here is able to provide a full account of the relationship between variables in this study. There is some evidence which accords with the use of 'alphabetic' strategies (Stage 2 of Frith's (1985) and Seymour & MacGregor's (1984) models), but although an association between phonological awareness and word recognition was not found at stage 1, an association between lexical knowledge and word recognition was not found either. The first of these 'non-results' is as was predicted would be found for data conforming to this model, however the second seems contrary to what might be anticipated from the descriptions given by Marsh *et al* (1981) and Frith (1985). Overall therefore the pattern of results must be regarded as neutral with respect to any possible reconciliation of theory and data at stage 1 of these models.

For the group presumed to be at stage 3 the picture is, conversely, that phonological awareness *was* found to be associated with word recognition which is again counter to the predictions derived from Marsh *et al* (1981) and Frith (1985).

With respect to Seymour & MacGregor's (1984) model, the data again does not seem to provide any clear confirmation or refutation of the predictions for children at stage 1 - since both phonological awareness and lexical knowledge were not associated with word recognition. At stage 3 of Seymour & MacGregor's (1984) model it was again predicted that both phonological awareness and lexical knowledge would be associated with word recognition. However, since analysis of the data does not indicate that there was an association either between lexical knowledge and word recognition or between lexical knowledge and phonological awareness, it seems that the existence of a 'phonological' lexicon is an untenable concept in relation to these children's word recognition. Further, it seems (contrary to the conjectures derived from the theory) that even when the data from the most competent readers in this study are examined (Tables 8.6, 8.7), there is no evidence of an association between lexical knowledge and word recognition or word reading. It may therefore be concluded that on this analysis the data from this study is not supportive of Seymour & MacGregor's (1984) view of stage 3 of their model and the role of the lexicon in word reading.

Similarly the interactive model, typified here by Barron's (1986) description, was found to be supported by the data from older children, but not by the data from the youngest children. It has been noted that the tests of prediction derived from Barron's (1986) model was carried out on a partitioned set of data in which the partitioning was carried out on the basis of age, rather than, as had been the case in the tests of the preceding models, on a partitioning of the data based on levels of achievement in reading.

Overall therefore it seems it has been possible to show that the theories which have been examined may provide an understanding of older children who are becoming proficient at reading, but have not reached a level of full competence. The theories examined do not however seem to provide an adequate description of the children in this study who were just starting to develop some word recognition ability. However all the analyses carried out in this section have been of bivariate relationships. It may be argued that a more 'realistic' stance is to consider multivariate relationships. This is precisely what will be done in the following section. Conceptually this approach contrasts with a linear progression of developmental stages (as exemplified by the models of Marsh *et al* (1981) and Frith (1985)) in that it will be possible to consider the changing relationship of variables 'in parallel' with age.

8.2 Towards a statistical model of word reading

8.2.1 Introduction

The task that will be addressed in this section is to pull together the implications of the separate analyses of data undertaken in chapters 4 - 7 (which derives from existing theory and research). Following a review of the findings a summary is presented in Figure 8.1 (below). Lastly confirmatory analysis (LISREL) is used to show how, in combination, the variables contributed to reading in the children in this study.

Throughout this, and others', work it is apparent that phonological awareness (in various different forms) is related to reading, though the evidence here is that the relationships are not consistent across age groups. One of the tasks of this thesis has been to describe the extent to which performance in phonological awareness tasks is mediated by memory and lexical knowledge. Thus, it is of interest here to explore the extent to which phonological awareness, memory and lexical knowledge covary and affect reading.

The relationship between phonological awareness and reading was reviewed in §4.1.1 and §4.2.1. The relationship between awareness of rhymes and reading was not found to be as consistent as might be anticipated from some previous work (eg Bradley & Bryant, 1983), whereas children's awareness of initial phonemes was found to be both a concurrent associate and a developmental predictor of reading. Whilst the views of Morais and colleagues (Morais *et al*, 1987; Morais, 1991) were that awareness of phonemes arises, causally, from instruction in literacy, Goswami & Bryant (1990), who partially shared that view, also pointed out that awareness of certain phonological units (onsets and rimes) may precede the development of reading. Awareness of units such as onsets and rimes is closely related to children's skills with alliteration and rhyme, and it is these skills which have been assessed in this study.

Also, as was discussed in §5.5, awareness of rhymes was found to be predictive of awareness of initial phonemes, as predicted by Burnham (1986). Thus whilst awareness of rhymes may not have a direct effect on reading, it has been found to be associated with the development of awareness of phonemes, and predictive of later success in reading (Bradley & Bryant, 1983). There would therefore seem to be a justified expectation that both the measures of phonological awareness used in this study would be associated with reading. In the case of awareness of initial phonemes, however, the relationship would appear to be direct, whereas awareness of rhymes may be more likely to be indirectly associated with reading through the association between awareness of rhymes and initial phonemes.

In Chapter 6 the relationship between memory, phonological awareness and reading was explored. The relationship between memory span and reading, in which reading difficulties have been found to be associated with reduced memory span (eg Byrne & Arnold, 1981; Holligan & Johnston, 1988), has been treated more cautiously by others (eg Ellis, 1979; Jorm, 1983). A simple relationship between memory span and reading was found in this present research only for the 5-year-old children.

In §6.1 the presence of memory effects on and within phonological awareness tasks was explored. The findings there were, in support of the views of Brady (1991), that increased efficiency of processing was associated with increased memory span. However, contrary to the expectations of Baddeley (1986), memory span was not clearly associated with phonological awareness. However, in support of the assumptions of MacLean, Bryant & Bradley (1987) performance in the test of awareness of rhymes was improved when the memory burden was relieved by the addition of pictures.

The role of memory within reading was also examined in Chapter 7 where the relationship of phonological awareness and lexical knowledge was the main focus of attention. The linear inter-relationship between memory span, phonological awareness and lexical knowledge was investigated in §7.2 where it was indicated that at age 5-years memory span and lexical knowledge were predictive of children's performance in the tests of phonological awareness, with an interaction between memory span and lexical knowledge in the prediction of awareness of rhymes. At age 7-years and at 5-years memory span and lexical knowledge made dissociable contributions to awareness of initial phonemes. In §7.4 it was suggested that, in line with the views of Dollaghan (1994) and others, children with greater lexical knowledge would also have developed the ability to discriminate between lexical items with phonologically similar representations, and that with age there was a trend toward indexation by initial sounds within the lexicon. Children who also have greater memory spans would, it was suggested, be able to maintain more items in working memory whilst undertaking tasks such as those required in assessing phonological awareness.

In support of findings summarised by Aitchison (1994), Aslin & Smith (1988) and Walley (1993) it was found in §7.1 that there were close associations between lexical knowledge and phonological awareness, and that the development of awareness of initial phonemes was predicted by earlier lexical knowledge. In §7.3 it was also found, in confirmation of findings by Kleiman (1975) and Tunmer & Nesdale (1985), that lexical knowledge was predictive of reading. Further, although it was possible to demonstrate that rhyme awareness made contributions to reading that were distinct from the contributions of lexical knowledge, the contributions of lexical knowledge and awareness of initial phonemes were not dissociable in the prediction of reading for most children. However a significant and distinct contribution of lexical knowledge to performance in the BAS test of word reading was found in Y2 (7-year-old) children.

At this level of generality the findings do not conflict with an overall view of early reading development such as that offered by Hulme, Snowling & Quinlan (1991) who emphasised the significance of the structure of the 'phonological lexicon' which, if sufficiently developed before children learn to read, would enable children to learn the associative links between spoken and written forms of words. On the basis of work that has been reviewed in this study it seems plausible that developments in the structure of children's lexicons will be associated with developments in their phonological awareness. Thus children will show greater awareness of 'large' phonological segments such as rimes before becoming more proficient at identifying onsets (or initial phonemes). These developments are necessary concomitants of developments in the lexicon. In relation to reading, in order to learn mappings between written segments and spoken words children need to have the ability to identify phonological segments in the speech stream. To 'make sense' of orthographic segments children will be helped if the phonological equivalents of the orthography match phonological representations within the lexicon. Implicit within this view would be a role for memory functions which facilitate the matching between phonological segments and lexical representations. It would not necessarily be expected that memory would therefore directly show as a contributor to reading, whereas phonological awareness and lexical knowledge would show independent associations with reading. At the beginning of learning to read the structure of children's lexicons would still show associations with rhymes, and children would have yet to have formed a consistent ability to identify initial phonemes. As they undergo training in literacy they will acquire greater awareness of initial phonemes, but this will also parallel the restructuring of the lexicon in favour of representations cued by word-initial sounds.

On this basis it would be expected that from the beginning lexical knowledge and phonological awareness would be significantly associated with reading. Memory span would be a contributor to phonological awareness and lexical knowledge, but not necessarily a direct associate of reading.

In summary, therefore, the evidence of the study of children with no hearing difficulties so far suggests that phonological awareness, memory and lexical knowledge may make direct contributions to performance in reading, but that associations vary with age and reading task. It has also been found that memory contributes to performance in tasks assessing phonological awareness and lexical knowledge. Thus, when the simultaneous (parallel) relationships of variables related to reading are examined the indirect effects of memory may be considered. These could occur via the involvement of memory span in either phonological awareness or lexical knowledge.

The data available from the sample of 7-year-old hearing-impaired children, however, is in contrast to the data from the children without hearing difficulties. It seems that for the hearing-impaired children there was no association between lexical knowledge and awareness of initial phonemes, and that in this respect the pattern of associations was similar to the 5-year-old children without hearing difficulties for whom lexical knowledge was found to be associated with awareness of rhymes. It is also notable that the hearing-impaired children's lexical knowledge was at an earlier stage of development than would be expected for their age, and was at a level comparable to the 5-year-old children without hearing difficulties. The hearing-impaired children's word recognition and word reading scores were, however, clearly associated with lexical knowledge with no apparent involvement of phonological awareness. For these hearing-impaired children it seems (see Table 7.28b) that lexical knowledge contributes between 21% and 27% of the variance in reading tasks, over and above any contribution from phonological awareness; whereas amongst the children without hearing difficulties (see Table 7.32) lexical knowledge contributes at most 11% of the variance over and above the contribution of phonological awareness.

The overall findings are now summarised in Figure 8.1, below.

Figure 8.1: Summary of relationships between variables examined in this study

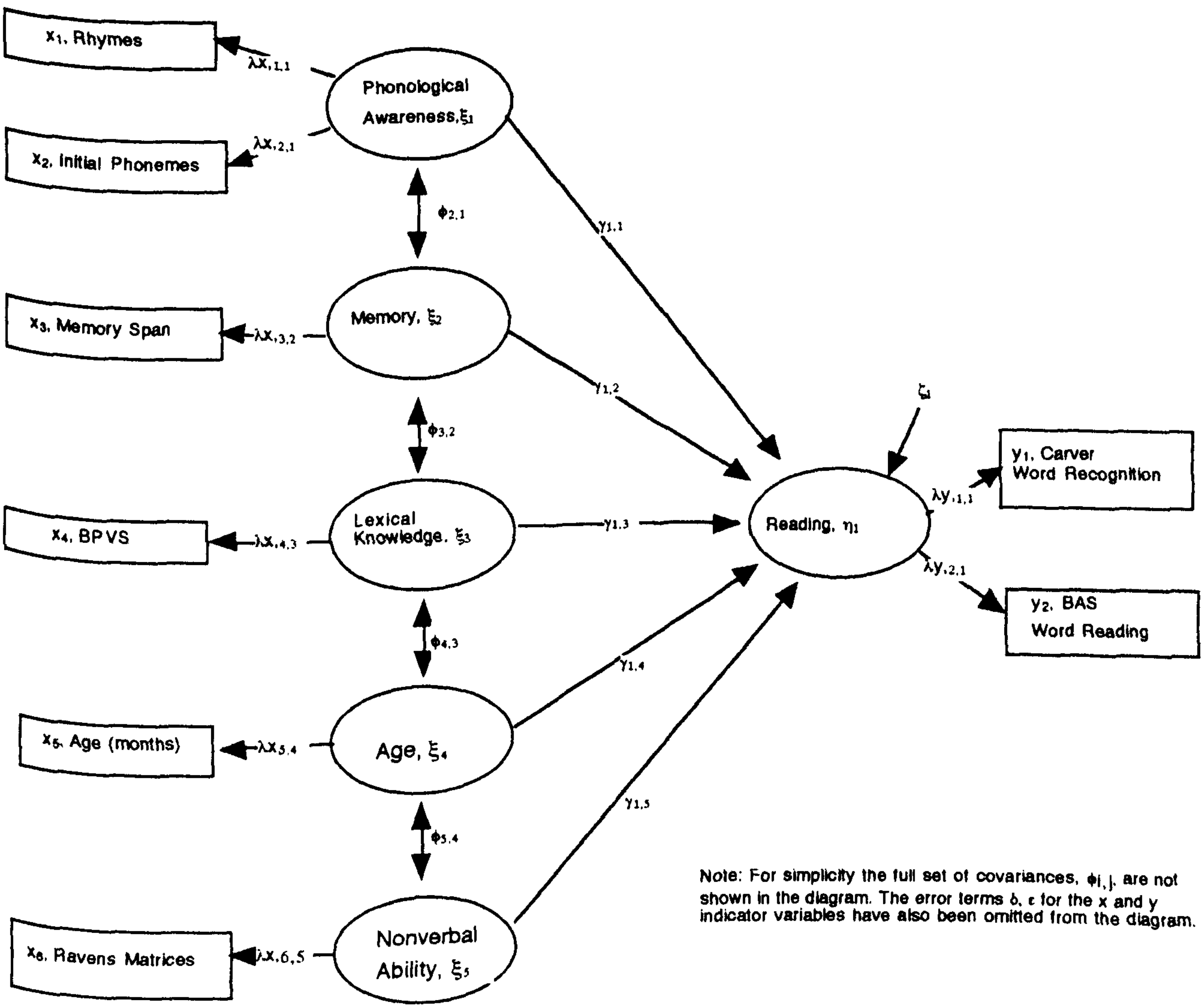
	Speech Perception	**Memory**	**Vocabulary**	**Phonological Awareness**
Changes with Age ?	Yes	Yes	Yes	Yes
Associated with Phonological Awareness ?	No	Yes; Some tasks easier when memory relieved; Efficiency of recall related to performance in Phonological Awareness	Yes. Rhyme awareness and vocabulary associated at age 5 years; Associations between awareness of Initial Phonemes and vocabulary emerging with age.	Differential awareness of Rhymes and Initial Phonemes.
Associated with other Variables ?	Not tested	Reading & Vocabulary	Memory & Reading	Memory, Vocabulary & Reading
Developmental Effects ?	Some evidence that perceptual ability associated with later phonological awareness	Interaction of reciprocal of memory span with vocabulary in longitudinal prediction of Initial Phoneme awareness	Interaction with memory span in prediction of concurrent awareness of Rhyme in 5-year-old children	Rhyme predicts Initial Phoneme awareness; Rhy & IPh predict Reading.
Affected by Hearing Impairment ?	Yes: depressed by two years.	Yes: depressed by one year.	Yes: depressed by two years.	Yes: depressed by one year.

8.2.1.1 *Proposed Overall Model*

On the basis of what has been shown in previous research and the results of this present study, the following general model is proposed (see Figure 8.2). In this, the effects of five underlying (latent/conceptual) variables - 'Phonological Awareness', 'Memory', 'Lexical Knowledge', 'Age' and 'Nonverbal Ability' are regarded as being simultaneous, independent, candidates for direct effects on 'Reading'. This conceptualisation of variables 'in parallel' contrasts with the linear developmental format of the stage models examined in §8.1. From the preceding section and earlier work it would be anticipated that 'Reading' would be likely to be most influenced by 'Phonological Awareness', 'Lexical Knowledge' and, in heterogeneous groups, by 'Age'. As discussed above, all the latent causal variables may be associated, and the extent of inter-relationship between these hypothesised variables may be estimated within the analytic procedure.

The inter-relationships between variables as now formulated above, may be represented diagrammatically, as shown in Figure 8.2:

Figure 8.2: Diagrammatic representation of inter-relationships between aspects of Phonological Awareness, Memory Span, BPVS scores, Age, Ravens matrices scores and performance in Word Recognition and Word Reading. (Greek letters are features of the LISREL modelling process described in the text, below.)



In this formulation, and in the LISREL analyses that follow, observable, ie measurable, variables [$x_1 \ldots x_6$; y_1, y_2] are shown within rectangles. Underlying, conceptual, variables are shown in ellipses and are denoted by Greek letters (ξ, η). Further Greek letters (λ, ϕ, ζ) are used to denote parameters that link variables. The values of these parameters indicate the size of the effect of one variable on another.

The above model is the proposed general formulation. Scores in the tests of Awareness of Rhymes and Awareness of Initial Phonemes are indicators of the functioning of the underlying concept of Phonological Awareness. Memory Span is the indicator of the functioning of Memory; BPVS scores indicate Lexical Knowledge and Ravens Matrices indicate Nonverbal Ability. In general, the findings of this study have so far indicated that Phonological Awareness, Memory and Lexical Knowledge on their own may have some effect on children's reading. The purpose of the following analysis is to evaluate the effects of these variables when placed together as 'competing' causes of Reading. The strength of the relationship in this formulation will be provided by the γ coefficients, which are calculated in the LISREL analysis. Reading ability itself is indicated by both scores in the Carver test of Word Recognition, and by scores in the BAS test of Word Reading.

It is clear from the work that has been reported in previous chapters that it might be anticipated that certain variables (or theoretical constructs) might have associative effects. That would be indicated in the above diagram (Fig 8.2) by linkages ($\phi_{i,j}$) between the underlying (conceptual) variables (ξ). In order to keep the diagram as simple as possible linkages ($\phi_{i,j}$) other than between immediate diagrammatic neighbours have been omitted.

As has been indicated above for some groups of children not all observable variables are necessarily applicable. When this is the case, in the interests of assessing the most parsimonious model, variables will be deleted. Thus, for instance, in assessing the model for 5-year old children BAS scores (all zero) and Age (the group is homogeneous with respect to age) will not be entered in the analysis.

8.2.1.2 *Investigation of the model*

The adequacy of the above proposal (Fig 8.2) will be assessed by means of LISREL analyses. This statistical methodology is described in the following section.

8.2.1.2.1 *A brief description of LISREL*

8.2.1.2.1.1 *The General Model*

The analysis of *L*inear *S*tructural *REL*ationships (Jöreskog & Sörebom, 1984) provides a means to integrate 'measurement concerns with structural equation modelling by incorporating both latent theoretical concepts and observed or measured indicator variables into a single structural equation model.' (Hayduk, 1987 p87)

Measurable indicator variables are distinguished from conceptual (underlying and not directly observable) variables. Conceptual variables are further classified as either *exogenous*, labelled ξ (ksi), if they may only be considered to be a cause of other conceptual variables, and *endogenous*, η (eta) if they may only be considered as the effect of other, exogenous, conceptual variables.

In general the direct effects between conceptual variables are represented by the equation

$$\eta = B\eta + \Gamma\xi + \zeta$$

where B and Γ represent the matrix of coefficients linking endogenous to endogenous, and exogenous to endogenous variables respectively. ζ represents the 'errors' within the conceptual model. This equation represents the *structural model*. In the model to be tested here, since there is just one conceptual variable (Reading), B will be set at zero, so the structural equation becomes

$$\eta = \Gamma\xi + \zeta$$

Two further equations link the conceptual variables to their observed indicators, and form the *measurement model*:

$$y = \Lambda_y\eta + \varepsilon$$

$$x = \Lambda_x\xi + \delta$$

where Λ_y/Λ_x represent the structural coefficients (parameters) which are to be estimated within the model. ε and δ represent the errors due to measurement error, or excluded variables. These may be estimated or fixed by the researcher. Hayduk (1987) recommends that measurement error terms should be fixed by the researcher by determining the proportion of the variance in an indicator variable due to measurement error. In general that recommendation has been followed here by using the reliability coefficients calculated for each variable in the study as an index of the proportion of variance due to errors. In line with other recommendations of Hayduk (1987) the Λ_y/Λ_x coefficients have also been fixed so that the underlying structural relations may be standardised and studied.

8.2.1.2.1.2 *LISREL input*

Data may be entered as the correlations between indicator variables or as the variances/covariances of indicator variables. If the variance/covariance matrix is used as the input, standardisation of the underlying concepts is obtained in the output whilst retaining the indicators in their original metrics (Hayduk, 1987, p179ff). Estimation may be carried out using several different procedures. Commonly the method of Maximum Likelihood estimation (ML) is used. However this procedure assumes multivariate normality. An alternative that is widely used which does not assume multivariate normality, but does provide a range of measures of the goodness of fit, is the method of Generalised Least Squares (GLS). Tanaka (1987) however indicates that ML estimation is more robust to the effects of small sample sizes, but Hayduk (1987) recommends that it may be appropriate to rerun a final model using a second estimation strategy. This recommendation has been followed here, in that following checks for univariate normality (with transformation of scores if necessary) Maximum Likelihood estimation was used as the primary strategy (since sample sizes are relatively small) but that each model has been rerun using GLS to confirm that the indices of fit do not appear to be compromised by unidentified non-normality.

8.2.1.2.1.3 *LISREL output*

For the measurement model the programme provides squared multiple correlations for each separate variable, and coefficients of determination for all the x- or y-variables jointly. These coefficients show how well the observed variables, separately and jointly, perform as indicators of the underlying conceptual variables. The values of these coefficients should range between 0 and 1, with values close to 1 representing a high level of reliability for that variable or set of variables. Negative values of any of these coefficients are an indication of a problem with the specification of the model.

LISREL also offers a number of possible indicators of the overall adequacy of the fit of the model to the data. Both Hayduk (1987) and Byrne (1990) provide discussion of these indicators and recommend that no one single indicator should be regarded as sufficient.

A χ^2 statistic is provided and is the only statistic provided in LISREL which has a known distribution. The associated degrees of freedom for χ^2 here is the difference between the number of observed variances/covariances and the total number of coefficients to be estimated. χ^2 provides a measure of how well the proposed model fits the observed covariances. Thus a statistically significant value of χ^2 indicates that there is a difference between the covariances implied by the model and the covariances within the sample data that are not due to mere sampling fluctuations. Therefore a model for which χ^2 is greater than might be expected by chance with the given number of degrees of freedom is not considered to have a close fit to the data. However as discussed by Marsh, Balla & McDonald (1988) χ^2 may be adversely affected by sample size, with the effect that for small samples the chances of non-significant χ^2 are increased, whereas for very large samples there is a high probability that trivial differences between the observed and model implied covariances will be detected as more than mere sampling fluctuations and hence yield large χ^2. Hayduk (1987) reports that he has found that χ^2 is useful for sample sizes between 50 and 500, and that models for sample size of 22 have been evaluated with 'no discernible problems' (Hayduk, 1987, p.188).

χ^2 statistics are also used when comparing models, since the difference between two χ^2s is also distributed as χ^2. Thus for example, if there are two models, one of which is 'nested' inside another since they both consist of the same variables, but one has fewer parameters to be estimated (ie has greater degrees of freedom), then the difference between the χ^2 statistics for the two models will give an indication of whether or not there is a significant difference between the fit of the data to the hypothesised models.

In addition to χ^2 a 'Goodness of Fit Index' (GFI) and an 'Adjusted GFI' (AGFI), which is the GFI adjusted for the degrees of freedom of the model, are provided. Jöreskog & Sörebom (1984) describe the GFI as a 'measure of the relative amount of variances and covariances jointly accounted for by the model... Unfortunately... its statistical distribution is unknown, even under idealised assumptions, so there is no standard to compare it with' (*ibid*, pl.41). Jöreskog & Sörebom (1984) also claim that GFI is independent of the size of the sample, and relatively robust in the face of departures from normality. Marsh *et al* (1988) however showed that in tests of the same model with sample sizes ranging from 25 to 1600, GFI and AGFI varied significantly. In fact Marsh *et al* concluded that all the 'stand alone' indices were affected by sample size. The GFI and AGFI may, in principle range from 0 to 1, with a value close to 1 indicating a good fit. However Mulaik, James, Van Alstine, Bennett, Lind & Stilwell (1989) discuss the limitations of these Goodness-of-Fit indices, and point out that not only can the AGFI take on negative values (thereby undermining the supposed absoluteness of zero), but that the index may also be unduly influenced by the fit of the measurement portion of the model. Thus they report that indices of 0.9 and above can be obtained even 'when the structural relations between latent variables are seriously misspecified' (Mulaik *et al*, p444/5)

The final 'stand alone' index routinely provided in the LISREL printout is the Root Mean square Residual (RMR). This is described (Jöreskog & Sörebom, 1984, I.41) as 'a measure of the average of the residual variances and covariances. *This can only be interpreted in relation to the size of the observed variances and covariances*' (italics added). When the data input is in the form of a variance/covariance matrix RMR has a lower bound of zero, but has no upper bound (Marsh *et al*, 1988, p392). Breckler (1990) also comments that when data is in the form of covariances the RMR will be in covariance units that may be difficult to interpret. Hayduk (1987, p169ff) does not discuss the RMR index, but does suggest that the residuals (the discrepancies between the sample covariances and the model implied covariances) should be carefully examined when evaluating the fit of a model, particularly if an acceptably fitting model has not been found.

In comparison to the 'stand alone' indices several 'Incremental Fit Indices' have also been proposed. These provide ways of comparing the fit of nested models for the same data. Marsh *et al* (1988) consider several of these. Hayduk (1987), Marsh *et al* (1988) and other researchers (eg Ferguson, Dodds, Craig, Flannigan & Yates, 1994) have employed the 'non-normed' (see Marsh *et al,* 1988) Tucker-Lewis Index (Tucker & Lewis, 1973) since it is relatively unaffected by sample size (Marsh *et al,* 1988). The Tucker-Lewis Index (TLI) compares χ^2 for a 'null' model which posits complete independence of all observed measurements (Byrne, 1990) and the specified (ie more restricted) model to be evaluated. The TLI is computed using the equation

$$TLI = (\chi_0^2/df_0 - \chi_s^2/df_s)/(\chi_0^2/df_0 - 1)$$

where subscripts 0 and s refer to the null (0) and specified (s) models, respectively. The TLI will, Tanaka (1987) reported, generally lie within a range of 0 to 1. Values close to 1 indicate a well fitting model.

Bentler & Bonett (1980) proposed an alternative to the TLI, the Bentler-Bonett Index (BBI). This is, in contrast to the TLI, sometimes referred to as a 'normed -index'. It is defined as

$$BBI = (\chi_0^2 - \chi_s^2)/\chi_0^2$$

As Marsh *et al* (1988) showed however, the BBI is susceptible to effects of sample size. The BBI is constrained to lie in the range 0 to 1, with values approaching 1 considered to be indicative of better fitting models.

Both the TLI and BBI are determined by the relationship with a putative 'null' model. Hayduk (1987), however, notes that there is no general agreement as to what constitutes the 'null' model. The issue of what constitutes an appropriate 'null' model for the purposes of the present research will be addressed below in §8.2.1.2.3.

In discussing the relative merits of indices of goodness of fit, Mulaik *et al* (1989) also recommended that researchers should systematically attend to the parsimony of specified models. Thus when developing a model, if a high proportion of the data has been used to estimate parameters, the resulting solution will not be highly parsimonious. They recommend that indices of parsimony should be reported when models are being developed, since it is possible for goodness of fit indices to be in support of a model, but that indices of parsimony might be more moderate. Mulaik *et al* (1989, p439) note that:

> 'A moderate parsimonious-fit index corresponding to a high ... goodness-of-fit index indicates that much of the good fit, that which is principally due to the estimated values of the free parameters, remains untested, unexplained (from outside the data), and in question.'

Mulaik *et al* recommend two parsimonious-fit indices. The first of these, the Parsimonious Goodness of Fit (PGFI) provides an index to account for all the information in the variance/covariance matrix for the observed variables. The PGFI is defined by the equation

$$PGFI = [2d/k(k+1)]GFI$$

where d is the degrees of freedom of the tested, specified, model; k the number of observed variables in the model; and GFI the goodness-of-fit index provided in the LISREL output.

The second index recommended by Mulaik *et al* provides an account of the relationship between just the covariances of the observed variables and relates to normed incremental-fit indices. Mulaik *et al* term this index a parsimonious normed-fit index (PNFI) and give its equation as

$$PNFI = \{2d/[k(k-1)]\}[(\chi_0^2 - \chi_\bullet^2)/(\chi_0^2 - d)]$$

8.2.1.2.2 *Modelling Procedure Adopted*

So that statistical analysis of models, taking into account the principle of parsimony, was not compromised by exploratory procedures, as recommended by Hayduk (1987) and Mulaik *et al* (1989) a model was developed for one sample of data and then tested for fit in a second sample. Since the two data sets collected in '92 and '93 represent independent samples, one set ('93) was chosen at random (by coin tossing) and the proposed model was investigated for that set. Subsequently the fit of this model was evaluated for the '92 set using methods for testing measurement and structural invariance as suggested by Byrne (1990) and Hayduk (1987).

Lastly the model was tested for subsets of data for children at ages 5-, 6-, and 7-years, as well as the group of partially-hearing children, with tests for invariance between groups. The analysis of the separate age groups will highlight any discontinuities in the relationships between variables that are obscured in analysis of heterogeneous age groups.

For each model data was entered in the form of variance/covariance matrices. Error terms were calculated from the reliability coefficient (r_{11}) and the variance for the variable, using the equation

$$\text{Error Variance} = (1 - r_{11}) \times \text{Variance of Variable}$$

Indicator variables were linked with their underlying conceptual variable with coefficients set at 1.0 except for the multiple indicators of Phonological Awareness and Reading where, as suggested by Hayduk (1987), the coefficients were fixed at the value of nonerror variance for each indicator, ie calculated by the equation

$$\lambda = \sqrt{[Var(X) - Var(meas.err)]}$$

8.2.1.2.3 *Results*

The means and standard deviations for all the observed variables for each group are shown in Table 8.12. As before, the kurtosis and skew of each variable was checked for departures from normality. Only in the case of BAS Word Reading scores was it found necessary to transform scores to achieve conformity with normal distributions.

In line with the conventions of LISREL, in the following tables the y-variables (Carver and BAS test scores) are cited before the x-variables.

Table 8.12: Group Mean (and standard deviations) of raw scores in Word Recognition (Carver test), Word Reading (BAS test), awareness of Rhymes, awareness of Initial Phonemes, Age (in months), Memory Span, BPVS (vocabulary), and Ravens matrices (non-verbal ability)

Group	Carv	BAS	Rhy	IPh	Age	MeS	BPVS	Rav
'93 N=45	4.4 (2.9)	0.46 (0.62)#	6.0 (2.4)	5.5 (2.8)	69.3 (10.5)	4.0 (1.3)	10.9 (3.5)	15.7 (4.8)
'92 N=45	4.0 (2.9)	0.39 (0.59)#	6.3 (2.3)	5.6 (2.3)	69.9 (9.9)	4.4 (1.5)	12.3 (2.8)	17.6 (4.0)
R, N=30	1.9 (1.5)	0	4.7 (2.3)	3.8 (1.5)	52.3 (1.7)	3.4 (1.0)	9.8 (3.1)	13.9 (3.3)
Y1, N=30	3.7 (2.5)	2.1 (1.1)†	6.5 (2.1)	5.6 (2.6)	69.8 (1.4)	4.0 (1.2)	11.4 (2.6)	17.1 (4.0)
Y2, N=30	7.0 (2.4)	3.5 (2.3)††	7.3 (1.9)	7.2 (2.2)	81.8 (1.5)	5.2 (1.2)	13.5 (3.0)	18.9 (4.8)
H-I, N=15	6.1 (2.7)	20.2 (18.0)	6.2 (1.6)	6.2 (2.4)	82.7 (4.8)	4.3 (1.0)	9.7 (2.4)	17.1 (3.4)

#BAS scores transformed: Ln(1+BAS); †BAS scores transformed: Ln(BAS); ††BAS scores transformed: √(BAS)

The correlations between variables in each group are shown next, in Table 8.13.

Table 8.13a: Pearson Correlations between raw scores in Word Recognition (Carver test), Word Reading (BAS test), awareness of Rhymes, awareness of Initial Phonemes, Age (in months), Memory Span, BPVS (vocabulary), and Ravens matrices (non-verbal ability) for '93 sample (N=45)

	Carv	BAS#	Rhy	IPh	Age	MeS	BPVS	Rav
Carv	1							
BAS#	0.87	1						
Rhy	0.644	0.659	1					
IPh	0.75	0.756	0.701	1				
Age	0.762	0.705	0.535	0.585	1			
MeS	0.635	0.551	0.498	0.566	0.575	1		
BPVS	0.56	0.624	0.382	0.623	0.567	0.428	1	
Rav	0.474	0.525	0.37	0.45	0.578	0.339	0.512	1

#BAS scores transformed: Ln(1+BAS)

Table 8.13b: Pearson Correlations between raw scores in Word Recognition (Carver test), Word Reading (BAS test), awareness of Rhymes, awareness of Initial Phonemes, Age (in months), Memory Span, BPVS (vocabulary), and Ravens matrices (non-verbal ability) for '92 sample (N=45)

	Carv	BAS#	Rhy	IPh	Age	MeS	BPVS	Rav
Carv	1							
BAS#	0.858	1						
Rhy	0.508	0.393	1					
IPh	0.717	0.633	0.738	1				
Age	0.659	0.703	0.359	0.538	1			
MeS	0.522	0.517	0.29	0.484	0.533	1		
BPVS	0.612	0.53	0.482	0.551	0.406	0.237	1	
Rav	0.541	0.499	0.275	0.398	0.39	0.251	0.394	1

#BAS scores transformed: Ln(1+BAS)

Table 8.13c: Pearson Correlations between raw scores in Word Recognition (Carver test), awareness of Rhymes, awareness of Initial Phonemes, Age (in months), Memory Span, BPVS (vocabulary), and Ravens matrices (non-verbal ability) for R-group (N=30)

	Carv	Rhy	IPh	Age	MeS	BPVS	Rav
Carv	1						
Rhy	0.426	1					
IPh	0.518	0.759	1				
Age	0.108	0.006	0.207	1			
MeS	0.463	0.306	0.342	0.569	1		
BPVS	0.167	0.391	0.505	0.155	0.021	1	
Rav	-0.186	0.124	0.01	0.191	0.123	0.472	1

Table 8.13d: Pearson Correlations between raw scores in Word Recognition (Carver test), awareness of Rhymes, awareness of Initial Phonemes, Age (in months), Memory Span, BPVS (vocabulary), and Ravens matrices (non-verbal ability) for Y1-group (N=30)

	Carv	Rhy	IPh	Age	MeS	BPVS	Rav
Carv	1						
Rhy	0.451	1					
IPh	0.603	0.486	1				
Age	0.164	0.024	0.167	1			
MeS	0.307	0.1	0.228	-0.135	1		
BPVS	0.417	0.166	0.475	0.308	-0.004	1	
Rav	0.27	0.188	0.422	0.301	0.069	0.453	1

Table 8.13e: Pearson Correlations between raw scores in Word Recognition (Carver test), Word Reading (BAS test), awareness of Rhymes, awareness of Initial Phonemes, Age (in months), Memory Span, BPVS (vocabulary), and Ravens matrices (non-verbal ability) for Y2-group (N=30)

	Carv	BAS††	Rhy	IPh	Age	MeS	BPVS	Rav
Carv	1							
BAS††	0.721	1						
Rhy	0.456	0.554	1					
IPh	0.611	0.586	0.781	1				
Age	0.324	0.214	-0.027	0.144	1			
MeS	0.215	0.311	0.255	0.438	0.141	1		
BPVS	0.444	0.535	0.242	0.428	0.228	0.341	1	
Rav	0.461	0.469	0.145	0.166	0.427	0.115	0.22	1

††BAS scores transformed:√(BAS)

Table 8.13f: Pearson Correlations between raw scores in Word Recognition (Carver test), Word Reading (BAS test), awareness of Rhymes, awareness of Initial Phonemes, Age (in months), Memory Span, BPVS (vocabulary), and Ravens matrices (non-verbal ability) for H-I-group (N=15)

	Carv	BAS††	Rhy	IPh	Age	MeS	BPVS	Rav
Carv	1							
BAS††	0.721	1						
Rhy	0.456	0.554	1					
IPh	0.611	0.586	0.781	1				
Age	0.324	0.214	-0.027	0.144	1			
MeS	0.215	0.311	0.255	0.438	0.141	1		
BPVS	0.444	0.535	0.242	0.428	0.228	0.341	1	
Rav	0.461	0.469	0.145	0.166	0.427	0.115	0.22	1

Since, as can be seen in Table 8.13c the Ravens matrices scores from 5-year-old children were not substantially correlated with other variables, this variable was not entered in LISREL analyses for that group. This strategy improves the ratio of cases to variables. Similarly BAS scores were not entered in the models of reading for either R-group or Y1-group because there were very few non-zero scores for this variable in these two groups. It was also observed (see Table 8.13 d,e,f) that Memory Span was generally only weakly correlated with other variables in the Y1-, Y2-, and H-I-groups. This variable was therefore not used in the LISREL analysis of these groups. Since, as would be expected (since each of these groups is homogeneous with respect to age), Age also did not show any substantial correlations with other variables in R-, Y1-, Y2-, and H-I-groups, for reasons of parsimony this variable was also not entered in the LISREL analyses.

The full LISREL analyses of the '93 and '92 sample are shown in Appendices 8 and 9. In the development of the model for the '93 sample it was found that if the error terms for awareness of Rhymes, awareness of Initial Phonemes, and error terms for Carver and BAS test scores were allowed to be estimated (ie the TD or TE terms for these variables were 'freed') a better fitting model (Model 2) was achieved than with them taking predetermined values (Model 1). Hayduk cautions against freeing parameters to obtain a better fit unless the step can be theoretically justified. This relaxation of the conditions here may be justified on the following grounds. In the case of the phonological awareness variables it will be recalled (see Chapter 4) that while the reliability-coefficients of these variables, particularly that for awareness of Initial Phonemes, were in some cases very low, it was argued that this was perhaps because some children experienced significant difficulties with the tasks. On this basis it may be misleading to fix the proportion of variance due to measurement error in these variables. With respect to the indicators of reading a similar argument may be put forward, that variance in these variables may not be due to the unreliability of the indicator *per se*, but that variance may be due to the range of difficulties experienced by some children.

The Indices of Fit of the model for the model developed for the data for the '93 sample are shown below in Table 8.14. For the 'null' model no inter-relationship between variables was permitted (technically by fixing at zero the matrix (ϕ) of covariances between exogenous variables, and by positing that no exogenous variable influenced the endogenous variable all γ-coefficients were fixed at zero). Model 1 represents the model in which all error terms for indicator variables were fixed (as recommended by Hayduk, 1987). Model 2 is the fully specified model in which the error terms for phonological awareness and indicators of reading were estimated by the programme, as discussed above.

Table 8.14: Indices of Goodness of Fit for the model of data obtained in '93

Model	$\chi 2$	df	$\Delta\chi 2$	GFI	BBI	TLI	PGFI	PNFI
'93, n=45								
Null	187.02**	30						
Model 1 (TD, TE fixed)	37.65**	15	149.37	0.871	0.799	0.712	0.363	0.465
Model 2(Specified model)	14.05ns	11	23.6	0.933	0.925	0.947	0.389	0.539

**$p<0.01$
GFI=LISREL Goodness of Fit Index; BBI=Bentler-Bonett Index; TLI=Tucker-Lewis Index; PGFI=Parsimonious Goodness of Fit Index; PNFI=Parsimonious Normed Fit Index.

It can be seen that the final, specified, model fits the data well (as indicated by the non-significant value of $\chi 2$, and values of GFI, BBI and TLI close to 1.) However it is clear from the modest parsimony indices that a high proportion of the data has been used to develop this model. In order to overcome the objection that there is a lack of 'disconfirmability' (Mulaik *et al*,1989, citing Popper, 1961) since a substantial number of the parameters had been estimated leaving insufficient fixed parameters to allow for disconfirmation, the model was therefore re-tested using the data obtained from the sample of children in '92. The procedures outlined by Byrne (1990) and Hayduk (1987) were used to test for the invariance of structural components of the model across both groups.

This procedure involves testing stacked models. Here this starts with a 'null' model (as before), followed by estimation of a model with the same overall design as the '93 data, but with start values derived from the variances for the '92 data. The fit statistics for the null and specified models for '92 data are shown in Table 8.15.

Table 8.15: Indices of Goodness of Fit for test of model for '92 data

Model	$\chi 2$	df	$\Delta\chi 2$	GFI	BBI	TLI
'92, n=45						
Null	145.47**	30				
Model 2(Specified model)	13.15ns	11	132.32	0.932	0.91	0.949

*$p<0.01$
GFI=LISREL Goodness of Fit Index; BBI=Bentler-Bonett Index; TLI=Tucker-Lewis Index.

The indices of fit indicate that the model as developed for the '93 sample also provides a reasonable fit for the data obtained from the '92 sample of children.

Following this the underlying structure of the models for both sets of data are compared. This is achieved by applying successively greater constraints of invariance across the two groups. By constraining structural effect coefficients to be equal, greater degrees of freedom are obtained. At each stage the programme compares the variance/covariance matrix that is implied by the constrained structure with the observed variance/covariances of the '92 data. If the differences between the implied and observed matrices are estimated as being likely to arise from sampling fluctuations a non-significant χ^2 is reported, indicating that the postulated model is a reasonably close fit to the data. With stacked models the programme conducts simultaneous estimation of parameters and provides one overall value of χ^2 . Since the process of analysis involves comparing nested models, the change in χ^2 ($\Delta\chi^2$) between models which are successively more constrained (ie with greater degrees of freedom) is of interest, and if found non-significant suggests that invariance is a tenable hypothesis at that point. The results of the analysis of these nested models is shown below in Table 8.16.

Byrne (1990) suggests that a logical start for such an investigation is a confirmation that the number of variables is invariant across the two groups. This is termed model 1 for comparative purposes.

Invariance in the variance/covariance matrix across the two groups was tested next (by setting the matrix Phi invariant) and the resulting χ^2 compared to model 1. Following this the matrices of coefficients linking exogenous and endogenous variable (Gamma) and subsequently the matrix (Psi) for 'errors' in the conceptual model were successively constrained to be invariant.

<u>Table 8.16: Results of simultaneous tests for Invariance between '93 and '92 samples for the Model of Reading Structure and Measurement.</u>

Model	χ^2	df	$\Delta\chi^2$	df	TLI
Null	329.39**	60			
1: Number Variables Inv	27.20ns	22	302.19**	38	1.05
2: Inv Var/Cov (Phi) Matrix	33.15ns	37	5.95ns	15	1.08
3: Inv Phi and Gamma	38.2ns	42	5.05ns	5	1.06
4: Inv Phi, Ga, & Psi	39.34ns	43	1.14ns	1	1.07

**p<0.01

The results of this analysis indicate that the underlying structure of conceptual variables that was developed using the data obtained in '93 has not been disconfirmed by the '92 data.

Finally, in order to check that the estimation strategy used (Maximum Likelihood) had not been invalidated by departures from the assumption of multivariate normality the specified models (for data at '93 and '92, and Model 1 of the simultaneous estimation of structural invariance across '93 and '92) were re-tested using the Generalised Least Squares (GLS) method of estimation. The results are summarised in Table 8.17 below

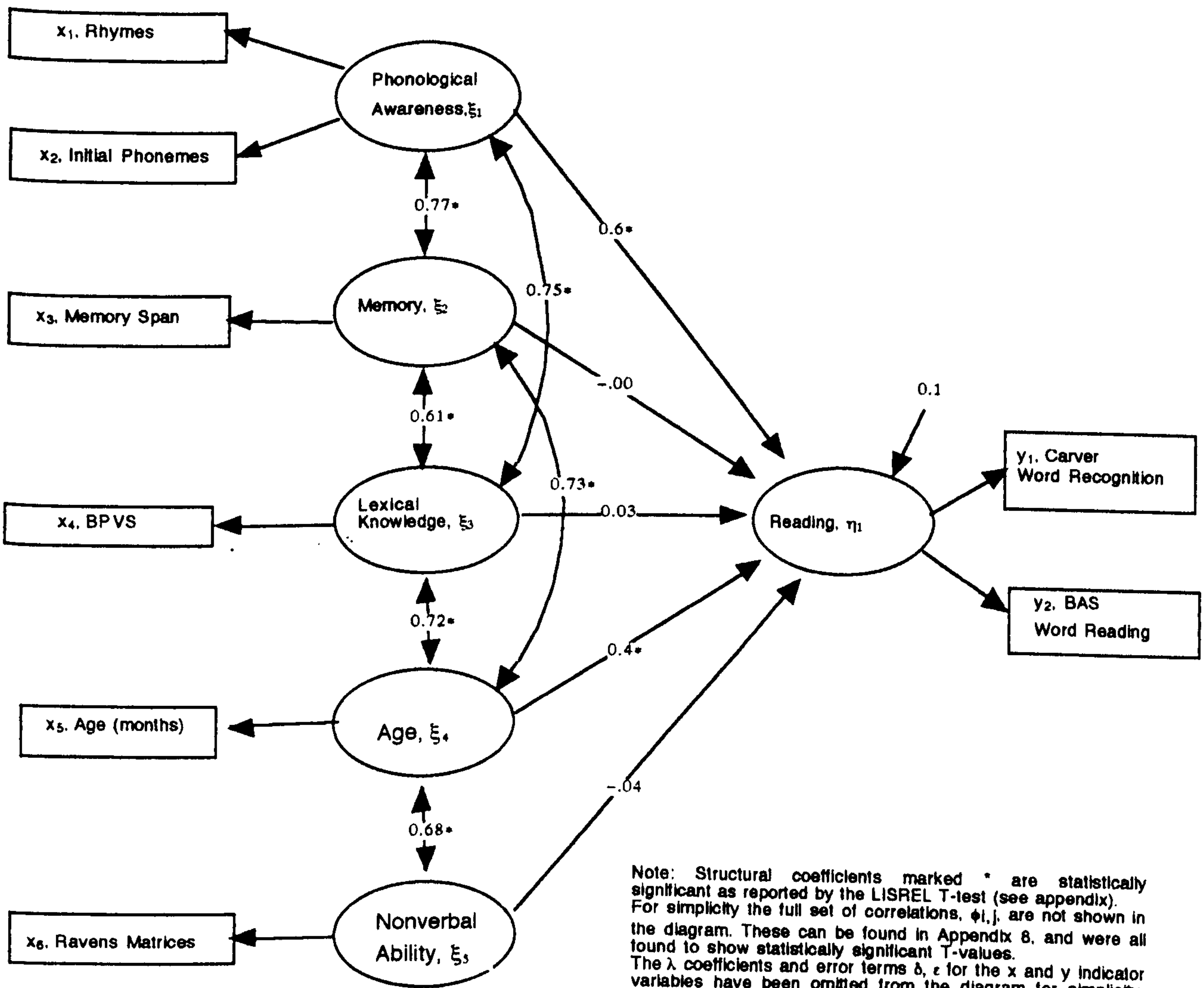
Table 8.17: Summary of fit statistics for re-test using GLS estimation of models of data at '93 and '92 and the simultaneous estimation of invariance across '93 and '92.

Model	χ^2	GFI
'93	11.61ns	0.934
'92	9.57ns	0.946
'93 & '92	21.18ns	-

A separate GFI for the stacked estimation is not given.

It may therefore be concluded that the model, first outlined as Figure 8.2, and developed for the '93 sample appears to be a reasonable descriptor of the data obtained in '92. Figure 8.3 (below) is provided to summarise these two models and to show the structural coefficients that have been estimated for each sample. The full details of both models are shown in the appendices.

Figure 8.3a: Estimated Standardised Structural Relationships between variables for '93 data.



Note: Structural coefficients marked * are statistically significant as reported by the LISREL T-test (see appendix). For simplicity the full set of correlations, $\phi_{i,j}$, are not shown in the diagram. These can be found in Appendix 8, and were all found to show statistically significant T-values. The λ coefficients and error terms δ, ϵ for the x and y indicator variables have been omitted from the diagram for simplicity. The values for these are reported in the appendix.

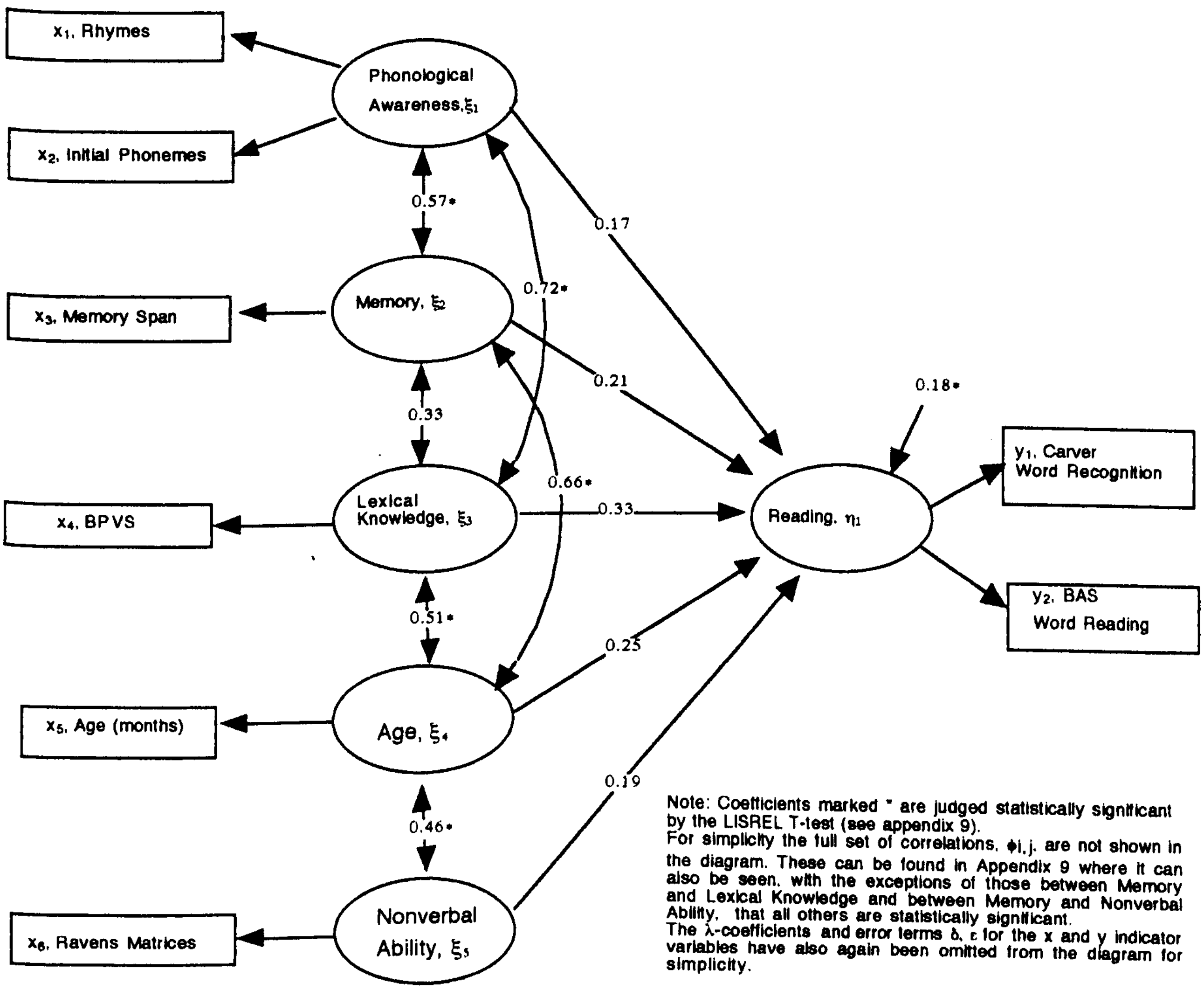
The standardised structural coefficients (γ) linking exogenous (ξ) to endogenous (η) conceptual variables may be interpreted as the number of standard deviations change in η expected to follow from one standard deviation increase in the associated ξ when other variables are left untouched at their original values (Hayduk, 1987). The T-values provided in LISREL output (see Appendix 8) indicate that for this model the coefficients linking Phonological Awareness and Age to Reading are statistically significant. However from the table of Total Effects (see Appendix 8) it can be seen that a unit change in Phonological Awareness, with other exogenous variables remaining unchanged (Hayduk, 1987), would result in a change of 0.725 units of change in Reading; whereas a unit change in Age would result in 0.048 unit of change in Reading. Both these total effects are at least twice the standard error of the estimate, and may therefore be considered statistically significant. Since the underlying conceptual variables are standardised in the procedure adopted here it is possible to conclude that for this model of the data Phonological Awareness appears to have much the greater effect on Reading than other variables. The total effect of Lexical Knowledge on Reading is 0.014 and is non-significant. Memory appears to have virtually no dissociable effect on Reading (with Total Effect given as -.002).

The value of 0.106 for ζ indicates that some 89% [(1 - 0.106) x 100] of the variance in Reading may be explained by modelled effects. This is reported in the LISREL results also as the 'Total Coefficient of Determination for Structural Equations.' The reported T-value for this coefficient (1.648) is less than the value of 2 generally regarded as a criterion of statistical significance, and thus it may be concluded that there are no significant un-modelled effects.

In §7.3 the relationship between lexical knowledge and reading was investigated, and on the basis of the analyses carried out at that stage it was concluded (7.3.4) that lexical knowledge was associated with reading. It was further concluded that the effects might be dissociated from the effects of phonological awareness. It is evident however from this LISREL analysis that when the effects of lexical knowledge were assessed as a concurrent associate of phonological awareness (and the other variables), the effects appear non-significant. It should however be noted that the model does uphold a significant association between phonological awareness and lexical knowledge in the matrix (ϕ) of covariances between exogenous latent variables. In standardised form these covariances are given as correlations and form part of the matrix labelled 'Correlation matrix of Eta and Ksi' (see appendix.) The T-values generated by the programme indicate that for this model all these correlations are significant.

Although the measurement model is of secondary interest here it should be noted that the squared multiple correlations and coefficients of determination for x- and y-variables are all acceptable. This indicates that the measurement model is generally reliable, and that the indicators are, separately and in combination, good measures of the underlying concepts and structure. Thus whilst the relationship between conceptual variables may alter between groups, as may be seen in the differences between the structural coefficients for the independent models of the '92 and '93 data sets, the indicator variables provide a stable picture of the conceptual variables.

Figure 8.3b: Estimated Standardised Structural Relationships derived from the '92 data



Note: Coefficients marked * are judged statistically significant by the LISREL T-test (see appendix 9).
For simplicity the full set of correlations, $\phi_{i,j}$, are not shown in the diagram. These can be found in Appendix 9 where it can also be seen, with the exceptions of those between Memory and Lexical Knowledge and between Memory and Nonverbal Ability, that all others are statistically significant.
The λ-coefficients and error terms δ, ε for the x and y indicator variables have also again been omitted from the diagram for simplicity.

For this model of the '92 data the error term (ζ = 0.18) suggests that 82% of the variance in Reading has been 'captured' by this model. Since this coefficient is shown as statistically significant the model may not be regarded as a fully sufficient descriptor of 'Reading' for this data. This should also be apparent since none of the structural (γ) coefficients were found to be significant.

However, it should also be noted that within the estimated matrix (ϕ) of covariances all those between Phonological awareness and the other exogenous variables are given T-values indicating statistically significant associations and that this implies that for this model, as for the model of the '93 data, Phonological Awareness, Memory and Lexical Knowledge showed significant covariance.

The details of the measurement model given within the LISREL results in Appendix 9 again show that the indicator variables are reliable for the structural model. This aspect of the overall model was further confirmed in the simultaneous estimation of invariance across '93 and '92 data. The relevant coefficients obtained from the estimation of Model 4 (see Table 8.16, above) are shown here in Table 8.18.

<u>Table 8.18: Coefficients for Measurement Model obtained during test of invariance across '93 and '92 data</u>

Squared Multiple Correlations for y-variables					
Carver	*BAS*				
0.921	0.754				
Total Coefficient of Determination for y-variables is 0.937					
Squared Multiple Correlations for x-variables					
Rhy	*IPh*	*Age*	*MeS*	*BPVS*	*Rav*
0.667	0.801	0.905	0.693	0.742	0.826
Total Coefficient of Determination for x-variables is 0.823					

Since it had been shown in earlier chapters that there were age related changes in many variables, and reading clearly shows changes with age, LISREL models were developed for the three age groups of children without hearing difficulties and also the group of partially-hearing children.

These models are obviously developed for relatively very small sample sizes, and cannot be re-tested on other samples here. They must therefore be regarded as exploratory conjectures. It has been possible, however, to use similar strategies to those employed and above and to test for the invariance of the underlying structural relations between Y1 and Y2, and between the Y2 (without hearing difficulties) and H-I groups. In order to be able to perform these latter comparisons two models for Y2 children were developed. In the first of these only Carver scores were used as the y-indicator, so that comparisons could be made with the Y1 group in which insufficient non-zero BAS scores were available for analysis. Since BAS scores were available for the H-I group tests of invariance can be done using both Carver and BAS scores as the two y-indicators. The Y2 (hearing) data for BAS was found to show a significant skew. Scores for this variable in this group were accordingly transformed by taking the square root of each score.

The indices of fit for the Null model and models 1 (error terms fixed) and 2 (error terms freed for estimation) are shown in Table 8.19.

Table 8.19: Indices of Goodness of Fit for tested models of data for R-, Y1-, Y2-, AND H-I-groups

Model	χ2	df	Δχ2	GFI	BBI	TLI	PGFI	PNFI
R: n=30								
Null	37.32**	11						
Model with TD,TE fixed	16.24**	5	21.08**	0.878	0.565	0.06	0.293	0.326
Model 2(Specified model)	12.13**	3	4.11ns	0.887	0.675	-0.271	0.178	0.234
Y1: n=30								
Null	37.54**	11						
Model with TD, TE fixed	8.10ns	5	29.44**	0.883	0.784	0.743	0.294	0.452
Model 2(Specified model)	3.33ns	3	4.77ns	0.956	0.911	0.954	0.191	0.316
Y2: n=30 (Carver only)								
Null	30.44**	11						
Model with TD, TE fixed	3.63ns	5	26.81**	0.958	0.881	1.152	0.319	0.527
Model 2(Specified model)	2.09ns	2	1.54ns	0.973	0.931	0.975	0.13	0.189
Y2: n=30 (Carver & BAS)								
Null	41.33**	17						
Model with TD, TE fixed	7.61ns	11	33.72**	0.935	0.816	1.027	0.49	0.815
Model 2(Specified model)	5.62ns	7	1.99ns	0.951	0.864	1.071	0.317	0.485
H-I: n=15								
Null	26.13ns	17						
Model with TD, TE fixed	9.26ns	11	16.87**	0.809	0.646	1.295	0.424	0.818
Model 2(Specified model)	3.59ns	7	5.67ns	0.927	0.863	1.907	0.309	0.55

**p<0.01

As can be seen, the models for the R-group (5-year-old children) all show significant χ^2 values and poor indices of fit. On this basis it may be concluded that the basic model as defined above does not provide an adequate description of the data for these children.

The models for the other groups, in which the indicator variables' error terms were fixed, show non-significant χ^2. Since the $\Delta\chi^2$ term for the change to the models with estimated error terms in these cases are also non-significant the 'fixed' (Model 1) models might be regarded as acceptable descriptions of the data. However, in every case the Tucker-Lewis Index is more acceptable for the 'free' (Model 2) models, but with less acceptable indices of parsimony. If the analysis of invariant structures were not to be carried out (reported below in Table 8.20) the 'safer' conclusion (in line with the overall view of goodness of fit, Hayduk's (1987) recommendation that models should be developed with error terms fixed by the researcher, and the more acceptable indices of parsimony) would therefore be to accept the fixed error term models as the best fit for the available data.

Since it is possible to test for invariance of structures across two pairs of groups the Model 2 versions were chosen for these comparisons since, apart from the loss of parsimony, these models do show the best 'stand alone' indices of fit. The tests for invariance followed the same procedures as used above for the data at '93 and '92 (reported in Table 8.16, above). The tests here were carried out for the Y1 & Y2 groups (with Carver test scores as the only y-variable), and for the Y2 & H-I groups (with both Carver and BAS test scores as y-variables). As before testing started with the establishment of the 'Null' model, which was followed by increasingly constrained (as invariant) matrices of coefficients. The results are shown below in Table 8.20.

Table 8.20: Results of simultaneous tests for invariant structures across groups

Model	$\chi2$	df	$\Delta\chi2$	df	TLI
Y1 vs Y2					
Null	62.46**	16			
1: Number Variables Inv	4.9ns	4	57.56**	12	0.923
2: Inv Var/Cov (Phi) Matrix	9.17ns	10	4.27ns	6	1.029
3: Inv Phi and Gamma	12.75ns	13	3.31ns	3	1.007
4: Inv Phi, Ga, & Psi	12.75ns	14	0	1	1.031
Y2 vs H-I					
Null	61.94**	26			
1: Number Variables Inv	9.22ns	14	52.72**	12	1.247
2: Inv Var/Cov (Phi) Matrix	14.15ns	20	4.93ns	6	1.212
3: Inv Phi and Gamma	16.15ns	23	2.00ns	3	1.215
4: Inv Phi, Ga, & Psi	16.41ns	24	0.26ns	1	1.229

**p<0.01

These results indicate that for both pairs of models the underlying structures may be regarded as invariant, and that the models are therefore reasonable descriptors of the relationships between the hypothesised latent variables. Clearly, however, there are differences between the groups since, as has been seen in earlier chapters the pattern of relationships between the variables studied in connection with reading varied. The following table (Table 8.21) therefore presents the γ- and ψ-coefficients (that is the structural coefficients linking hypothesised latent variables, and the error term for the endogenous variable, Reading) as estimated within the model for each group.

Table 8.21a: Values of standardised γ, ψ coefficients for best fitting models for data from 5-year-old children without hearing difficulties.

Model	γ1	γ2	γ3	ψ
	Phon	*Mem*	*LexK*	
R	.540ns	.479ns	0.081	.301ns

Phon = coefficient linking Phonological Awareness to Reading; Mem = Coefficient linking Memory to Reading
LexK = Coefficient linking Lexical Knowledge to Reading;

Table 8.21b: Values of standardised γ, ψ coefficients for best fitting models for data from 6-, 7-year-old children without hearing difficulties and 7-year-old hearing-impaired children.

Model	γ1	γ2	γ3	ψ
	Phon	*LexK*	*NVAb*	
Y1	.733*	.206ns	-.179ns	.385ns
Y2 (Carv only)	.533*	.216ns	.434*	.222ns
Y2 (Carv & BAS)	.508*	.305ns	.425*	.156ns
H-I	-.259ns	1.00ns	.214ns	.093ns

*significant LISREL T-values; Phon = coefficient linking Phonological Awareness to Reading;
LexK = Coefficient linking Lexical Knowledge to Reading; NVAb = Coefficient linking nonverbal ability to Reading.

For all these groups some caution in interpretation must be exercised since these are small groups and no replication with similar groups was possible. It can be seen that as might be expected, significant proportions of the variance in the latent variable Phonological Awareness was associated with variance in Reading in the groups of children without hearing difficulties, except the youngest (R-group). It does not seem, however, that Lexical Knowledge can be considered to make any significant direct contribution to Reading in any of the models for the children with no hearing difficulties. It also seems that Non-Verbal Ability made a significant contribution to Reading in the Y2 (7-year-old) children.

In the model for Reading in the partially-hearing children the standardised coefficient for the relationship between Lexical Knowledge and Reading is substantial and implies that a change of 1 standard deviation in Lexical Knowledge would be associated with a change of 1 standard deviation in Reading. Clearly a coefficient of such a magnitude would most often be regarded as statistically significant. LISREL's process for determining significance is, however, one in which the estimated coefficient is divided by the estimated standard error (deviation) of the coefficient. The estimated (unstandardised) coefficient is 0.578, with an estimated standard error of 1.1. On this basis the value of the coefficient cannot be considered as being significantly greater than its standard error of measurement.

As was noted above, earlier analyses in this study (see §7.3) of the relationship between lexical knowledge, phonological awareness and reading, suggested that lexical knowledge and phonological awareness were significantly associated with reading and that the effects might be dissociable. Clearly the LISREL analyses of the concurrent effects of phonological awareness and lexical knowledge indicate that the effects of lexical knowledge may not in fact be dissociated from the more obvious direct effects of phonological awareness on reading. Inspection of the (ϕ) matrices of covariance (which are given below in Table 8.22) between Phonological Awareness, Lexical Knowledge and Non-Verbal Ability for the estimated models for these groups of 6- and 7-year-old children however showed that Lexical Knowledge was consistently the only significant covariate of Phonological Awareness. In Table 8.22 the total effects on Reading of the latent variables Phonological Awareness, Lexical Knowledge and Non-verbal Ability are also shown.

Table 8.22a: Estimated Standardised Covariances (Correlations) between latent variables and total effects on Reading of Phonological Awareness (Phon), Memory (Mem) and Lexical Knowledge (LexK) for R-group

		Phon	Mem	LexK
	Phon	1		
	Mem	.456ns	1	
	LexK	.559*	.029ns	1
Total	Effects	0.504	0.616	-0.032

Table 8.22b: Estimated Standardised Covariances (Correlations) between latent variables and total effects on Reading of Phonological Awareness (Phon), Lexical Knowledge (LexK) and Non-verbal Ability (NVAb) for Y1 group

		Phon	LexK	NVAb
	Phon	1		
	LexK	.608*	1	
	NVAb	.513*	.614*	1
Total	Effects	1.796	0.222	-0.116

Table 8.22c: Estimated Standardised Covariances (Correlations) between latent variables and total effects on Reading (Carver test) of Phonological Awareness (Phon), Lexical Knowledge (LexK) and Non-verbal Ability (NVAb) for Y2 group

		Phon	LexK	NVAb
	Phon	1		
	LexK	.501*	1	
	NVAb	.193ns	.290ns	1
Total	Effects	1.042	0.177	0.212

Table 8.22d: Estimated Standardised Covariances (Correlations) between latent variables and total effects on Reading (Carver and BAS tests) of Phonological Awareness (Phon), Lexical Knowledge (LexK) and Non-verbal Ability (NVAb) for Y2 group

		Phon	LexK	NVAb
	Phon	1		
	LexK	.493*	1	
	NVAb	.196ns	.290ns	1
Total	Effects	0.502	0.124	0.103

The caveat relating to small group size is especially true for the Hearing-Impaired group. Here it seems that a very large proportion of the variance in Lexical Knowledge was associated with Reading (see table 8.21, above), but the T-value (which is based on the estimate of the standard error of the estimated coefficient) was not found to be statistically significant. The possibility that this was in fact due to a large estimated standard error (1.1) for this coefficient, and not from a violation of the assumptions upholding the use of ML estimation, was confirmed by a retest of the model using GLS estimation, which yielded a similar value for $\chi^2 = 2.95$, to that ($\chi^2 = 3.95$) found using ML estimation. There is clearly a need here for a much larger sample (than 15) for modelling of these variables. The model for the data from the Hearing-Impaired children does however restate the conclusion arrived at in Chapter 4 (§4.4) that phonological awareness did not appear to be associated with these children's performance in these tests of reading. It is further evident (see Table 8.22e, below) that although there was some substantial covariance between lexical knowledge and phonological awareness in this group, in comparison to the standard error for the estimate this covariance was not found to be greater than might have occurred by chance

Table 8.22e: Estimated Standardised Covariances (Correlations) between latent variables and total effects on Reading (Carver and BAS tests) of Phonological Awareness (Phon), Lexical Knowledge (LexK) and Non-verbal Ability (NVAb) for H-I group

		Phon	LexK	NVAb
	Phon	1		
	LexK	.834ns	1	
	NVAb	-0.272	0.134	1
Total	Effects	-0.376	0.578	0.075

8.2.1.2.4 Discussion

The results of the replicated tests of models within the two independent samples ('93 and '92) of children suggest that the proposed overall model of the concurrent effects of all the variables studied is a valid structure to describe the inter-relationship of the proposed latent causal and dependent variables. It is notable however that the significance of the standardised effect coefficients differ between the two models, and that in particular phonological awareness was not confirmed as accounting for a significant proportion of the variance in reading for the models derived from the separate data sets. This is in contrast to existing theory (as outlined for example by Adams, 1990) and the evidence of earlier analyses of the data in this study (see §4.3 and §7.3). As anticipated, however, lexical knowledge and phonological awareness do show significant covariance in both samples. Contrary to expectation lexical knowledge did not however emerge as significantly associated with reading in either model. Given the heterogeneity with respect to age in both groups, it might also be expected that age should be confirmed as a significant predictor of reading in both groups. The finding that age was not, for the '92 data set, a significant predictor of reading might, alternatively, suggest that other variables in the model sufficiently account for the variance in reading scores. However, it appears that for this particular group none of the tested variables contribute a significant proportion of the variance in reading, and that since the error term for the model is significant it might be considered that other (unmodelled) variables should be invoked as being implicated in 'Reading'.

Thus although the overall structure appears to provide a good fit to the data, the magnitude of the effects of the variables on Reading within the model appear to vary considerably. The hypothesised causal variables (Phonological Awareness, Memory, Lexical Knowledge and Age) all show a consistent level of significant covariance in both groups, but not at a level that might suggest problems of collinearity. The lack of consistent associations between certain hypothesised causal variables (notably Phonological Awareness) and Reading possibly suggests that some of the apparent covariance between Phonological Awareness and Reading in more conventional analyses (as in §4.3) is due in part to covariance between Reading and other variables which may ordinarily be subsumed within Phonological Awareness tasks. The nature of the LISREL analysis allows for the effects of variables to be separated. It is therefore possible that the lack of significance exhibited between variables in the model of the '92 data has become apparent when the total covariance is more accurately represented as being between distinct variables. Thus no one variable is spuriously represented as being significantly associated with the dependent variable (Reading). However it should also be noted that when the structure and parameters that had been estimated for the '93 data were constrained to apply to the '92 data (in the tests of invariant structures) it was found that estimates of the difference between the model implied and the observed matrices of covariances were not significant. Thus while the model derived from the '92 data showed nonsignificant relationships, the structural relationships found for the '93 data set can also be considered to provide a good description of the underlying relationships within the '92 data set.

In the separate analyses of the groups of children at specific ages however it appears that the estimated coefficients confirm earlier findings of the significant effects of phonological awareness on reading for children aged 6-years and over, but not for the 5-year-old children. Phonological awareness and lexical knowledge were again also found to covary for all groups of children without hearing difficulties. It should be recalled that since memory span did not appear as a significant correlate of other variables in the sub-groups of 6- and 7-year-old children the effects of that variable were not modelled for those groups. Age also was deleted from these analyses because the groups were homogeneous with respect to age. On the basis of the analyses carried out on the three different age groups in this study it appears that there are some differences between the patterns of relationships between variables that might support notional discontinuous 'stages'. It is not, however, possible to confirm an overall pattern that corresponds to the stage models discussed earlier in this chapter. It is also interesting to note that for the youngest children in this study there does not appear to be a clear structure to the variables' inter-relationship.

The evidence provided by the model of factors implicated in partially-hearing children's reading must clearly be regarded as provisional since these findings originate from a small number of children and no replication has been possible. Whilst it seems that the overall structure was found to be an adequate description of the inter-relationships between variables it is not possible to confidently confirm which variables are most closely associated with reading for this group of children. Only tentatively can it be suggested, in line with earlier tests of the data (see §7.3), that phonological awareness does *not* seem to be associated with reading for these children (unlike children of the same age without hearing difficulties). Lexical knowledge however had earlier (§7.3.2.2.2) been shown to be associated with partially-hearing children's reading (again to an extent unlike children of the same age without hearing difficulties). The LISREL model for the partially-hearing children's reading does not in fact confirm lexical knowledge as a statistically significant predictor of Reading, although of the variables entered Lexical Knowledge makes by far the greatest contribution to Reading. As has been discussed earlier (§7.3.4, §7.4.3) it may be that at the age and stage of reading that the partially-hearing children were studied they were able to use solely their lexical knowledge in the reading tasks given them, without recourse to phonological awareness. This evidence also suggests that the aspects of reading assessed by the tests used here do not necessarily depend on phonological awareness.

In relation to the theories of reading discussed in the first part of this chapter, the LISREL analyses do not add any further corroborative evidence towards a reconciliation between the data from this study and the models outlined in §8.1. With particular reference to the models of Marsh *et al* (1981) and Frith (1985) which claimed that children's knowledge of word meanings would become increasingly important to their reading, the clear and replicated lack of association between Lexical Knowledge and Reading might imply a need for a reformulation of those theories in that respect. Seymour & MacGregor's (1984) and Barron's (1986) models fare no better for essentially the same reason.

8.3 Overall Concluding Comments

This thesis set out to explore aspects of the relationship between phonological awareness and reading, and what might influence the development of that relationship. The main study consisted of analyses of children's performance in tests of children's categorical perception of speech, their awareness of rhymes and initial phonemes, memory span, lexical (vocabulary) knowledge and non-verbal ability. Children aged 5-, 6-, and 7-years took part in the study and it was found that with increasing age there were significant changes in responses to all measures. What has also emerged from the 'case study' approach adopted is that

a) the relationship between the measures of phonological awareness and reading was not consistent across ages;

b) the development of phonological awareness may not be dependent on acuteness of hearing, or on the accuracy of perception of speech;

c) performance in tasks assessing phonological awareness may be influenced by factors relating to children's memory;

d) memory span itself may not have a direct causal influence on reading;

e) phonological awareness and children's lexical knowledge may be closely associated, with phonological awareness developing from growth in children's lexical knowledge;

f) children's lexical knowledge itself does not seem directly relevant to reading, unless phonological skills are not employed in reading;

g) children with moderate hearing-impairment are able to develop phonological awareness, but their skills in this domain were not associated with their reading;

h) it has not been possible to reconcile the data from this study to theoretical or statistical models of reading.

The evidence from this study has failed to support parts of existing theory and research, but in other respects has provided counter examples to existing theory. Clearly all the conclusions of this research could form the basis for further experimental studies using larger groups of randomly selected children. Such studies might also include children with clearly established and specific difficulties with reading or spelling. It would also be of great importance to use a wider range of tasks that might be indicative of the underlying concepts particularly phonological awareness, lexical knowledge and memory.

There are, however, some specific issues which the present author would wish to pursue.

In the study of the relationship between speech perception and phonological awareness, it would be important to establish if the lack of a concurrent relationship was found for other speech contrasts, such as place of articulation, or, with slightly younger children, a vowel contrast. It would also be important to repeat the developmental investigations in this study, but over a longer time scale, since that aspect of this study has suggested that accuracy of speech perception might presage later phonological skills.

With regard to the role of memory within phonological awareness and processing tasks the nature of the memory 'load' and the effects of rhyming stimuli versus non-rhyming stimuli has not yet been fully worked out. It would be of great interest to see if the ratio of recall of non-rhyming to rhyming stimuli could be replicated in other, and clinically diverse groups - such as children with dyslexia, and in work involving other sensory modalities, such as visual perception of stimuli.

The statistical modelling of variables here only represents a sample of the exploratory and confirmatory techniques available within LISREL. It is clearly important for researchers to develop ways of examining the complexities of the simultaneous inter-relationship of several variables, since, especially for applied psychologists, multivariate views of variables are often closer to the nature of problems presented by children in schools. Multivariate analysis may also be preferred to uni-/ bi-variate analyses since the former can give estimates of the relative salience and effect size when causal variables are assessed *in situ* as competing for shared variance with dependent variables. If two of the conclusions of this research, that the apparent relationship between phonological awareness and reading is dissociable into relationships between inter-related but distinct variables, and that phonological awareness may not be consistently related to all children's reading is replicated in other statistical models of real data this would represent a significant challenge to current orthodoxies in the fields of reading research and educational policy.

Finally, this research has presented some findings about partially-hearing children. At the stage at which the children here were seen, it was apparent that they showed levels of 'reading' very comparable to the children of the same age without hearing difficulties. However it was also evident that the partially-hearing children's reading was not dependent on phonological skills, but was more likely to be dependent on their prior knowledge of words. It is interesting that these children had developed some awareness of phonological segments at levels similar to those which might be expected for children a year younger. The study has not however been able to clearly elucidate the source of such abilities, but, as with children with no hearing difficulties, it has been suggested that the development of phonological awareness may be associated with the growth of the lexicon.

At this stage there is very little in the way of further corroborative, or contrasting, evidence about children with this level of hearing. There is a need, in order to inform the work of teachers and parents of children with moderate hearing difficulties, to have both cross-sectional and developmental analyses of the skills such children use in reading. The present finding, that for this group of children reading was not associated with phonological awareness, could challenge views (see Share, 1995; Siegel, 1993; Snowling, 1996) that phonological awareness is critical to the development of reading. However this conjecture, that reading might develop adequately without phonological awareness (see also Seymour & Elder, 1986) could be further explored within a prospective longitudinal study of partially-hearing children. It would be of great interest to establish if delays in the development of phonological awareness might again be accompanied by the continuing development of age appropriate word (and non-word) reading. In such a study it would be important to compare hearing-impaired children's skills in phonological awareness and reading, as well as their lexical knowledge, with the skills and knowledge of children without hearing difficulties over a wider age-range than that studied here. All such findings would undoubtedly have implications for the continuing development of understanding of how reading develops in both hearing and hearing-impaired children.

Appendices

Appendix 1

Raw Scores

Sp= Speech Perception; Rhy= Rhyme awareness; IPh=Initial Phoneme awareness; MeS=Memory Span; MSim=No.phonologically similar items; MDis=No.phonologically dissimilar items; BPVS=British Picture Vocabulary Scale; Rav=Ravens Matrices; Carv=Carver Word Recognition Test; BAS=British Ability Scales Word Reading test; Age=Age in months; Gender: 1=boy, 2=girl.

R ('92)

Sp	Rhy	IPh	Mes	MSim	MDis	BPVS	Rav	Carv	BAS	Age	Gender
5	4	5	5	2	2	15	18	4	0	60	2
2	3	3	3	2	2	8	10	2	0	58	2
1	3	2	3	0	5	9	14	0	0	58	2
5	9	5	4	3	6	11	17	1	0	58	1
2	7	3	4	2	2	13	18	3	0	57	1
5	6	4	4	0	1	11	15	3	0	60	1
5	9	7	3	2	7	16	16	4	0	56	2
1	4	3	4	6	5	8	15	0	0	58	1
4	2	2	5	0	6	6	15	1	0	59	2
2	7	7	4	3	7	12	11	5	0	59	2
5	3	2	3	0	2	10	21	1	0	56	2
5	3	3	2	7	7	13	17	2	0	58	2
5	7	5	4	1	7	10	14	2	0	58	1
1	4	5	4	5	7	10	17	1	0	58	2
1	2	3	2	5	7	12	14	1	0	57	2

R ('93)

Sp	Rhy	IPh	Mes	MSim	MDis	BPVS	Rav	Carv	BAS	Age	Gender
2	6	4	3	1	3	10	18	1	0	58	1
5	3	3	3	2	4	8	16	2	0	55	1
5	2	4	5	0	0	6	9	4	0	60	2
3	4	4	2	4	7	18	13	0	0	56	2
3	6	5	4	4	6	9	9	4	0	54	2
1	4	4	2	6	7	7	14	1	0	57	1
5	9	6	6	0	2	12	15	3	0	60	2
5	3	3	3	3	4	9	11	1	0	57	2
1	3	2	3	2	2	8	13	1	0	55	2
4	5	5	4	2	7	11	15	1	0	57	2
2	2	1	3	0	0	5	10	3	0	55	1
2	4	4	2	7	6	7	8	0	0	57	1
3	4	3	2	5	7	8	15	0	0	55	2
1	3	2	3	0	1	6	10	1	0	58	2
2	9	5	3	0	0	7	9	4	0	54	2

Y1 ('92)

Sp	Rhy	IPh	Mes	MSim	MDis	BPVS	Rav	Carv	BAS	Age	Gender
5	5	5	4	4	7	10	15	3	0	70	2
2	9	9	5	3	5	17	30	10	12	70	2
5	8	8	5	1	5	15	20	6	0	69	2
2	8	6	4	4	6	14	19	3	0	72	1
2	7	5	2	2	4	12	18	4	0	70	2
3	4	3	4	5	5	14	15	4	0	70	2
5	7	6	4	2	6	10	17	3	0	71	1
1	5	9	5	2	4	13	22	4	4	71	2
5	9	9	4	3	6	14	19	7	7	72	2
5	7	5	0	7	7	11	17	1	0	71	2
5	6	3	4	3	6	14	22	0	0	71	2
5	9	5	4	1	7	10	15	3	0	68	1
5	8	6	8	0	5	7	14	2	0	67	1
4	5	5	4	4	7	9	15	1	0	69	1
5	8	5	4	1	7	15	15	3	0	68	1

Y1 ('93)

Sp	Rhy	IPh	Mes	MSim	MDis	BPVS	Rav	Carv	BAS	Age	Gender
2	8	3	4	2	4	8	19	4	0	72	1
3	6	9	4	4	7	13	17	7	6	72	2
3	2	4	4	3	5	14	11	2	0	70	2
3	3	2	4	5	5	10	17	1	0	70	2
3	9	8	4	4	7	10	17	4	2	70	1
5	3	9	4	1	4	12	23	3	0	69	1
3	9	9	4	3	5	12	17	9	52	68	2
2	4	1	5	6	7	9	15	3	0	70	1
2	9	8	5	0	2	14	11	8	23	71	2
2	5	4	3	0	3	9	11	3	0	68	2
2	8	6	3	3	3	11	18	1	0	70	2
2	8	9	5	0	0	10	17	5	0	70	1
5	5	3	4	4	7	9	18	4	3	70	2
2	5	3	4	0	2	9	17	4	0	69	2
5	6	1	3	2	4	7	11	3	0	68	1

Y2 ('92)

Sp	Rhy	IPh	Mes	MSim	MDis	BPVS	Rav	Carv	BAS	Age	Gender
4	4	6	5	0	2	8	18	3	0	81	1
5	9	9	6	2	3	16	14	7	15	82	2
1	4	6	6	1	5	15	24	8	33	83	1
5	4	4	6	0	3	14	14	6	10	81	2
5	9	9	4	7	7	14	19	7	16	80	2
4	9	9	6	7	7	16	14	8	63	81	2
5	9	7	6	1	5	17	22	8	37	82	1
3	5	3	4	2	6	12	15	3	0	82	2
5	5	3	4	5	7	10	24	8	10	83	2
5	9	9	7	0	6	12	27	10	23	83	2
5	8	9	7	0	2	15	22	4	4	84	2
5	6	7	6	1	1	15	18	7	18	82	2
5	6	5	5	0	1	12	13	2	0	81	1
3	9	9	4	4	7	12	21	9	27	80	1
5	8	9	6	1	5	16	20	9	5	83	2

Y2 ('93)

Sp	Rhy	IPh	Mes	MSim	MDis	BPVS	Rav	Carv	BAS	Age	Gender
5	3	3	4	6	4	13	19	6	0	82	2
3	9	9	5	4	6	18	29	10	71	82	2
5	8	8	4	2	6	18	23	7	30	84	1
5	9	9	7	0	3	17	16	10	12	81	2
5	9	8	4	6	7	8	21	8	12	84	1
5	6	9	4	6	5	16	14	9	8	82	1
2	7	3	3	1	5	8	12	2	0	80	1
5	7	5	4	0	4	11	24	6	7	79	1
5	7	8	5	0	1	12	14	9	9	83	1
5	8	9	6	1	5	15	27	10	22	83	2
5	9	9	6	0	4	14	21	10	50	84	2
5	7	7	4	4	7	18	18	7	9	81	2
5	9	9	4	2	4	10	12	8	10	80	1
5	9	9	8	0	3	13	16	6	14	79	1
4	7	7	6	1	3	11	15	4	7	81	1

Hearing-Impaired Children

Sp	Rhy	IPh	Mes	MSim	MDis	BPVS	Rav	Carv	BAS	Age	Gender
5	8	6	5	6	7	12	16	9	31	81	1
2	7	4	4	2	5	8	10	1	0	84	1
1	8	9	4	1	7	13	17	9	16	84	2
4	4	9	4	2	7	9	20	7	0	77	1
4	4	7	4	2	7	10	18	7	11	79	1
3	5	3	3	0	4	7	24	4	11	74	1
3	6	6	5	4	6	10	17	2	10	81	1
4	6	5	5	0	2	7	13	2	0	80	2
1	7	2	3	-	-	5	17	5	2	84	1
5	4	9	5	0	3	9	16	6	15	83	1
4	8	7	4	3	7	11	17	9	48	85	2
4	6	9	7	0	7	11	13	6	47	85	2
1	9	3	4	0	6	14	21	9	37	86	1
2	6	6	5	2	6	10	18	8	47	87	2
5	5	8	3	6	7	9	19	7	28	94	2

Note: It was not possible to get clearly audible responses to the Similar/Dissimilar items in the phonological similarity test for one partially-hearing child.

Appendix 2

Coefficients of Kurtosis and Skew

	Sp	Rhy	IPh	MeS	BPVS	Rav	Carv
R (T1)							
Kurtosis	-1.796	-1.13	-0.746	-0.605	-0.455	0.026	-0.773
Skew	-0.191	0.507	0.587	-0.306	0.142	-0.171	0.513
R (T2)							
Kurtosis	-1.351	0.101	-0.528	0.593	2.764	-1.233	-1.226
Skew	0.238	1.047	-0.277	1.072	1.665	0.18	0.473
R (combined)							
Kurtosis	-1.659	-0.655	-0.393	-0.231	0.182	-0.759	-0.963
Skew	0.021	0.758	0.348	0.46	0.74	-0.103	0.492
Y1 (T1)							
Kurtosis	-0.988	-1.109	-0.832	2.278	-0.795	2.187	0.855
Skew	-0.829	-0.397	0.38	-0.204	-0.254	1.539	1.112
Y1 (T2)							
Kurtosis	-0.488	-1.294	-1.6	-0.5	-0.917	-0.494	-0.195
Skew	0.977	-0.13	0.049	0	0.322	-0.127	0.778
Y1 (combined)							
Kurtosis	-1.634	-0.926	-1.157	4.982	-0.89	2.217	0.292
Skew	0.025	-0.432	-0.044	-0.173	0.176	0.949	0.905
Y2 (T1)							
Kurtosis	2.288	-1.623	-1.141	-1.168	-0.342	-1.102	-0.861
Skew	-1.772	-0.282	-0.561	-0.282	-0.683	0.15	-0.637
Y2 (T2)							
Kurtosis	2.873	2.072	0.221	-0.315	-1.189	-0.85	-0.104
Skew	-2.07	-1.443	-1.277	0.787	-0.102	0.483	-0.773
Y2 (combined)							
Kurtosis	2.976	-0.656	-0.656	-0.859	-0.824	-0.878	-0.497
Skew	-1.958	-0.764	-0.888	0.272	-0.293	0.352	-0.686

cont....

Appendix 2 (cont)

Coefficients of Kurtosis and Skew

	MeSim	MeDis	BAS	Age
R (T1)				
Kurtosis	-0.828	-1.458	.	-0.45
Skew	0.561	-0.514	.	0
R (T2)				
Kurtosis	-0.897	-1.527	.	-0.742
Skew	0.555	-0.084	.	0.442
R (combined)				
Kurtosis	-0.863	-1.444	.	-0.727
Skew	0.555	-0.336	.	-0.179
Y1 (T1)				
Kurtosis	0.031	-1.159	3.459	-1.112
Skew	0.6	-0.294	2.168	-0.235
Y1 (T2)				
Kurtosis	-1.095	-0.677	6.029	-0.571
Skew	0.081	-0.268	2.688	0.167
Y1 (combined)				
Kurtosis	-0.512	0.289	14.608	-0.86
Skew	0.289	-0.836	3.817	-0.098
Y2 (T1)				
Kurtosis	-0.283	-1.402	1.168	-0.926
Skew	1.068	-0.299	1.232	-0.003
Y2 (T2)				
Kurtosis	-1.121	-0.343	2.163	-1.135
Skew	0.657	-0.19	1.763	-0.074
Y2 (combined)				
Kurtosis	-0.682	-0.996	1.844	-0.833
Skew	0.874	-0.279	1.551	-0.133

Coefficients of Kurtosis and Skew for Hearing-Impaired group (n=15)

	Kurtosis	Skew
Speech Perception	-1.248	-0.355
Rhyme awareness	-1.096	0.089
Initial Phoneme awareness	-1.135	-0.308
Memory Span	0.899	0.846
Memory Similar	-0.28	0.842
Memory Dissimilar	0.344	-1.253
BPVS	-0.388	-0.05
Ravens	0.211	-0.115
Carver	-0.905	-0.591
BAS	-1.283	0.416
Age	0.407	0.35
Hearing Threshold (dB)	0.15	-0.757

Appendix 3

Hearing Thresholds (L and R ears) for Hearing-Impaired group
(Data from audiograms supplied by child's teacher. - indicates no data at that frequency; NR indicates no response recorded)

	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	Average
1L	50	60	70	55	60	60	59
1R	50	60	70	55	75	75	62
2L	45	60	75	90	70	70	68
2R	50	50	75	80	70	55	63
3L	35	30	50	65	55	80	52.5
3R	30	25	50	55	65	75	50
4L	50	-	50	75	-	-	58
4R	50	-	50	95	-	-	65
5L	45	55	65	55	65	85	62
5R	85	75	70	60	80	75	74
6L	30	50	85	100	90	100	91
6R	25	55	75	100	90	100	74
7L	50	65	70	85	75	-	69
7R	45	50	70	75	75	-	63
8L	60	50	50	70	70	-	60
8R	50	50	60	70	70	-	60
9L	30	55	85	115	120	-	81
9R	25	45	65	80	95	-	62
10L	45	45	65	60	55	70	57
10R	55	55	55	60	60	NR	57

cont...

Appendix 3 (cont)

	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	**Average**
11L	35	45	60	60	65	60	54
11R	40	50	75	70	70	85	65
12L	40	50	65	60	60	80	60
12R	50	65	80	75	80	85	73
13L	20	30	80	95	90	-	63
13R	20	45	80	95	100	-	68
14L	-	30	25	45	75	-	44
14R	-	25	25	90	105	-	49
15L	65	-	50	-	60	-	58
15R	60	-	55	-	60	-	58
Means	44.1	49	63.3	74.6	75.2	77	62.25
sd	14.2	12.7	15.2	17.7	16.1	13.2	9.56

Appendix 4

Rhyme Awareness Test Introductory Script and Test Items

E: Do you know Humpty Dumpty sat on a wall, Humpty Dumpty had a great ....?
C: Fall ?
E: Yes. Fall. Wall and Fall end with the same sound /-all/ dont they. Do you know any other words that end with /-all/ ?
C: Ball?
E: Tall?
C: Call ?
E: ...[continue to establish understanding of (rhyme) 'ending with same sound.' Use other rhyme ends such as Jack & Jill went up the ... ? Hickory Dickory Dock the mouse ran up the .... ? as stimuli.]

E & C go on telling rhyming words until E introduces a word that does not rhyme. If there is no response to indicate that the error has been spotted, then draw attention to it. For example:

E: mat
C:...
E: cat
C:...
E: table
C: ?
E: That doesnt sound right does it ?

Now we are going to play a game with words. Some of the words end with the same sound and some dont. Like this [emphasising the word end (rhyme) sound]

FISHCAP TAP

Can you hear that Cap and Tap both end with the same sound /-ap/, and Fish doesnt ?

Now listen to these three words and try to hear which two end with the same sound

GOAT PAN COAT

Can you hear that Goat and Coat both end with a /-oat/ sound ?

Now you try these three and tell me which two words end with the same sound ?

CARSTARDOLL

Praise success. If necessary supply more examples, but if no consistent success is achieved after three more practice trials discontinue.

Otherwise... *Now you try these. You tell me which two words end with the same sound ?*

RHYME TEST (with pictures) Record form

NAME................................
SCHOOL...............................
DATE OF BIRTH...............................
DATE OF TEST...............................

LOG	[__]	BALL	[__]	DOG	[__]
CAT	[__]	HAT	[__]	BELL	[__]
COMB	[__]	NAIL	[__]	WHALE	[__]
BED	[__]	HEAD	[__]	KNIFE	[__]
CHAIR	[__]	DRUM	[__]	BEAR	[__]
SOCK	[__]	HEN	[__]	PEN	[__]
GUN	[__]	HOUSE	[__]	SUN	[__]
LEG	[__]	PEG	[__]	WALL	[__]
FOOT	[__]	KEY	[__]	TREE	[__]

Appendix 5

Initial Phoneme Awareness Test Introductory Script and Test Items

Begin with a game of 'I-spy' using immediately apparent objects. Continue alternating turns to establish the child is confident about attending to initial sounds.

Then say:
"*This is a game where we have to listen to some words. I will say three words, two of them have names that start with the same sound and one will start with a different sound.*
Listen to these words:
[emphasise intitial sounds]

GATE SUN SOCK

Can you hear how SUN and SOCK both start with a /s/ sound, and GATE starts with a /g/ sound? So which two start with the same sound....[if necessary prompt with *with a /s/ sound*]... *That's right, SUN and SOCK both start with the same sound.*

Now you try ilstening to these three words:

*/k k k/*CAT */d d d/* DOG */k k k/*COW

Which two start with the same sound? That's right CAT and COW both start with a /k/ sound.

Now listen to these three words
[emphasise the initial sound]

BIKE BED PAN

[Praise success. If the child clearly has difficulty understanding the task, give more instruction ad lib ! If child is unable to achieve unaided success within three more practices then discontinue.]

Otherwise...*Now you try these. You tell me which two start with the same sound.*

INITIAL PHONEME TEST (with pictures) Record Form

NAME................................
SCHOOL................................
DATE OF BIRTH................................
DATE OF TEST................................

CAR	[__]	GOAT	[__]	CUP	[__]
CAKE	[__]	HOUSE	[__]	HAT	[__]
DOOR	[__]	DUCK	[__]	TAP	[__]
FLY	[__]	SHOE	[__]	FLAG	[__]
NAIL	[__]	KNIFE	[__]	BIRD	[__]
MOUSE	[__]	BOOK	[__]	BELL	[__]
PEN	[__]	PIG	[__]	CHAIR	[__]
FOOT	[__]	VAN	[__]	FISH	[__]
KEY	[__]	BALL	[__]	BEAR	[__]

Appendix 6

Memory Span Test

NAME................................
SCHOOL................................
DATE OF BIRTH................................
DATE OF TEST................................

i) Play sequence of letters (practice for sound level, identification and speach quality):
B C D G H K L P Q R S T V W
with pauses to allow child to say each letter immediately after hearing it.

ii) Test for memory span. (Dissimilar sounding letter items)
Discontinue when child fails both strings of given length (N). Tick boxes for items repeated correctly in the same serial order.

SQ	[__]	RW	[__]
RKS	[__]	HWL	[__]
QWLH	[__]	SHKQ	[__]
LQHKR	[__]	HRQSK	[__]
RQKHWS	[__]	LQWSKH	[__]
LKSWQHR	[__]	SWQRHLK	[__]
		Total Score	[__]

Appendix 7

Test for Phonological Similarity Effect

Using strings of length (N-1), as determined above from first string length (N) in which child fail both items, give alternating trials of phonologically similar and dissimilar letter strings. *Tick over letter string if recalled in correct serial order. Enter total passed in each category.*

N-1 = 2

VP DC GB TD BV PG CT *Total* [__]

SR QL HK WQ LS RH KW *Total* [__]

N-l = 3

CDV BGT VCB DPG TBC PVD GTP *Total* [__]

RKS HQW KWL SRH WLR QSK LHK *Total* [__]

N-1 = 4

DBGC TCDB BPCD VDBT PVTG GTVP CGVP *Total* [__]

LHQK SKLH HRKL WLHS RWSK QSRW KQWR *Total* [__]

N-1 = 5

DCGVB PVBTD VBCDP CPTVG GTPBV TDGPC BGDCT *Total* [__]

LKHWR RWSKL WRLQH SQRLW KSWHQ HLQSK QHKRS *Total* [__]

Appendix 8
LISREL analysis of '93 sample

```
        Mac-L I S R E L 7.17

              BY

        KARL G JORESKOG AND DAG SORBOM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THE FOLLOWING LISREL CONTROL LINES HAVE BEEN READ :
TI All (N=45; 93)
DA NG=1 NI=8 NO=45 MA=CM
LA
'Carv' 'BAS' 'Rhy' 'IPh' 'Age' 'MeS' 'BPVS' 'Rav'
CM=SY
9.923
3.892    2.016
4.929    2.274    5.905
6.521    2.963    4.701    7.618
25.227   10.522   13.664   16.969   110.46
2.600    1.017    1.573    2.031    7.856    1.69
6.227    3.128    3.277    6.070    21.036   1.964   12.461
7.167    3.578    4.316    5.962    29.159   2.115   8.675    23.04
MO NY=2 NX=6 NE=1 NK=5 LY=FI LX=FI GA=FI PH=FR BE=FU PS=FR TD=DI,FI TE=FI
LK
'Phon' 'Mem' 'LexK' 'Age' 'NVAb'
LE
'Reading'
VA 1.7 TD(1,1)
VA 3.0 TD(2,2)
VA 11.0 TD(3,3)
VA 0.51 TD(4,4)
VA 3.75 TD(5,5)
VA 4.6 TD(6,6)
ST 2.1 LX(1,1)
ST 2.1 LX(2,1)
ST 1.0 LX(3,4) LX(4,2) LX(5,3) LX(6,5)
FR TD(1,1) TD(2,2)
FR GA(1,1) GA(1,2) GA(1,3) GA(1,4) GA(1,5)
VA 2.4 LY(1,1)
VA 1.1 LY(2,1)
FR TE(1,1) TE(2,1)
VA 3.97 TE(1,1)
VA 0.81 TE(2,1)
OU ML SE SS TV EF AD=OFF
```

NUMBER OF INPUT VARIABLES 8

NUMBER OF Y - VARIABLES 2

NUMBER OF X - VARIABLES 6

NUMBER OF ETA - VARIABLES 1

NUMBER OF KSI - VARIABLES 5

NUMBER OF OBSERVATIONS 45

TI All (N=45; 93)

COVARIANCE MATRIX TO BE ANALYZED

	CARV	BAS	RHY	IPH	AGE	MES
CARV	9.923					
BAS	3.892	2.016				
RHY	4.929	2.274	5.905			
IPH	6.521	2.963	4.701	7.618		
AGE	25.227	10.522	13.664	16.969	110.460	
MES	2.600	1.017	1.573	2.031	7.856	1.690
BPVS	6.227	3.128	3.277	6.070	21.036	1.964
RAV	7.167	3.578	4.316	5.962	29.159	2.115

COVARIANCE MATRIX TO BE ANALYZED

	BPVS	RAV
BPVS	12.461	
RAV	8.675	23.040

PARAMETER SPECIFICATIONS

LAMBDA Y

	READING
CARV	0
BAS	0

LAMBDA X

	PHON	MEM	LEXK	AGE	NVAB
RHY	0	0	0	0	0
IPH	0	0	0	0	0
AGE	0	0	0	0	0
MES	0	0	0	0	0
BPVS	0	0	0	0	0
RAV	0	0	0	0	0

BETA

	READING
READING	0

GAMMA

	PHON	MEM	LEXK	AGE	NVAB
READING	1	2	3	4	5

PHI

	PHON	MEM	LEXK	AGE	NVAB
PHON	6				
MEM	7	8			
LEXK	9	10	11		
AGE	12	13	14	15	
NVAB	16	17	18	19	20

PSI

	READING
READING	21

THETA EPS

CARV	BAS
22	23

THETA DELTA

RHY	IPH	AGE	MES	BPVS	RAV
24	25	0	0	0	0

INITIAL ESTIMATES (TSLS)

LAMBDA Y

	READING
CARV	2.400
BAS	1.100

LAMBDA X

	PHON	MEM	LEXK	AGE	NVAB
RHY	2.100	.000	.000	.000	.000
IPH	2.100	.000	.000	.000	.000
AGE	.000	.000	.000	1.000	.000
MES	.000	1.000	.000	.000	.000
BPVS	.000	.000	1.000	.000	.000
RAV	.000	.000	.000	.000	1.000

BETA

	READING
READING	.000

GAMMA

	PHON	MEM	LEXK	AGE	NVAB
READING	.783	.030	-.009	.053	-.022

COVARIANCE MATRIX OF ETA AND KSI

	READING	PHON	MEM	LEXK	AGE	NVAB
READING	1.106					
PHON	1.136	1.022				
MEM	1.056	.858	1.180			
LEXK	2.638	2.225	1.964	8.711		
AGE	10.347	7.294	7.856	21.036	99.460	
NVAB	3.033	2.447	2.115	8.675	29.159	18.440

PSI

	READING
READING	-.268

THETA EPS

CARV	BAS
3.970	.810

THETA DELTA

RHY	IPH	AGE	MES	BPVS	RAV
1.700	3.000	11.000	.510	3.750	4.600

SQUARED MULTIPLE CORRELATIONS FOR Y - VARIABLES

CARV	BAS
.616	.623

TOTAL COEFFICIENT OF DETERMINATION FOR Y - VARIABLES IS .765

SQUARED MULTIPLE CORRELATIONS FOR X - VARIABLES

RHY	IPH	AGE	MES	BPVS	RAV
.726	.600	.900	.698	.699	.800

TOTAL COEFFICIENT OF DETERMINATION FOR X - VARIABLES IS .997

SQUARED MULTIPLE CORRELATIONS FOR STRUCTURAL EQUATIONS

READING
1.242

LISREL ESTIMATES (MAXIMUM LIKELIHOOD)

LAMBDA Y

	READING
CARV	2.400
BAS	1.100

LAMBDA X

	PHON	MEM	LEXK	AGE	NVAB
RHY	2.100	.000	.000	.000	.000
IPH	2.100	.000	.000	.000	.000
AGE	.000	.000	.000	1.000	.000
MES	.000	1.000	.000	.000	.000
BPVS	.000	.000	1.000	.000	.000
RAV	.000	.000	.000	.000	1.000

BETA

	READING
READING	.000

GAMMA

	PHON	MEM	LEXK	AGE	NVAB
READING	.725	-.002	.014	.048	-.013

COVARIANCE MATRIX OF ETA AND KSI

	READING	PHON	MEM	LEXK	AGE	NVAB
READING	1.479					
PHON	1.158	1.106				
MEM	1.011	.875	1.180			
LEXK	2.707	2.326	1.964	8.711		
AGE	10.083	7.413	7.856	21.036	99.460	
NVAB	3.107	2.507	2.115	8.675	29.159	18.440

PSI

	READING
READING	.157

THETA EPS

CARV	BAS
1.149	.291

THETA DELTA

RHY	I PH	AGE	MES	BPVS	RAV
2.373	1.748	11.000	.510	3.750	4.600

SQUARED MULTIPLE CORRELATIONS FOR Y - VARIABLES

CARV	BAS
.881	.860

TOTAL COEFFICIENT OF DETERMINATION FOR Y - VARIABLES IS .931

SQUARED MULTIPLE CORRELATIONS FOR X - VARIABLES

RHY	IPH	AGE	MES	BPVS	RAV
.673	.736	.900	.698	.699	.800

TOTAL COEFFICIENT OF DETERMINATION FOR X - VARIABLES IS .998

SQUARED MULTIPLE CORRELATIONS FOR STRUCTURAL EQUATIONS

READING
.894

TOTAL COEFFICIENT OF DETERMINATION FOR STRUCTURAL EQUATIONS IS .894

CHI-SQUARE WITH 11 DEGREES OF FREEDOM = 14.05(P = .230)

GOODNESS OF FIT INDEX = .933
ADJUSTED GOODNESS OF FIT INDEX = .781
ROOT MEAN SQUARE RESIDUAL = .690

SUMMARY STATISTICS FOR FITTED RESIDUALS
SMALLEST FITTED RESIDUAL = -1.903
MEDIAN FITTED RESIDUAL = 0.000
LARGEST FITTED RESIDUAL = 1.402
STEMLEAF PLOT

```
- 1|96
- 1|3
- 0|996
- 0|4333211000000000000
  0|122233
  0|77
  1|0024
```

SUMMARY STATISTICS FOR STANDARDIZED RESIDUALS
SMALLEST STANDARDIZED RESIDUAL = -2.585
MEDIAN STANDARDIZED RESIDUAL = 0.000
LARGEST STANDARDIZED RESIDUAL = 2.585
STEMLEAF PLOT

```
- 2|6
- 1|96542210
- 0|9764400000000000
  0|4679
  1|0122246
  2|6
```

LARGEST NEGATIVE STANDARDIZED RESIDUALS

RESIDUAL FOR BPVS AND RHY = -2.585

PAGE
MISSING
IN
ORIGINAL

PSI

	READING
READING	1.648

THETA EPS

CARV	BAS
2.681	3.018

THETA DELTA

RHY	IPH	AGE	MES	BPVS	RAV
3.561	3.057	.000	.000	.000	.000

TOTAL AND INDIRECT EFFECTS

TOTAL EFFECTS OF KSI ON ETA

	PHON	MEM	LEXK	AGE	NVAB
READING	.725	-.002	.014	.048	-.013

STANDARD ERRORS FOR TOTAL EFFECTS OF KSI ON ETA

	PHON	MEM	LEXK	AGE	NVAB
READING	.295	.256	.095	.024	.046

INDIRECT EFFECTS OF KSI ON ETA

	PHON	MEM	LEXK	AGE	NVAB
READING	.000	.000	.000	.000	.000

STANDARD ERRORS FOR INDIRECT EFFECTS OF KSI ON ETA

	PHON	MEM	LEXK	AGE	NVAB
READING	.000	.000	.000	.000	.000

TOTAL EFFECTS OF ETA ON ETA

	READING
READING	.000

STANDARD ERRORS FOR TOTAL EFFECTS OF ETA ON ETA

	READING
READING	.000

INDIRECT EFFECTS OF ETA ON ETA

	READING
READING	.000

STANDARD ERRORS FOR INDIRECT EFFECTS OF ETA ON ETA

	READING
READING	.000

TOTAL EFFECTS OF ETA ON Y

	READING
CARV	2.400
BAS	1.100

STANDARD ERRORS FOR TOTAL EFFECTS OF ETA ON Y

	READING
CARV	.000
BAS	.000

INDIRECT EFFECTS OF ETA ON Y

	READING
CARV	.000
BAS	.000

STANDARD ERRORS FOR INDIRECT EFFECTS OF ETA ON Y

	READING
CARV	.000
BAS	.000

TOTAL EFFECTS OF KSI ON Y

	PHON	MEM	LEXK	AGE	NVAB
CARV	1.739	-.004	.032	.116	-.030
BAS	.797	-.002	.015	.053	-.014

STANDARD ERRORS FOR TOTAL EFFECTS OF KSI ON Y

	PHON	MEM	LEXK	AGE	NVAB
CARV	.708	.614	.228	.057	.111
BAS	.324	.281	.104	.026	.051

STANDARDIZED SOLUTION

LAMBDA Y

	READING
CARV	2.919
BAS	1.338

LAMBDA X

	PHON	MEM	LEXK	AGE	NVAB
RHY	2.209	.000	.000	.000	.000
IPH	2.209	.000	.000	.000	.000
AGE	.000	.000	.000	9.973	.000
MES	.000	1.086	.000	.000	.000
BPVS	.000	.000	2.951	.000	.000
RAV	.000	.000	.000	.000	4.294

BETA

	READING
READING	.000

GAMMA

	PHON	MEM	LEXK	AGE	NVAB
READING	.627	-.001	.033	.396	-.044

CORRELATION MATRIX OF ETA AND KSI

	READING	PHON	MEM	LEXK	AGE	NVAB
READING	1.000					
PHON	.906	1.000				
MEM	.766	.766	1.000			
LEXK	.754	.749	.613	1.000		
AGE	.831	.707	.725	.715	1.000	
NVAB	.595	.555	.453	.684	.681	1.000

PSI

	READING
READING	.106

REGRESSION MATRIX ETA ON KSI (STANDARDIZED)

	PHON	MEM	LEXK	AGE	NVAB
READING	.627	-.001	.033	.396	-.044

THE PROBLEM USED 10304 BYTES (= 3.9% OF AVAILABLE WORKSPACE)
TIME USED : 23 SECONDS

Appendix 9
LISREL analysis of '92 sample

Mac-LISREL 7.17

BY

KARL G JORESKOG AND DAG SORBOM

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THE FOLLOWING LISREL CONTROL LINES HAVE BEEN READ :

```
)
DA NG=1 NI=8 NO=45 MA=CM
LA
'Carv' 'BAS' 'Rhy' 'IPh' 'Age' 'MeS' 'BPVS' 'Rav'
CM=SY
8.644
3.456    1.877
3.390    1.222    5.153
4.912    2.021    3.903    5.429
19.258   9.573    8.100    12.460   98.804
2.256    1.041    0.968    1.658    7.788    2.161
5.074    2.048    3.085    3.620    11.381   0.982    7.952
6.442    2.769    2.528    3.756    15.700   1.493    4.500    16.403
MO NY=2 NX=6 NE=1 NK=5 LY=FI LX=FI GA=FI PH=FR BE=FU PS=FR TD=DI,FI TE=FI
LK
'Phon' 'Mem' 'LexK' 'Age' 'NVAb'
LE
'Reading'
VA 1.6 TD(1,1)
VA 2.2 TD(2,2)
VA 9.9 TD(3,3)
VA 0.6 TD(4,4)
VA 2.4 TD(5,5)
VA 3.3 TD(6,6)
ST 1.9 LX(1,1)
ST 1.8 LX(2,1)
ST 1.0 LX(3,4) LX(4,2) LX(5,3) LX(6,5)
FR TD(1,1) TD(2,2)
FR GA(1,1) GA(1,2) GA(1,3) GA(1,4) GA(1,5)
VA 2.28 LY(1,1)
VA 0.9 LY(2,1)
FR TE(1,1) TE(2,2)
VA 3.4 TE(1,1)
VA 0.76 TE(2,1)
OU ML SE SS TV EF AD=OFF
```

NUMBER OF INPUT VARIABLES 8

NUMBER OF Y - VARIABLES 2

NUMBER OF X - VARIABLES 6

NUMBER OF ETA - VARIABLES 1

NUMBER OF KSI - VARIABLES 5

NUMBER OF OBSERVATIONS 45

COVARIANCE MATRIX TO BE ANALYZED

	CARV	BAS	RHY	IPH	AGE	MES
CARV	8.644					
BAS	3.456	1.877				
RHY	3.390	1.222	5.153			
IPH	4.912	2.021	3.903	5.429		
AGE	19.258	9.573	8.100	12.460	98.804	
MES	2.256	1.041	.968	1.658	7.788	2.161
BPVS	5.074	2.048	3.085	3.620	11.381	.982
RAV	6.442	2.769	2.528	3.756	15.700	1.493

COVARIANCE MATRIX TO BE ANALYZED

	BPVS	RAV
BPVS	7.952	
RAV	4.500	16.403

PARAMETER SPECIFICATIONS

LAMBDA Y

	READING
CARV	0
BAS	0

LAMBDA X

	PHON	MEM	LEXK	AGE	NVAB
RHY	0	0	0	0	0
IPH	0	0	0	0	0
AGE	0	0	0	0	0
MES	0	0	0	0	0
BPVS	0	0	0	0	0
RAV	0	0	0	0	0

BETA

	READING
READING	0

GAMMA

	PHON	MEM	LEXK	AGE	NVAB
READING	1	2	3	4	5

PHI

	PHON	MEM	LEXK	AGE	NVAB
PHON	6				
MEM	7	8			
LEXK	9	10	11		
AGE	12	13	14	15	
NVAB	16	17	18	19	20

PSI

	READING
READING	21

THETA EPS

CARV	BAS
22	23

THETA DELTA

RHY	IPH	AGE	MES	BPVS	RAV
24	25	0	0	0	0

INITIAL ESTIMATES (TSLS)

LAMBDA Y

	READING
CARV	2.280
BAS	.900

LAMBDA X

	PHON	MEM	LEXK	AGE	NVAB
RHY	1.900	.000	.000	.000	.000
IPH	1.800	.000	.000	.000	.000
AGE	.000	.000	.000	1.000	.000
MES	.000	1.000	.000	.000	.000
BPVS	.000	.000	1.000	.000	.000
RAV	.000	.000	.000	.000	1.000

BETA

	READING
READING	.000

GAMMA

	PHON	MEM	LEXK	AGE	NVAB
READING	.204	.223	.176	.032	.068

COVARIANCE MATRIX OF ETA AND KSI

	READING	PHON	MEM	LEXK	AGE	NVAB
READING	1.106					
PHON	.977	1.040				
MEM	1.012	.704	1.561			
LEXK	2.232	1.807	.982	5.552		
AGE	8.742	5.521	7.788	11.381	88.904	
NVAB	2.859	1.688	1.493	4.500	15.700	13.103

PSI

	READING
READING	-.183

THETA EPS

CARV	BAS
3.400	.760

THETA DELTA

RHY	IPH	AGE	MES	BPVS	RAV
1.600	2.200	9.900	.600	2.400	3.300

SQUARED MULTIPLE CORRELATIONS FOR Y - VARIABLES

CARV	BAS
.628	.541

TOTAL COEFFICIENT OF DETERMINATION FOR Y - VARIABLES IS .742

SQUARED MULTIPLE CORRELATIONS FOR X - VARIABLES

RHY	IPH	AGE	MES	BPVS	RAV
.701	.605	.900	.722	.698	.799

TOTAL COEFFICIENT OF DETERMINATION FOR X - VARIABLES IS .999

SQUARED MULTIPLE CORRELATIONS FOR STRUCTURAL EQUATIONS

READING
1.166

LISREL ESTIMATES (MAXIMUM LIKELIHOOD)

LAMBDA Y

	READING
CARV	2.280
BAS	.900

LAMBDA X

	PHON	MEM	LEXK	AGE	NVAB
RHY	1.900	.000	.000	.000	.000
IPH	1.800	.000	.000	.000	.000
AGE	.000	.000	.000	1.000	.000
MES	.000	1.000	.000	.000	.000
BPVS	.000	.000	1.000	.000	.000
RAV	.000	.000	.000	.000	1.000

BETA

	READING
READING	.000

GAMMA

	PHON	MEM	LEXK	AGE	NVAB
READING	.192	.216	.177	.033	.067

COVARIANCE MATRIX OF ETA AND KSI

	READING	PHON	MEM	LEXK	AGE	NVAB
READING	1.600					
PHON	1.068	1.241				
MEM	1.020	.791	1.561			
LEXK	2.235	1.888	.982	5.552		
AGE	8.846	6.079	7.788	11.381	88.904	
NVAB	2.871	1.847	1.493	4.500	15.700	13.103

PSI

	READING
READING	.294

THETA EPS

CARV	BAS
.580	.405

THETA DELTA

RHY	IPH	AGE	MES	BPVS	RAV
2.022	.844	9.900	.600	2.400	3.300

SQUARED MULTIPLE CORRELATIONS FOR Y - VARIABLES

CARV	BAS
.935	.762

TOTAL COEFFICIENT OF DETERMINATION FOR Y - VARIABLES IS .946

SQUARED MULTIPLE CORRELATIONS FOR X - VARIABLES

RHY	IPH	AGE	MES	BPVS	RAV
.689	.827	.900	.722	.698	.799

TOTAL COEFFICIENT OF DETERMINATION FOR X - VARIABLES IS .999

SQUARED MULTIPLE CORRELATIONS FOR STRUCTURAL EQUATIONS

READING
.816

TOTAL COEFFICIENT OF DETERMINATION FOR STRUCTURAL EQUATIONS IS .816

CHI-SQUARE WITH 11 DEGREES OF FREEDOM = 13.15(P = .284)

GOODNESS OF FIT INDEX = .932
ADJUSTED GOODNESS OF FIT INDEX = .776
ROOT MEAN SQUARE RESIDUAL = .819

SUMMARY STATISTICS FOR FITTED RESIDUALS
SMALLEST FITTED RESIDUAL = -3.449
MEDIAN FITTED RESIDUAL = 0.000
LARGEST FITTED RESIDUAL = 1.611
STEMLEAF PLOT
- 3|4
- 2|
- 1|420
- 0|9655331100000000000
0|1222223456
1|56
SUMMARY STATISTICS FOR STANDARDIZED RESIDUALS
SMALLEST STANDARDIZED RESIDUAL = -2.329
MEDIAN STANDARDIZED RESIDUAL = 0.000
LARGEST STANDARDIZED RESIDUAL = 2.075
STEMLEAF PLOT
- 2|33100
- 1|97
- 1|400
- 0|95
- 0|20000000000
0|2
0|59
1|00044
1|79
2|011

STANDARD ERRORS

GAMMA

	PHON	MEM	LEXK	AGE	NVAB
READING	.230	.180	.114	.021	.045

PHI

	PHON	MEM	LEXK	AGE	NVAB
PHON	.308				
MEM	.290	.461			
LEXK	.581	.642	1.695		
AGE	2.007	2.496	4.561	21.065	
NVAB	.779	.925	1.851	6.514	3.497

PSI

	READING
READING	.124

THETA EPS

CARV	BAS
.444	.109

THETA DELTA

RHY	IPH	AGE	MES	BPVS	RAV
.592	.406	.000	000	.000	.000

T-VALUES

GAMMA

	PHON	MEM	LEXK	AGE	NVAB
READING	.836	1.199	1.555	1.539	1.508

PHI

	PHON	MEM	LEXK	AGE	NVAB
PHON	4.035				
MEM	2.729	3.388			
LEXK	3.250	1.529	3.275		
AGE	3.029	3.120	2.495	4.220	
NVAB	2.371	1.613	2.432	2.410	3.747

PSI

	READING
READING	2.370

THETA EPS

CARV	BAS
1.307	3.717

THETA DELTA

RHY	IPH	AGE	MES	BPVS	RAV
3.417	2.078	.000	.000	.000	.000

TOTAL AND INDIRECT EFFECTS

TOTAL EFFECTS OF KSI ON ETA

	PHON	MEM	LEXK	AGE	NVAB
READING	.192	.216	.177	.033	.067

STANDARD ERRORS FOR TOTAL EFFECTS OF KSI ON ETA

	PHON	MEM	LEXK	AGE	NVAB
READING	.230	.180	.114	.021	.045

INDIRECT EFFECTS OF KSI ON ETA

	PHON	MEM	LEXK	AGE	NVAB
READING	.000	.000	.000	.000	.000

STANDARD ERRORS FOR INDIRECT EFFECTS OF KSI ON ETA

	PHON	MEM	LEXK	AGE	NVAB
READING	.000	.000	.000	.000	.000

TOTAL EFFECTS OF ETA ON ETA

	READING
READING	.000

STANDARD ERRORS FOR TOTAL EFFECTS OF ETA ON ETA

	READING
READING	.000

INDIRECT EFFECTS OF ETA ON ETA

	READING
READING	.000

STANDARD ERRORS FOR INDIRECT EFFECTS OF ETA ON ETA

	READING
READING	.000

TOTAL EFFECTS OF ETA ON Y

	READING
CARV	2.280
BAS	.900

STANDARD ERRORS FOR TOTAL EFFECTS OF ETA ON Y

	READING
CARV	.000
BAS	.000

INDIRECT EFFECTS OF ETA ON Y

	READING
CARV	.000
BAS	.000

STANDARD ERRORS FOR INDIRECT EFFECTS OF ETA ON Y

	READING
CARV	.000
BAS	.000

TOTAL EFFECTS OF KSI ON Y

	PHON	MEM	LEXK	AGE	NVAB
CARV	.438	.494	.403	.075	.153
BAS	.173	.195	.159	.030	.060

STANDARD ERRORS FOR TOTAL EFFECTS OF KSI ON Y

	PHON	MEM	LEXK	AGE	NVAB
CARV	.524	.412	.259	.049	.102
BAS	.207	.162	.102	.019	.040

STANDARDIZED SOLUTION

LAMBDA Y

	READING
CARV	2.884
BAS	1.138

LAMBDA X

	PHON	MEM	LEXK	AGE	NVAB
RHY	2.117	.000	.000	.000	.000
IPH	2.005	.000	.000	.000	.000
AGE	.000	.000	.000	9.429	.000
MES	.000	1.249	.000	.000	.000
BPVS	.000	.000	2.356	.000	.000
RAV	.000	.000	.000	.000	3.620

BETA

	READING
READING	.000

GAMMA

	PHON	MEM	LEXK	AGE	NVAB
READING	.169	.214	.330	.245	.192

CORRELATION MATRIX OF ETA AND KSI

	READING	PHON	MEM	LEXK	AGE	NVAB
READING	1.000					
PHON	.758	1.000				
MEM	.645	.568	1.000			
LEXK	.750	.719	.334	1.000		
AGE	.742	.579	.661	.512	1.000	
NVAB	.627	.458	.330	.528	.460	1.000

PSI

	READING
READING	.184

REGRESSION MATRIX ETA ON KSI (STANDARDIZED)

	PHON	MEM	LEXK	AGE	NVAB
READING	.169	.214	.330	.245	.192

THE PROBLEM USED 10304 BYTES (= 3.9% OF AVAILABLE WORKSPACE)
TIME USED : 25 SECONDS

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