The Development Of Skills Associated With Early Reading Success

Shirley Cobbold

A thesis submitted to
Cheltenham and Gloucester College of Higher Education
in accordance with the requirements of the degree of
Doctor of Philosophy in the Faculty of Education and
Social Sciences

May 2001

Cheltenham and Gloucester College of Higher Education

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ABSTRACT

This thesis investigates the development of phonological awareness, rapid serial naming, speed of learning verbal/visual symbol associations, letter knowledge and verbal short-term memory in children aged 4.0 to 5.5 years and the relationship of these skills to reading ability at age 5.5 years. Data from a longitudinal study of 68 children are analysed and discussed.

A review of the literature suggests uncertainties concerning the structure and development of phonological awareness. The current study measures phonological awareness at the linguistic levels of rhyme, syllable, onset-rime and phoneme and investigates whether the various skills comprise a unitary construct. Developmental pathways through the linguistic levels are also investigated.

Most previous research investigating the relationship of phonological awareness, verbal short-term memory, letter knowledge and rapid naming with reading ability focuses on the skills of children who have already started learning to read. In such cases, the predictive direction of any relationships cannot be established. The current study therefore also investigates longitudinally predictive relationships between the skills of non-readers and subsequent reading ability. At initial testing, all children were non-readers. Progress in skills was assessed at three time points as children progressed through their first year at school. Reading ability was measured at the end of the study.

The results suggest that phonological awareness is a unitary, developmental construct within which most children follow similar developmental patterns, although some children exhibit considerable developmental lag. The phonological awareness and letter knowledge of non-readers were found to be the major significant predictors of subsequent reading ability. In rapid serial naming, the component elements of inter-stimulus interval (ISI) time and articulation time were measured independently. The results suggest that the ISI component is significantly associated with concurrent reading ability in children aged 5.0 to 5.5 years. The educational implications of the research findings and suggestions for future research are discussed.

Author's Declaration

I declare that the work in this thesis was carried out in accordance with the regulations of Cheltenham and Gloucester College of Higher Education and is original except where indicated by specific reference in the text. No part of the thesis has been submitted as part of any other academic award. The thesis has not been presented to any other institution in the United Kingdom or overseas.

Any views expressed in this thesis are those of the author and in no way represent those of the College.

Acknowledgements

I am indebted to my supervisors, Professor Colin Terrell and Dr. Terri Passenger who guided and encouraged me through this project and to the Hornsby International Dyslexia Centre who funded my studentship.

My thanks also go to the staff and children at the following pre-schools and schools in Herefordshire and Gloucestershire:

Pre-School Settings

Ashfield Park Nursery, Ross-on-Wye, Herefordshire
Eastholme Pre-School Playgroup, Hereford
Hampton Dene Pre-School Playgroup, Hereford
Oak House Nursery School, Bridstow, Herefordshire
Ross-on-Wye Pre-School Playgroup, Herefordshire
St Paul's Pre-School Playgroup, Hereford
Withington Nursery, Herefordshire

Primary Schools

Ashfield Park Primary School, Ross-on-Wye, Herefordshire
Bridstow Primary School, Herefordshire
Goodrich Primary School, Herefordshire
Gorsley Goff's Primary School, Herefordshire
Hampton Dene Primary School, Hereford
Hunderton Infant's School, Hereford
Huntley Primary School, Gloucestershire
Lea Primary School, Herefordshire
Lugwardine Primary School, Herefordshire
Marlbrook Primary School, Hereford
Much Marcle Primary School, Herefordshire
Our Lady's Primary School, Hereford
Peterchurch Primary School, Herefordshire
St Francis Primary School, Hereford
St Josephs's Primary School, Ross-on-Wye, Herefordshire
St Mary's Primary School, Fownhope, Herefordshire
St Paul's Primary School, Hereford
Trinity Primary School, Hereford
Walford Primary School, Herefordshire
Weston-under-Penyard Primary School, Herefordshire
Withington Primary School, Herefordshire

I would also like to thank Paul, Simon and Gina for their support, tolerance and humour.

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Chapter 1

Introduction

This chapter presents a brief introduction to the study under the following headings:

- rationale and aims of the study
- design of the study.

1.1 Rationale and aims of the study

The study developed from the interest of a practising teacher in the precursors of reading difficulty in some young children. Classroom teachers frequently encounter children who experience significant and sometimes unexpected delay in developing early reading skills. Such delay can be a cause of considerable anxiety for children, parents and teachers.

The current study therefore aims to:

- refine existing knowledge concerning the development of reading related skills in children aged 4.0 to 5.5 years
- contribute to existing knowledge about the proposed relationship between a range of pre-literate skills and later word-level reading ability.

Specifically, the skills investigated are:

- phonological awareness
- verbal short-term memory
- letter knowledge
- rate of learning sound/symbol associations
- rapid serial naming

The rationale for the inclusion of each of these areas of investigation in the study is outlined below.

1.1.1 Phonological awareness

Phonological awareness is an awareness of sounds in speech (Blachman, 1997) and is generally measured at one or more of four linguistic levels: rhyme, syllable, onset-rime or phoneme. Over recent years, many studies (for example, Goswami & Bryant, 1990; Wagner, Torgesen & Rashotte, 1994) have argued that phonological awareness is a significant predictor of reading ability. However, the tasks used to measure the construct have varied considerably and are sometimes poorly defined. Consequently, the literature presents an unclear picture concerning which skills are predictive of reading ability at the various stages of a child's development. The research literature raises several questions that the current study aims to address:

1. What is the normal developmental pattern for acquiring phonological awareness skills?
2. How much variability is there in the timing and speed of phonological awareness development?
3. Do the phonological awareness skills investigated form a unitary construct?
4. Which phonological awareness skills are the best predictors of subsequent reading ability?

1.1.2 Verbal short-term memory

It has been suggested that verbal short-term memory is related to reading because it is predictive of the ability to learn phoneme/grapheme correspondences (Gathercole, 1990) and because it is necessary to store sounds in memory before blending them into words when reading (Baddeley, 1978). Research has suggested a link between verbal short-term memory and articulation rate (Baddeley, 1986) but Gathercole (1994) argues that although this relationship is apparent in children aged five it is not apparent in children aged four. The current study investigates the relationships between verbal short-term memory, articulation rate and reading ability in children aged 4.0 to 5.5 years.

1.1.3 Letter knowledge and rate of learning verbal/visual symbol associations

Letter knowledge has frequently been found to be a reliable predictor of reading ability (for example, Chall, 1967; Gallagher, Frith & Snowling, 2000). It has also been suggested that poor readers need more teaching trials to learn verbal/visual symbol associations (such as phoneme/grapheme associations) than more able readers (Mauer & Kamhi, 1996). It could be argued that it is not letter knowledge per se that predicts reading ability but the speed with which children learn verbal/visual symbol associations. The current study investigates relationships between letter knowledge, speed of learning verbal/visual symbol associations and reading ability.

1.1.4 Rapid serial naming

It has been suggested that slow serial naming is frequently associated with severe reading disability (Wolf, Bally, & Morris, 1986). However, many studies use letters as stimuli in rapid serial naming tests, leading to the possibility that measurement of naming fluency is confounded by measurement of letter knowledge. The current study measures serial naming of pictured objects to avoid the confounding influence of letter knowledge and to enable serial naming speed to be measured in non-readers and emergent readers.

Measures of serial naming time comprise two elements: articulation time and the time of the 'gaps' between the spoken words. Wolf and Bowers (1999) use the term 'inter-stimulus interval' (ISI) to describe the gaps between the spoken words. Obregon (1994) suggests that ISI time significantly differentiates average from dyslexic readers. The current study investigates this hypothesis, measuring articulation time and ISI time as components of overall serial naming time and investigating the relationship of each element to reading ability.

1.2 The design of the study

The study comprises two phases. During the first phase, a range of tests designed to address the research questions is piloted. The main pilot study involves 25 children aged 4.0 to 4.5 years. Following analysis of the results of the pilot study, a further group of 74 children participate in a longitudinal study lasting 12 months. Participants in the longitudinal phase of the study are aged 4.0 to 4.5 years at the first time of testing. The children are tested three times at six-monthly intervals.

1.3 Summary

This chapter has presented an overview of the current study. The following two chapters will review the associated literature.

Chapter 2

Phonological Awareness

Introduction and chapter overview

There is extensive literature relating to phonological awareness. Over the past 20 years, research interest has been fuelled by suggestions that there is a significant relationship between phonological awareness and reading ability, leading to a plethora of correlational and intervention studies, (for example, Bryant, Maclean, Bradley & Crossland, 1990; Bradley & Bryant, 1983; Byrne & Fielding Barnsley, 1990; Gallagher, Frith & Snowling, 2000; Hoien, Lundberg, Stanovich & Bjaalid, 1995; Vellutino & Scanlon, 1987; Wagner, Torgesen & Rashotte, 1994.)

This chapter discusses the literature under the following headings:

- What is phonological awareness?
- Measuring development in phonological awareness as children progress from a pre-literate stage into the early stages of reading;
- The conceptual structure of phonological awareness
- The association between phonological awareness and reading ability
- The prediction of reading from different levels of phonological awareness.

2.1 What is phonological awareness?

Phonological awareness is described by Mattingly (1972) as ' sensitivity to the sound structure of one's language' and by Blachman (1997) as 'an awareness of the phonological segments in speech' (p. 409). Treiman and Zukowski (1991) suggest that phonological awareness skills can be measured at various linguistic levels, which are hierarchical in nature.

According to this theory, awareness of syllables in words is at the lower end of the hierarchy and awareness of phonemes is at the higher end of the hierarchy. Four linguistic levels are generally acknowledged in the literature: rhyme, syllable, onset-rime, and phoneme. Some definitions of phonological awareness have suggested that measurement of lower levels is superfluous and that measurement should focus on awareness of phonemes. For example, Tunmer and Rohl (1991) state that:

> Phonological awareness is... awareness of phonemes. It is not an awareness of syllables, awareness of intrasyllabic units, or awareness of words (p. 8).

However, this level of specificity is unusual and more recent definitions are generally similar to that given by Blachman (1997).

2.2 Measurement of phonological awareness

The research literature reports on measurement of phonological awareness at the various linguistic levels, with a variety of tasks used to measure the construct. Tests either require the participant to demonstrate a global awareness of sounds within words, or to demonstrate the ability to manipulate sounds in words. The manipulations used most frequently are blending (sometimes called synthesis), segmenting (sometimes called analysis) and deleting (sometimes called elision). It has been suggested that within each linguistic level the levels of difficulty can be influenced by task complexity (Yopp, 1988) or by verbal memory demands (Bradley & Bryant, 1983; McBride-Chang, 1997). Rhyme awareness is typically measured through rhyme identification or rhyme production tasks, with rhyme identification suggested to be easier than rhyme production (for example, Muter, Hulme, Snowling & Taylor, 1997). The diverse range of tasks used to measure phonological awareness makes it difficult to compare results from different studies. McBride-Chang (1995) comments that:

> Most published investigations on phonological awareness have used their own experimental tests to assess the construct. Thus a vast array of tests supposedly measuring phonological awareness has accumulated. Experimental control is lacking across tasks (p. 179-180).

2.2.1 Measuring the development of phonological awareness

Adams (1990) proposes that tasks can be ordered into five levels of difficulty:

- A global awareness for the sounds in words, revealed by the ability to remember familiar rhymes
- The ability to recognize and sort patterns in rhyme and alliteration, revealed by the ability to perform 'odd-one-out' tasks such as those used by Bradley & Bryant (1983)
- Awareness of phonemes within syllables, revealed by the ability to perform blending tasks
- The ability to segment syllables into phonemes, revealed by the ability to tap out the individual phonemes (for example, Liberman, Shankweiler, Fischer & Carter, 1974)
- The ability to delete, move, or otherwise manipulate phonemes and to regenerate a resultant word or pseudoword (for example, Bruce, 1964; Rosner & Simon, 1974).

Adams (1990) suggests specifically that:

> Syllabic awareness constitutes an essential link between the seemingly easy-to-acquire ability underlying our sensitivity to sound similarity and rhyme, and that hard to acquire capacity to recognise individual phonemes (p. 53).

Goswami and Bryant (1990) and Treiman (1992) suggest that, when considering the developmental path of phonological awareness, account should be taken of the intra-syllabic units of onset and rime, which are larger than syllables but smaller than phonemes. If, as Adams (1990) suggests, children refine awareness of speech segments of decreasing length, it would follow that the order of development during emerging literacy would be:

- rhyme awareness
- syllable awareness
- onset and rime awareness
- phoneme awareness.

However, empirical research has not always found this to be the case. The following section discusses studies that have investigated the development of phonological awareness skills.

2.2.2 Investigations into the development of phonological awareness skills during emergent literacy

Although many research studies have concluded that phonological awareness is a significant predictor of reading ability, there has been relatively little empirical research investigating developing phonological awareness in children aged 4.0 to 5.5 years by longitudinally monitoring progression in task difficulty and/or linguistic level. Much of our knowledge about the development of phonological awareness comes from reviews of the variety of studies that have investigated specific levels of awareness in children of particular ages. These studies have generally been more concerned with establishing the nature of the relationship with reading, than with developing an understanding of the progressive nature of phonological awareness. Nevertheless, evidence about the stages of development does emerge from the research findings. Research that has provided information about the developing abilities of children aged four to seven years at the various linguistic levels is discussed below.

2.2.2.1 Rhyme awareness

There is general support for the idea that a global awareness of rhyme occurs early in natural language development for many children (Bradley & Bryant, 1983; Goswami 1993; Muter, Hulme & Snowling, 1997). Stanovich, Cunningham and Cramer (1984) measured rhyme and phoneme awareness in six year-old children and commented that the rhyme awareness tests were too easy for most of the children. Cardoso-Martins (1994) tested the rhyme awareness of five and six-year-old Brazilian children and reported that children who performed above chance level on a simple rhyme awareness task were not necessarily successful on a more advanced rhyme awareness task that used non-rhyming words that were globally similar. For example, children who could successfully select from 'bala' and 'fogo' to rhyme with 'sala', could not necessarily select correctly from 'soco' and 'coro' to rhyme with 'soro'. On the basis of results from this study, Cardoso-Martins (1994) suggests that:

> Rhyme detection may be best described in terms of a sensitivity to some sort of global phonological similarity (p. 26).

2.2.2.2 Syllable awareness

The ability to detect syllables in words is also considered to be an early developing skill (Fox & Routh, 1975; Treiman & Zukowski, 1991). Liberman, Shankweiler, Fischer and Carter (1974) report that pre-literate children can successfully complete syllable awareness tests. The test used in their study to measure syllable awareness was a 'syllable tapping' test. The children were asked to tap out the number of syllables in a word. However, the children were not required to say the syllables and it is therefore possible that an element of guesswork influenced performance. Rosner and Simon (1974) report that four-year-old children can be taught to segment words into syllables, but that very few can be taught to segment syllables into phonemes. This conclusion has recently been endorsed by Johnston, Anderson and Holligan (1996) following an investigation into the phonological awareness of a group of 51 four-year-old children.

2.2.2.3 Onset-rime awareness

Goswami (1999) defines an onset of a word as 'the spoken sound that corresponds to any consonants at the beginning of each written syllable' (p. 177). In linguistic theory, the remainder of the syllable is the 'rime'. Treiman (1992) suggests that awareness of the intrasyllabic units of onset and rime plays an important role in reading development. Relatively few studies have set out to investigate the position of onset-rime awareness in the hierarchy of difficulty but there are two studies that deserve mention. These are discussed below.

In a cross-sectional study, Seymour and Evans (1994) investigated the development of phonological awareness in a group of 80 children aged four to six years. The authors report that all of the children performed poorly on the onset-rime segmenting test. The six-year-old children found the phoneme segmenting tasks easier than the onset-rime segmenting tasks. The authors suggest that the reason might lie in the methods of instruction adopted in the school which all of the children attended. There was an emphasis on teaching phoneme awareness and onset-rime awareness was not taught. Consequently, Seymour and Evans (1994) conclude that awareness of onsets and rimes does not occur naturally, but only as a consequence of instruction. However, Goswami (1999) suggests that children's poor performance on the onset-rime tests in the Seymour and Evans (1994) study might be due to lack of explicit task instructions because the children were asked to divide words into 'two distinct parts' (p. 233). Forty-nine percent of the responses from six-year-old children and forty-five percent of the responses from seven-year-old children were incorrect because they divided words at places that were not onset-rime boundaries. For example, where words contained onset-rimes composed of two phonemes, such as blunt, the division into b-lunt may have been 'distinct', as requested by the instruction, but was incorrect.

In contrast to the results from the Seymour and Evans (1994) study, a longitudinal study by Wood and Terrell (1998) with 25, four- and five-year-old children suggests a sequential order of linguistic development, with syllable awareness developing earliest, followed by onset-rime awareness, with phonemic awareness developing later. The conflicting results of these two studies suggest that more investigation is needed.

2.2.2.4 Phoneme Awareness

Phonemes have been described as 'the smallest units of sound that can change the meaning of a word' (Goswami & Bryant, 1990, p.2). These authors argue that there is a clear distinction between awareness of phonemes and phonological awareness at lower linguistic levels, such as rhyme awareness. They suggest that phonological awareness at lower linguistic levels, such as syllable and onset-rime awareness, develops naturally before reading instruction, whereas phoneme awareness generally only develops as a consequence of teaching. It has frequently been suggested that non-readers find phoneme awareness a particular problem (Liberman, Shankweiler & Carter, 1974; Byrne, 1998) and there is debate in the literature concerning the extent to which pre-literate children can develop awareness of phonemes. Adams (1990) suggests that phoneme awareness is particularly difficult for pre-literate children because individual phonemes are not easily detectable in the speech stream.

Three recent studies have specifically set out to investigate the development of phonological awareness skills. Chafouleas, Lewandowski, Smith and Blachman (1997) examined the phonological awareness of 171 children between the ages of five and eight years. They measured rhyme awareness, alliteration, phoneme blending, phoneme segmenting and phoneme manipulation. They conclude that the greatest increases in awareness take place between the ages of five and six years. The hierarchy of difficulty is suggested to be: rhyme awareness, alliteration, phoneme blending, phoneme segmenting, phoneme elision and substitution. The authors comment that:

> ... knowing the age at which students typically master these tasks and the order in which they acquire these skills should enhance our ability to assess both normal and delayed phonological awareness performance and help to inform instructional practices (p.334).

The investigation by Chafouleas and her colleagues (Chafouleas et al., 1997) provides some useful empirical data about the rapid development of phonological awareness that takes place as children are emerging from a pre-literate stage. It is unfortunate, that neither syllable awareness, nor onset-rime awareness was measured. The cross-sectional nature of the study means that individual developmental patterns cannot be investigated.

In a longitudinal study, Stainthorp and Hughes (1998) monitored the development of phonological awareness in two groups of children from age five to age seven. The first group comprised 15 'precocious' readers who could already read well by the age of five years. A control group comprised 15 children matched on verbal ability to the first group, but following a more normal reading developmental pattern. Children's awareness of shallow, intermediate, and deep levels of phonological awareness was investigated through rhyme awareness and rhyme production tasks (defined as shallow phonological sensitivity), blending, addition and deletion of phonemes (defined as intermediate sensitivity), and phoneme segmentation (defined as deep sensitivity). Reporting on their investigation, the authors suggest a hierarchical order of difficulty, with the sequence being: rhyming, phoneme blending and addition, phoneme deletion and phoneme segmentation. This study was exclusively concerned with children of higher ability, and the numbers involved were small. However, the results provide converging evidence for the hierarchy of skill development suggested by Chafouleas and her colleagues (Chafouleas et al., 1997).

Burt, Holm and Dodd (1999) provide further support for this hierarchy of skill development. These authors measured the development of phonological awareness skills in children aged 46 to 58 months. Their study measured rhyme identification, syllable segmentation, onset-rime awareness and phoneme segmentation. The results suggest that the hierarchy of difficulty is syllable segmentation, rhyme awareness, onset-rime segmentation, phoneme segmentation. However, like the study by Chafouleas and her colleagues (Chafouleas et al., 1997) the development of phonological awareness in individual children over time was not measured, as the study only spanned a five week period.

2.2.3 Section summary

Phonological awareness is typically measured using tests at one or more of four linguistic levels (rhyme, syllable, onset-rime and phoneme). Tasks either require the participant to demonstrate a global awareness of sounds within words or to demonstrate the ability to manipulate sounds in words.

At each linguistic level, the difficulty of a task can be varied according to whether a global or analytical awareness is being measured, or the type of manipulation of sounds that the participant has to perform. Three of the most commonly used manipulations are blending (sometimes called synthesis), segmenting (sometimes called analysis) and deleting (sometimes called elision).

Although the idea that phonological awareness develops in a sequential pattern seems to be generally accepted, there is a lack of reliable, empirical evidence showing how the component skills develop in individual children. There is particular ambiguity concerning the place of onset-rime awareness in the developmental sequence.

The research literature lacks information about the developing phonological awareness skills of children aged four to five years. This is a period of rapid linguistic and cognitive development, but knowledge of developmental routes remains limited. The current study aims to refine understanding of the order of acquisition of phonological awareness skills and the relationships between specific skills and reading ability at different stages of children's phonological awareness development.

2.3 The Conceptual Structure of Phonological Awareness

The previous section discussed the development of phonological awareness and considered suggestions that children move rapidly through a series of stages of development as they begin to receive reading instruction. There has been considerable debate in the research literature concerning whether the various phonological awareness skills comprise a unitary construct or are composed of one or more factors. The debate is relevant to the relationship between phonological awareness and reading ability because, although the research literature converges on the opinion that 'phonological awareness' is predictive of reading ability, there is a lack of consensus concerning the structure of the predictive construct. If phonological awareness comprises different factors, it is important to know the extent to which the individual factors relate to reading ability. In the studies discussed below, the structure of phonological awareness was investigated using either factor analyses or principal components analyses. Tabachnick and Fidell (1996) explain that:

> Principal components analysis and factor analysis are statistical techniques applied to a single set of variables when the researcher is interested in discovering which variables in the set form coherent subsets.... Variables that are correlated with one another but largely independent of other subsets of variables are combined into factors (p. 635).

2.3.1 Investigations into the structure of phonological awareness

In a cross-sectional study, Stanovich, Cunningham and Cramer (1984) investigated phonological awareness using exploratory factor analysis. Forty-nine five-year-old children participated in the study. Ten phonological awareness tests were given comprising three rhyming tests and seven tests that involved awareness of phonemes. Principal components analysis revealed only one significant factor. One of the principal aims of this study was to determine the degree of convergence between the phonological awareness tests because the authors felt that:

> ... the general absence of direct comparisons between tasks in the published literature places arguments for convergence on shaky grounds (p. 177).

It is surprising, therefore, that the ten tests concentrated on rhyme and phoneme awareness and did not include a measure of syllable awareness. It is less surprising that onset-rime awareness was not measured, as this intra-syllabic linguistic level was not well recognised in the research literature at this time. The results of the study suggest that the linguistic levels of rhyme and phoneme measure one underlying phonological awareness construct.

Wagner, Torgesen, Laughon, Simmons and Rashotte (1993) investigated phonological awareness in a cross-sectional study involving 184 kindergarten and second grade children. Their confirmatory principal components analysis suggests two distinct elements to the overall construct and they therefore argue for a two-factor model. Their battery of phonological awareness tests comprised phoneme blending, phoneme segmenting, phoneme elision, phoneme isolation, sound categorisation based on phonemes and onset-rime blending. Again, no syllable awareness tests were included. The two factors identified were classified as blending and segmenting. Although the authors propose a two-factor model, they recognise that the correlation between the two factors is high ($r = .87$, $p \leq .001$).

In a Norwegian study, Hoien, Lundberg, Stanovich and Bjaalid (1995) investigated the phonological awareness of 128 children aged 6.5 to 7.5 years. The tests given comprised one measure of rhyme awareness, one measure of syllable awareness and four measures of phoneme awareness. Their principal components analysis produced three factors, which they identified as a phoneme factor, a syllable factor and a rhyme factor. In a follow-up study with 1509 children aged 7.5 to 8.5 years, a phoneme factor and a rhyme factor were identified. Although separate factors were identified, it is noteworthy that the correlations between the tests of rhyme, syllable and phoneme awareness were all reported to be significant at or above the $p \leq .001$ level. Hoien and his colleagues (Hoien et al., 1995) consider that, although different factors emerge in the analysis, it is possible that:

> ... the various phonological tasks are simply differentially sensitive or differentially age-appropriate indicators of a unitary construct of phonological sensitivity (p. 172).

Schatschneider, Francis, Foorman, Fletcher and Metha (1999) conducted a large, longitudinal study involving 945 children aged five to eight years. This appears to be the only study to date that has investigated the structure of phonological awareness longitudinally. The authors used the seven tests of phonological awareness that had been constructed by Wagner et al. (1993). Like Wagner and his colleagues, their principal components analysis suggested a two-factor structure but, because the two factors were so closely aligned, they suggest that a one-factor structure is more appropriate. In accepting the evidence for a unitary construct these authors warn that:

> The unitary nature of phonemic awareness does not imply that all items or tasks are equally effective in measuring the construct. It is clear from the test information functions that the various phonological awareness tasks differ in their ability to provide information about phonemic awareness and that their effectiveness depends on the overall latent ability of the child (p. 448).

Schatschneider and his colleagues' concept of phonological awareness as a unitary, but developmental, construct (Schatschneider et al., 1999) could be said to reconcile previous differing conclusions and opinions. It could also be argued that, if correlations between the various linguistic levels of phonological awareness and the different types of task are likely to be significantly affected by the age and stage of development of the participants, investigations into the conceptual structure of phonological awareness that involve children at diverse stages of development might lack validity.

2.3.2 Section summary

Investigations into the conceptual structure of phonological awareness have measured the elements of phoneme awareness and rhyme awareness most frequently. In two of the three studies that included a measure of rhyme awareness, rhyme awareness aligns with the unitary factor (Schatschneider et al., 1999; Stanovich et al., 1984). In the third study, rhyme awareness emerges as a separate factor although the correlations between rhyme, syllable and phoneme awareness are all significant at the $p \leq .01$ level (Hoien et al., 1995).

In the one study that measured onset-rime awareness (Wagner et al., 1993) it did not emerge as a separate factor. All of the studies that were reviewed measured phoneme awareness and two studies conclude that phoneme blending and phoneme segmenting are separate, although strongly correlated, factors (Wagner et al., 1993; Schatschneider et al., 1999).

The process of principal components analysis is based on correlational data (Vogt, 1999). Analyses can only extract factors relating to the linguistic levels that have been measured. For example, if syllable awareness is not measured, it cannot emerge as a factor and neither can it be assumed to align with a unitary construct. It is difficult to understand how the study by Hoien and his colleagues (Hoien et al., 1995) identified three separate factors when the correlations between the tasks were strongly significant.

Schatschneider and his colleagues (Schatschneider et al., 1999) suggest that phonological awareness might be a unitary construct with the various tasks used to measure it being age sensitive. The studies discussed above investigated the structure of the construct in relation to children aged from five to eight years. It could be argued that the abilities of younger children should also be measured in order to fully investigate the construct.

2.4 The association between phonological awareness and reading

Many studies have shown a relationship between children's phonological awareness and the ease with which they learn to read (Badian, 1995, 1998; Bradley & Bryant, 1983; Bryant, MacLean, Bradley & Crossland, 1990; Muter, Hulme, Snowling & Taylor, 1997; Vellutino & Scanlon, 1987; Wagner et al., 1994, 1997). Phonological awareness has been found to associate more strongly with later reading than general intelligence, and measures of socio-economic status (Share, Jorm, MacLean & Matthews, 1984). Weaknesses in phonological awareness have also been found to be associated with poor reading comprehension (Shankweilwer, Lundquist, Katz, Fletcher, Brady, Fowler, Dreyer, Marchione, Shaywitz & Shaywitz, 1999).

Evidence of the link between phonological awareness and reading has come from research of different kinds, including longitudinal studies that monitor children's development (Byrne, Freebody & Gates, 1992; Foorman, Francis, Novy & Liberman, 1991) and intervention studies that attempt to ameliorate reading difficulties (Ball & Blachman, 1991; Cunningham, 1990; Bradley & Bryant, 1985; Byrne & Fielding-Barnsley, 1995; Hatcher, Hulme & Ellis, 1994).

Torgesen and Wagner (1998) make the point that:

> ... because phonological skills can be measured with oral language tasks, they can also be used to identify children who are 'at risk' for the development of phonologically based reading disabilities before reading instruction begins (p.221).

It could be argued that, in order to use tests of phonological awareness to reliably identify pre-literate children who are at risk of reading disability, it is necessary to have secure empirical evidence concerning the relationship of specific phonological awareness tasks to subsequent reading ability.

2.4.1 Clarifying definitions of phonological awareness and reading

When discussing the relationship between phonological awareness and reading, it is important to be clear about definitions of 'phonological awareness' and 'reading'. This chapter argues that the literature presents a confused picture because of insecure classification of the variety of tasks used to measure the phonological awareness construct. In relation to the extent to which phonological awareness is related to later reading ability, this lack of clarification is all-important. In particular, when looking at possible predictive relationships, the ways in which both phonological awareness and reading are defined is likely to affect the results of investigations. For example, Wagner, Torgesen, Rashotte, Hecht, Barker, Burgess, Donahue and Garon (1997) state that:

> ...individual differences in phonological awareness were related to subsequent individual differences in word-level reading for every time period examined (p. 468).

However, it is important to bear in mind that most of the phonological awareness tests used in the Wagner et al. (1997) study were at the phoneme level. The findings do not report on the possible predictive influences of phonological awareness at other linguistic levels.

Established developmental models of reading can inform definitions of reading and provide a useful insight into the relationship with phonological awareness. Two broadly similar models of reading that are well represented in the research literature are discussed below. Frith (1985) proposed a three-stage model, with reading progressing through the logographic, alphabetic and orthographic stages. Ehri (1995) proposed a four-stage model, with the stages labeled as pre-alphabetic, partial alphabetic, full alphabetic and consolidated alphabetic. The characteristics of each stage are described below.

Frith's Model Of Reading (1985)		
Logographic Stage	**Alphabetic Stage**	**Orthographic Stage**
Relies on visual clues and context. No phonological strategies available.	Uses developing knowledge of phoneme/grapheme rules to help to read regular and irregular words.	Uses non-phonological recognition of orthographic and morphemic units. Phoneme/grapheme associations no longer consciously used.

Ehri's Model Of Reading (1995)			
Pre-Alphabetic Stage	**Partial Alphabetic Stage**	**Full Alphabetic Stage**	**Consolidated Alphabetic Stage**
Relies on context and visual clues.	Uses developing phoneme/grapheme knowledge to read regular words and nonwords. In particular, utilizes knowledge of initial and final sounds.	Uses fully developed phoneme/grapheme knowledge, blends sounds and uses higher order phonological rules.	Uses knowledge of letter strings to read familiar and unfamiliar words.

Analysis of the two models suggests that, after a brief phase that relies on visual recognition strategies, the early stages of reading are dependent on children being able to make links between their developing phonological awareness and their developing knowledge of letter sounds. Byrne (1998) describes this process as the development of the alphabetic principle.

2.4.2 The Causality Debate

Although a correlational relationship between phonological awareness and reading ability is well established, the issue of causality has been the subject of considerable debate. Wagner, Torgesen and Rashotte (1994) put forward three alternative views about the nature of the relationship between phonological awareness and reading.

The first view is that 'the development of phonological processing abilities enables or at least facilitates the acquisition of beginning reading' (p. 73). Support for this view has come from longitudinal studies that have measured phonemic awareness in pre-literate children and subsequently monitored their progress over a period of time (for example, Liberman, Shankweiler & Liberman, 1989) and from training studies (for example, Cunningham, 1990).

The second of the three alternative views suggests a reversed direction of causality, in which children only gain phonological awareness through learning to read an alphabetic script. For example, Scholes (1998) argues that an explicit awareness of the sound structure of oral language is 'a limited consequence of acquiring literacy' (p. 177). In this argument, the definition of phonological awareness is particularly important. Scholes (1998) comments that:

> There are two very different abilities known as phonological awareness. One is the ability to isolate and sound out syllabic segments of speech.... The other is the ability to isolate and manipulate (sub-syllabic) segmental phones (p. 180).

In the first of the two 'abilities' Scholes includes syllable and onset-rime awareness. The second of the two 'abilities' is phoneme awareness. Having identified that there are two different phonological awareness 'abilities' Scholes (1998) concentrates on phoneme awareness to develop the argument that phonological awareness is not an essential prerequisite for learning to read and is only acquired through instruction. He does not discuss the possible contribution of lower levels of phonological awareness to the development of early reading skills. It could be argued, therefore, that Scholes' opinions are not as contrary to previous research as they initially appear. Byrne (1998) also presents evidence to suggest that most children do not start to develop phoneme awareness unless explicitly taught to do so, but he does not suggest that phonological awareness at lower linguistic levels is similarly inaccessible to non-readers.

The third view of the relationship between phonological awareness and reading is one of reciprocal causation. This theory proposes that early phonological awareness helps children to acquire early reading skills and that reading experiences in turn help to reinforce phonological skills, particularly at the phonemic level (Ehri, 1992; Treiman & Zukowski, 1996). Share and Stanovich (1995) describe a mechanism by which the reciprocal relationship might occur:

> ... each successful decoding encounter with an unfamiliar word provides an opportunity to acquire the word-specific orthographic information that is the foundation of skilled word recognition and spelling. In this way, phonological recoding acts as a self-teaching mechanism or built in teacher enabling a child to independently develop knowledge of specific word spellings and more general knowledge of orthographic conventions (p. 18).

Elbro, Borstrom and Petersen (1998) put forward an alternative theory. They suggest that the quality of phonological representations stored in memory might be important for the development of phonological sensitivity and (indirectly) reading ability. These authors use the term 'distinctness' to describe the quality of representations, explaining that:

> ...distinctness means degree of separation – that is, the relative distance between a phonological representation and its neighbours (p. 40).

In a similar vein, Brady (1997) suggests that the quality of a child's speech perception might be an underlying factor that affects both phonological awareness and reading. She argues that poor speech perception, leading to indistinct phonological representations might adversely affect other skills that have been found to be closely associated with reading, such as letter knowledge and verbal short-term memory. These skills will be discussed in later chapters.

From a practitioner's viewpoint, the issue of causality is extremely important and is associated with the importance of understanding the construct of phonological awareness. Adams (1990) points out that early identification of children who may go on to develop reading difficulties could help to prevent such children from failure and its associated disaffection if appropriate and effective intervention programmes could be implemented. However, if phonological awareness comprises different factors, it is important to know whether all, or only some, of the factors promote reading. If phonological awareness is a unitary construct, as argued by Schatschneider and his colleagues (Schatschneider et al., 1999) it is important to know which levels of intervention are most effective at the various stages of a child's development. This point is stressed by Hatcher and Hulme (1999):

> One theoretical issue continues to generate some controversy, however. This is the question of the structure of phonological skills and whether different phonological tasks vary in terms of their predictive relationship to reading (p. 132).

2.4.3 Section summary

Converging evidence suggests that there is a correlational relationship between phonological awareness and reading ability. However, in the research literature 'phonological awareness' has been measured at different linguistic levels and with different types of task and the direction of the proposed predictive relationship is hard to establish. It has been argued that weaknesses in both phonological awareness and reading may be caused by poor speech perception leading to indistinct phonological representations in memory. In appreciation of difficulties in establishing causality, most researchers prefer to use terminology suggesting a 'predictive' rather than a 'causal' relationship when reporting on correlational studies.

2.5 Predicting reading from the various linguistic levels of phonological awareness

This section investigates the extent to which the various linguistic levels of phonological awareness (rhyme, syllable, onset-rime and phoneme awareness) have been suggested to be predictive of subsequent reading ability.

2.5.1 The predictive influence of rhyme awareness

There has been interest in sensitivity to rhyme as a possible predictor of later reading success since the late 1970's, but there is still a lack of consensus about the extent to which rhyme awareness predicts later reading. A number of longitudinal studies have reported significant correlations between early rhyming skills and later reading ability (Bryant, Maclean, Bradley & Crossland, 1990; Ellis & Large, 1987; Hoien, Lundberg, Stanovich & Bjaalid, 1995; Wood & Terrell, 1998).

A study by Bradley and Bryant (1983) is frequently cited in the research literature (for example, by Muter, Hulme, Snowling & Taylor, 1997) as evidence of a significant association between rhyme awareness and reading ability. Bradley and Bryant (1983) used a sound categorisation task to test the rhyme and alliteration awareness of 403 children aged four and five years Their results suggest a significant predictive relationship between the rhyme and alliteration awareness of four-year-old children and reading ability three years later ($r = .57$, $p \leq .001$). In regression analysis, the relationship remained significant even when intelligence, memory and vocabulary were controlled in the equation. In order to investigate the direction of the predictive relationship, Bradley and Bryant (1983) carried out an intervention study with 65 of the children who had performed poorly on the categorisation test. The intervention study took place twelve months after the initial rhyme categorisation test and all of the children were non-readers when the intervention study began. The 65 children were divided into four groups, closely matched on age, verbal intelligence and their sound categorisation abilities. One of the groups received training in sound categorisation, one group received training in sound categorisation and letter knowledge, one group received training that did not focus on phonological awareness and the fourth group received no training at all. The intervention comprised 40 sessions over a two-year period. By the end of the intervention, the groups that had been trained in sound categorisation had made significantly greater progress in reading than the untrained groups ($p \leq .001$). It is important to note, however, that the initial sound categorisation task did not focus exclusively on rhyme, as alliteration was also an important element, and that the intervention study focused on phoneme segmentation. This is apparent from the description of the training provided by Bradley and Bryant (1983):

> With the help of coloured pictures of familiar objects the children were taught that the same word shared common beginning (hen, hat) middle (hen, pet) and end (hen, man) sounds with other words and thus could be categorised in different ways (p. 420).

It could be argued, therefore, that the results of this study do not suggest that there is a relationship between rhyme awareness and reading ability, as is sometimes claimed.

Goswami (1993) and Treiman (1992) suggest that children who are able to recognise and categorise words that rhyme are aware of the onset and rime units that underpin early reading and are therefore likely to become successful readers. However, as previously discussed, Cardoso-Martins (1994) challenges this assumption, suggesting that it is possible for participants to operate at a level of global phonological similarity that does not necessarily mean that they can segment words into onsets and rimes. Morais (1991) provides support for this suggestion, reporting that illiterate, Portuguese poets who have a good global awareness of rhyme cannot necessarily segment the onsets from the rimes in monosyllabic words.

The results of a longitudinal study by Muter, Hulme, Snowling and Taylor (1997) suggest that the rhyme awareness of four-year-old children is not significantly associated with later reading ability. However, the small sample size in this study (38 children) gives rise to concerns about the reliability of the regression analyses. Additionally, Bryant (1998) carried out a reanalysis of the data from study by Muter and her colleagues (Muter et al., 1997) because he was concerned that the instructions given to children in the rhyme production task were misleading. Children had been asked to provide a word that 'rhymes or sounds like' the word given by the tester. Responses that shared onsets, rather than rimes with the given word were scored as incorrect. Bryant (1998) reanalyzed the data and suggests that the reanalysis confirms a significant association between rhyme awareness at age four with later reading. Muter and her colleagues (Muter et al., 1998) subsequently accepted that there was a predictive relationship between rhyme awareness and reading, but suggested that it was a weaker relationship than had been suggested by previous research.

Hoien, Lundberg, Stanovich and Bjaalid (1995) provide additional evidence about the relationship between rhyme awareness and reading ability. These authors carried out a large cross-sectional study involving 1509 seven and eight year old children who had been in school for about nine months. The children were tested on rhyme, syllable and phoneme awareness. In the rhyme awareness test, the children were shown pictures of three objects, and were asked to choose the picture of an object whose name rhymed with a target word. The results suggest that rhyme awareness makes a small unique contribution to variance in reading ability.

In summary, the research literature suggests that rhyme awareness can be classified as global or analytical. Global awareness of rhyme has been identified in pre-literate children and is suggested be associated with later reading ability (Goswami & Bryant, 1990; Hoien et al., 1995). Analytical rhyme awareness, requiring participants to demonstrate an explicit awareness of the onset and rime units, appears to develop later and may be a product of learning to read (Cardoso-Martins, 1994). Several recent studies converge on the opinion that rhyme awareness is less predictive of reading ability that it was once thought to be (for example, Muter et al, 1997; Nation & Hulme, 1997).

2.5.2 The predictive influence of syllable awareness

Mann and Liberman (1984) report that the ability of five-year-old children to tap out the number of syllables in words is significantly related to reading ability one year later. However, Badian (1998) suggests that syllable awareness does not contribute to variance in reading ability and also suggests that the Mann and Liberman study may have found a contribution from syllable tapping only because these authors did not carry out a full regression analysis. This hypothesis is supported by Hoien, Lundberg, Stanovich and Bjaalid (1995), who report that although there is a moderately significant correlation between syllable awareness and reading in five and six-year-old children, it becomes redundant when other levels of phonological awareness are entered into the regression equation.

2.5.3 The predictive influence of onset-rime awareness

The association between onset-rime awareness and reading has received surprisingly little attention in the research literature. A search of the literature reveals some confusion between the definitions of rhyme awareness and onset-rime awareness. As previously discussed, Cardoso-Martins (1994) stresses the importance of differentiating tests that measure a 'global' awareness of rhyme from those that require some analytical skill. It could be argued that this distinction is particularly important when examining relationships with reading, as the different levels of awareness may have different associations with reading ability.

In a cross-sectional study with three cohorts of primary school children, Nation and Hulme (1997) tested children on rhyme awareness and alliteration (measured with categorisation tasks), and onset-rime and phoneme awareness (measured with non-word segmenting tasks). The mean ages of the three cohorts of pupils involved in the study were 6.1, 8.0 and 9.0 years. The authors present three results of particular relevance to the current study. Each of the three points is discussed below.

The first point of interest is that onset-rime awareness did not improve with age. Each cohort of children was approximately 55% successful on onset-rime segmentation tasks for both shorter (CVC) and longer (up to CCCVCC words). This would appear to question Goswami and Bryant's (1990) suggestion that:

> ...young children who are at the beginning stages of reading can break up syllables into onsets and rimes with ease (p. 22).

In consideration of the possibility that the complexity of the words may have confounded results, the authors carried out separate analyses using only the CVC nonwords. Results must be treated with caution as there were only three CVC test items, but the results concurred with the results computed using all of the test items.

The second point of interest is that onset-rime awareness was not correlated with reading ability (r = .17 *ns*). However, the authors make the point that the age of the children may have influenced this result. Discussing the limitations of their study, Nation and Hulme (1997) comment that:

> It would be of considerable interest to investigate to what extent pre-school assessments of onset-rime awareness, as measured by a segmentation task, would predict later reading and spelling ability (p.167).

The third point of interest in the study is a lack of association between rhyme awareness and onset-rime segmentation (r = .12 *ns*). This finding provides support for the suggestion put forward by Cardoso-Martins (1994) and Morais (1991) that the explicit awareness needed for segmentation of onsets and rimes is more demanding than the more global awareness required for rhyme awareness tasks.

2.5.4 The predictive influence of phoneme awareness

In the debate concerning whether pre-literate children demonstrate phoneme awareness and whether early phoneme awareness predicts later reading ability, the definition of 'phoneme awareness' plays a central role. In the research literature, phoneme awareness is defined in a variety of different ways. For example:

- The ability to recognise alliteration
- The ability to blend phonemes to form words or nonwords (task difficulty affected by number of phonemes)
- The ability to segment words or nonwords into individual phonemes (task difficulty affected by length of words)
- The ability to remove phonemes from words and articulate the remaining word (tasks difficulty affected by length of word and position of phoneme to be deleted)
- The ability to transpose phonemes in phrases (e.g. to transpose initial phonemes in 'car park' to make 'par cark').

A number of studies have reported that phoneme awareness tests are more strongly related to reading than tests that measure phonological awareness at other linguistic levels (McDougall, Hulme, Ellis & Monk, 1994; Muter et al, 1997; Nation & Hulme, 1997). Stuart (1990) suggests that children who have appropriate reading skills are able to use 'pictured spelling' as a means of performing phoneme awareness tests. In a similar vein, Scholes (1998) suggests that good readers are able to use 'letter analysis' (p. 182) to perform phoneme manipulation tasks. Where research studies have reported high correlations between phoneme awareness and concurrent reading ability it could be argued that there is an extent to which tests of reading ability and tests of phonemic awareness might be measuring the same skills. For example, Muter and Snowling (1998) report a high correlation of .84 ($p \leq .001$) between phoneme deletion and reading ability following a study involving a group of 34, nine-year-old children.

Studies that have measured the longitudinally predictive relationship between phonological awareness and reading ability, in which the child's phonological awareness is measured initially before they learn to read any words, can make more valid hypotheses about the relationship between phonological awareness and reading ability. Goswami and Bryant (1990) suggest that many longitudinal studies start too late, after children have started to learn to read. These authors comment that:

> In some studies it is clear that those taking part knew a great deal about reading by the time the first measures were taken. Thus, one of the main advantages of the longitudinal study – that of being certain of the direction of cause and effect – is often lost (p. 103).

Investigations into whether phoneme awareness is longitudinally predictive of subsequent reading ability have generally addressed one of two questions.

1. Can non-readers demonstrate awareness of phonemes?
2. Is there a significant association between pre-literate phoneme awareness and subsequent reading?

Each of these areas of investigation is discussed below.

2.5.4.1 Can non-readers demonstrate awareness of phonemes?

Lundberg, Frost and Peterson (1988) investigated whether it was possible to train pre-literate children in phoneme awareness without reference to reading or to letters. They found that their training programme, lasting for the full pre-school year with children aged six to seven years, was successful. Reporting on the results of the study, Lundberg (1994) concludes:

> Phonemic awareness can be developed among pre-readers by training without introducing letters or written text (p. 186).

However, it must be noted that this study took place in Scandinavia, where children do not start school until the end of August in the year that they are seven years old. According to Lundberg (1994), Scandinavian pre-school children rarely start to learn to read until formal schooling begins, but it could be argued that children below that age are likely to learn a great deal about reading from environmental print, especially if they are curious and have relevant pre-school experiences, either at nursery school, at home, or through training studies.

Wood and Terrell (1998) report on the ability of 30 four-year-old non-readers to perform phoneme awareness tasks. The authors tested children on a 'simple' phoneme awareness task (alliteration) and a 'complex' phoneme awareness task (phoneme deletion). There was a 47% correct response rate on the alliteration task and a 26% correct response rate on the phoneme deletion task, suggesting that many pre-literate children can demonstrate phonemic awareness at a global level and that some children can manipulate phonemes in words.

Muter, Hulme, Snowling and Taylor (1997) tested a group of 38 non-readers (aged three years and ten months to four years and nine months) on phoneme awareness using a test that required children to supply the final phoneme of a word. For example, children were shown a picture of a cat and the tester said 'this is a picture of a ca...'. The children were required to supply the final phoneme. The mean score on this test was two from a maximum of eight, again providing some support for the hypothesis that non-readers can perform simple, or global, phoneme awareness tasks.

The studies discussed above suggest that some children can demonstrate phoneme manipulation skills at a pre-literate stage and that many more can demonstrate simple phoneme awareness. Commenting on the results of their intervention study with pre-readers, Lundberg, Frost and Peterson (1988) conclude that although phonemic manipulation skills in pre-literate children occur, they do so rarely. Lundberg and Hoien (1991) support this view, suggesting that the exceptional cases occur in children who have developed phoneme awareness through word-play activities. As mentioned previously, the type of phoneme awareness task used is likely to be influential in determining results. It could be argued that some phoneme awareness tests, such as awareness of alliteration, may be measuring a global awareness of sounds in words in much the same way that rhyme awareness tests have been suggested to measure global awareness of rhyme (Cardoso-Martins, 1994).

2.5.4.2 The association between pre-literate phoneme awareness and subsequent reading?

Twenty-five of the children in the Wood and Terrell (1998) study went on to take part in a longitudinal study that investigated the relationship between early phoneme awareness and reading ability two years later. Stepwise regression analyses suggested that children's phoneme awareness at age four did not contribute unique variance to later reading ability. The only significant predictor was rhyme awareness. Similarly, Muter and her colleagues (Muter et al., 1997) report no significant relationship between their phoneme awareness measure with non-readers and subsequent reading ability. Although they suggest that phoneme segmentation at age five is significantly associated with concurrent reading ability ($r = .62$, $p \leq .01$), by age five several of the children in their study were already reading. Therefore, it is not possible to establish the direction of the relationship. The results of both of these studies must be treated with some caution because of the small number of children involved. The number of participants required to ensure reliability of results when using multiple regression analyses is discussed in Chapter 7.

Studies that have reported significant associations between pre-literate phoneme awareness and subsequent reading ability have included Bradley and Bryant (1983), Stanovich, Cunningham and Cramer (1984) and Stuart and Coltheart (1988). In the studies carried out by Bradley and Bryant (1983) and Stanovich and his colleagues (Stanovich et al., 1984), the phoneme awareness task was one of initial sound categorisation. The children listened to a list of four words and were asked to identify either the word with the different initial sound or identify the word that had the same initial sound as the first word in the list. This type of phoneme awareness task is at the easier level of the phoneme awareness difficulty continuum and could equally well be classified as an awareness of onset and rime.

2.5.5 Section summary

The weight of evidence suggests that some pre-literate children demonstrate phonemic awareness, although the majority do not. There is substantial, converging evidence that phoneme awareness is associated with concurrent reading ability (for example, Muter & Snowling, 1998) but evidence both for and against the suggestion that pre-literate phonemic awareness is a significant predictor of subsequent reading ability. It has been suggested that the significant relationships reported between phonemic awareness and concurrent reading ability may be influenced by the fact that good readers can perform 'pictured spelling' (Stuart, 1990), or 'letter analysis' (Scholes, 1998) to perform phoneme manipulation tasks, whereas poor readers cannot.

2.6 Chapter summary

A global awareness of rhyme has been reported to be significantly predictive of later reading ability (Goswami & Bryant, 1990; Wood & Terrell, 1998) but it has been suggested that children find more analytic rhyme awareness tasks, or onset-rime manipulations, such as segmenting, more difficult than global rhyme awareness tasks (Cardoso-Martins, 1994; Nation & Hulme, 1997). Several recent studies have suggested that the association between rhyme awareness and reading may be weaker than was previously thought (Muter et al, 1997; Nation & Hulme, 1997).

There has been comparatively little research investigating the association between syllable awareness and reading. The limited research available suggests that there may be a significant relationship in younger children but that, with older children, syllable awareness becomes redundant because other phonological awareness tests have a stronger predictive influence on reading.

Goswami and Bryant (1990) suggest that onset-rime awareness is predictive of reading ability, but recent research evidence suggests that both rhyme and onset-rime awareness tests are less predictive of reading ability than phoneme awareness tests (Nation & Hulme, 1997; Muter et al. 1997; Seymour & Evans, 1994).

There is a great deal of converging evidence of a significant relationship between phoneme awareness and reading in children who are already learning to read (Hoien et al., 1995; McDougall, Hulme, Ellis & Monk, 1994; Muter & Snowling, 1998; Nation & Hulme, 1997; Wagner et al, 1993; 1997). Some pre-literate children are able to perform simple phoneme awareness tests, but most pre-literate children cannot perform such tests (Muter et al. 1997; Wood & Terrell, 1998). There is evidence both for and against the suggestion that pre-literate phonemic awareness is a significant predictor of subsequent reading ability. It could be argued that insecure classifications of phoneme awareness tasks have contributed to conflicting results. Some studies that have concluded that phoneme awareness is predictive of reading ability have used tests that might be better classified as awareness of onset-rime. It has been suggested that literate children can perform phoneme manipulation tasks by means of 'pictured spelling' strategies (Stuart, 1990). It could be argued that, in such populations, measures of phoneme awareness may actually be measuring reading and spelling ability.

Several researchers have recently suggested that the nature of the relationship between phonological awareness and reading may be developmentally determined. For example, Wagner et al. (1997) comment that:

> The influences of individual differences in phonological processing abilities on subsequent reading skills may be developmentally limited, and, in fact, the predominant direction of such influences may reverse as reading skill develops (p. 469).

It could be argued that the lack of clarity in research studies concerning the definition of phonological awareness has led to confusion about the direction of predictive relationships. If specific phonological awareness skills are predictive of subsequent reading ability, and reading ability is predictive of some subsequent phonological awareness, it is important to clarify which skills predict reading ability and which skills are predicted by reading ability.

Chapter 3

Predictors Of Early Word-Level Reading

Introduction and chapter overview

The previous chapter discussed the structure and development of phonological awareness and its relationship to reading. It was noted that a wide variety of tests have been used to measure phonological awareness, leading to difficulty in determining common developmental patterns and uncertainty about the relationships between the various tasks and reading ability.

The current chapter discusses other cognitive and linguistic skills that have been considered to be significantly related to children's early reading development. Specifically, these are:

- verbal short-term memory (Baddeley, 1986; Gathercole, 1990)
- speed of serial naming and the component elements of articulation rate and inter-stimulus interval rate (Obregon, 1994; Wolf & Bowers, 1999)
- letter knowledge (Chall, 1967; Gallagher, Frith & Snowling, 2000)
- speed of learning sound/visual symbol relationships (Mauer & Kamhi, 1996).

3.1 Verbal short-term memory

Significant associations have frequently been found between verbal short-term memory, phonological awareness and reading ability, but the relationships appear to be complex. Before moving on to discuss these relationships, this section will:

- explore the definition of verbal short-term memory
- discuss measurement procedures
- discuss two skills that have been suggested to influence performance on verbal short-term memory tasks: speed of retrieval of phonological codes from long-term memory and articulation rate.

3.1.1 Definition of verbal short-term memory

Verbal short-term memory tasks measure a participant's ability to attend to, store and retrieve verbal stimuli. Hulme and Roodenrys (1995) attribute the following characteristics to verbal short-term memory:

- it has limited capacity
- it is subject to rapid loss of information unless material is actively rehearsed.

In the research literature, verbal short-term memory is sometimes referred to as phonological or auditory short-term memory. There is also some overlap in the definitions of verbal short-term memory and verbal or phonological working memory. Hulme and Roodenrys (1995) comment that:

> Most of the research concerned with working memory has in fact focused on short-term memory (p. 374).

In an attempt to clarify definitions, these authors suggest that a short-term memory task might require the participant to store and retrieve information, whereas a short-term working memory task would require the participant to store, manipulate and then retrieve the information. For example, a short-term memory task might require a participant to recall a list of recently heard words, whereas a short-term working memory task might require the participant to recall the list of words in reverse order.

An established model for short-term memory was first put forward by Baddeley and Hitch in 1974. The current version of the original model (Baddeley, 1986) describes a sub-system of working memory that is closely associated with verbal short-term memory: the articulatory loop. Baddeley (1986) suggests that the articulatory loop comprises two related components. One element is the phonological store and the other is an active rehearsal process that involves sub-vocal articulation. The sub-vocal rehearsal process is thought to improve short-term memory performance by refreshing decaying phonological representations within the phonological store. Hulme, Roodenrys, Schweickert, Brown, Martin and Stuart (1997) suggest that:

> The processes involved in short-term memory tasks are sensitive to the properties of the representations of items held in lexical memory... our argument is that processes analogous to speech perception are involved in short-term recall tasks (p. 1217).

This theory has interesting associations with the theory put forward by Brady (1997) that phonological awareness is also influenced by the quality of a child's speech perception (discussed in Chapter 2, section 2.4.2).

3.1.2 Measuring verbal short-term memory

Verbal short-term memory is usually measured by asking participants to repeat auditory stimuli. The auditory stimuli are generally in the form of sequences of digits (for example, the British Ability Scales Digit Span Test (Elliott, Murray, & Pearson, 1983), words (for example, Muter & Snowling, 1998) or individual nonwords (for example, Gathercole & Adams, 1994). In 'memory span' tests children listen to strings of stimuli of gradually increasing length. The tester records how many test items at each span length the child is able to repeat accurately. As an alternative to a span test, Gathercole, Willis and Baddeley (1994) designed a nonword repetition test as a measure of verbal short-term memory (see also

Gathercole, Willis, Emslie & Baddeley, 1991; Gathercole & Adams, 1994). In this test, children are asked to repeat forty nonwords of between two and five syllables. The tester records how many of the nonwords have been repeated accurately. A shorter version of the test was designed for children aged below four years (Gathercole & Adams, 1993). The nonword repetition test used by Gathercole and Adams (1993, 1994) was designed to counteract possible influences of phonological codes stored in long-term memory on short-term memory performance. This is discussed in more detail later in this chapter (section 3.1.4).

Hulme and Roodenrys (1995) stress that tests of short-term memory are not clear measures of an isolated construct. They suggest that factors such as attention, motivation, long-term memory and motoric abilities can influence performance. It might be expected that these factors would particularly affect testing of younger children unless specific steps were taken to improve test reliability by, for example, stimulating interest to improve attention and motivation. Gathercole and Adams (1993) conducted a study to investigate whether verbal short-term memory could be measured reliably in children aged two to three years. The authors report that:

> Phonological memory skills can be reliably assessed in very young children using conventional serial span and repetition procedures (p. 770).

However, closer inspection of the test results show that of the 111 children who took part in the study, 57 failed to co-operate with the tester. Results of only 54 children are therefore reported. The reliability of the study as being representative of a normal population of two and three year old children must therefore be questioned. The authors report that each child was given a battery of tests over a one-hour period. It could be argued that the design of the study influenced the reported poor levels of co-operation as children of this age are typically not able to concentrate for one-hour periods under test conditions.

3.1.3 The relationship between verbal short-term memory and reading ability

There is converging evidence to suggest that children who have difficulty learning to read have poor verbal short-term memories (Jorm, 1983; Katz, Healy & Shankweiler, 1983; Mann, Liberman & Shankweiler, 1980; Siegel & Linder, 1984; Passenger, Stuart, & Terrell, 2000). Two studies, discussed below, have investigated differences in short-term memory between average and poor reader groups.

McDougall, Hulme, Ellis and Monk (1994) investigated short-term memory differences between three reading ability groups. Sixty-nine children, aged from seven to nine years, were divided into three groups based on their performance on the British Ability Scales Word Reading Test (Elliott, Murray & Pearson, 1983). Their verbal short-term memory was tested with a word span test using the procedure described in section 3.1.2. Non-verbal short-term memory was also tested. The procedure for testing non-verbal short-term memory was similar to that for verbal short-term memory, but the stimulus items were abstract shapes and children's recall was tested by their ability to choose a row of shapes to match the stimulus items that they had been shown. After analysis of the results, the authors conclude that:

> In line with many previous studies, we have confirmed that differences in reading ability are associated with differences in short-term memory for verbal materials, but not for abstract shapes that are difficult to name (p. 126).

Vellutino, Scanlon and Sipay (1997) investigated the relationship between reading ability and verbal short-term memory in 183 children aged five to seven years. The results of their longitudinal study suggest that short-term memory for words, sentences and nonsense syllables 'reliably and robustly' differentiate normal readers from poor readers (p. 373). Following a remedial intervention study with the poor reader group, Vellutino and his colleagues (Vellutino et al., 1997) suggest that verbal short-term memory ability also differentiates poor readers who are 'easily remediated' from poor readers who are 'difficult to remediate'.

Passenger (1997) investigated the direction of the relationship between verbal short-term memory and reading ability during a longitudinal study of 80 children aged four to five years. All children were non-readers when first tested. Passenger (1997) concludes that the verbal short-term memory of pre-literate children makes a significant contribution to subsequent phonetic nonword reading ability.

McDougall and her colleagues (McDougall et al., 1994) investigated two 'mechanisms', which they hypothesised might account for the short-term memory differences found between groups of children differing in reading ability. The two mechanisms are verbal long-term memory and articulation rate. Each of these is discussed below.

3.1.4 The contribution of verbal long-term memory to performance on verbal short-term memory tasks

Gathercole and Adams (1994) and McDougall and Hulme (1994) claim that verbal long-term memory contributes to verbal short-term memory performance. This is hypothesised to be because phonological representations of words in long-term memory can be called upon to 'refresh' phonological traces that are gradually being lost from short-term memory. Hulme and his colleagues (Hulme et al., 1997) define this as the process of redintegration.

Evidence for the redintegration process comes from a study carried out by Hulme, Roodenrys, Brown and Mercer (1995), involving 24 university students. The students' recall of nonwords was found to be inferior to their recall of words. However, when students had an opportunity to become familiar with the phonological forms of the nonwords before testing, performance on the short-term memory tasks using the nonwords improved. From these results, the authors conclude that phonological forms of words stored in long-term memory are accessed in order to refresh items that are gradually being lost from short-term memory.

It could be argued that the small number of participants in this study makes the results unreliable, but Hulme and his colleagues (Hulme et al., 1995) point out that their findings converge with previous research carried out by Hulme, Maughan and Brown (1991) and Schweickert (1993) in which it is claimed that familiar words are recalled more efficiently than foreign words and high frequency words are recalled more efficiently than low frequency words.

Research by Gathercole and Adams (1994) investigated the contribution of long-term memory to the verbal short-term memory performance of four- and five-year-old children. In a longitudinal study, the verbal short-term memory of a group of 70 children was tested at two time points twelve months apart. The test used to measure short-term memory performance was a nonword repetition test. Children listened to forty nonwords of varying complexity and were asked to repeat the words back to the tester as accurately as possible. The nonwords used in the test were assigned to one of two categories: low wordlike nonwords and high wordlike nonwords. The nonwords were assigned to categories according to the judgments made by 20 adults, each of whom were asked to rate each nonword on its 'wordlikeness' using a score ranging from one to five. Subsequently, words such as 'perplisteronk' and 'loddernapish' were assigned to the 'low wordlike' set and words such as 'sepretennial' and 'defermication' were assigned to the 'high wordlike set'. Children of age four and age five were more successful at repeating the high wordlike nonwords accurately than they were at repeating the low wordlike words accurately. From these results Gathercole and Adams (1994) conclude:

> The present findings establish that familiarity with memory stimuli facilitates memory performance when the task involves remembering an unfamiliar phonological sequence (p. 984).

The categorisation of words as wordlike or nonwordlike was an important element of this study. It could be argued that the procedure for making these decisions was both subjective and overly biased towards an adult's perspective. Adults have a considerably greater knowledge of words than four and five-year-old children and the words considered by an adult to be wordlike may not correspond to the words considered by a young child to be wordlike.

3.1.5 The relationship between verbal short-term memory and articulation rate

The research literature suggests that the relationship between verbal short-term memory and articulation rate may be influenced by the ages of participants. Research that has investigated this relationship with older and younger participants is discussed below.

3.1.5.1 The relationship between verbal short-term memory and articulation rate in older children and adults

Converging evidence suggests that there is a relationship between verbal short-term memory and speech rate in participants aged over seven years (Avons & Hannah, 1995; Hulme, Thompson, Muir & Lawrence, 1984). An established model for short-term working memory that incorporates the articulatory loop (Baddeley, 1986) has previously been discussed in Section 3.1.1. An important element of the articulatory loop is suggested to be an active rehearsal process that involves sub-vocal articulation. The relationship between verbal short-term memory and speech rate is thought to occur because overt articulation rate equates to the covert articulation rate of the sub-vocal rehearsal system

Hulme and his colleagues (Hulme et al., 1984) investigated the relationship between verbal short-term memory and articulation rate in three separate groups of children aged four, seven, and eleven years. The results of their study suggest that there is a relationship between verbal short-term memory and articulation speed, with the elements increasing in parallel through childhood. They conclude that, on average, children can recall as much as they can articulate in 1.5 seconds, with the number of words recalled being less relevant than the length of the words and the speed at which individual participants can articulate them.

Hulme and Muir (1985) investigated the causality of the relationship between verbal short-term memory and articulation rate by training children to articulate words more quickly in an attempt to induce improved verbal short-term memory. However, they found that the training had little effect, suggesting that the relationship between verbal short-term memory and articulation rate is not a simple one of cause and effect.

Following a review of research evidence to date, Hulme and Roodenrys (1995) conclude that the association between verbal short-term memory and articulation rate is robust to variations in testing methods, type of individuals tested, (for example, different ages and abilities), and language. Hulme and Roodenrys (1995) argue that:

> Short-term memory problems are an index of other phonological deficits, that are actually tapped more effectively by simply having children repeat words as quickly as they can (p. 386).

However, it could be argued that in research with younger children, whose speaking and other motoric skills are at a rapidly developing stage, articulation rate is likely to be a less reliable measure of phonological deficits than might be the case with older children or adults. Studies that have investigated the relationship between articulation rate and verbal short-term memory in younger children are discussed below

3.1.5.2 The relationship between verbal short-term memory and articulation rate in younger children

In a longitudinal study involving 70 children, Gathercole and Adams (1994) measured verbal short-term memory and articulation rate at age four and five years. They found that there was a significant association between articulation rate and verbal short-term memory (measured by digit span) in children aged five ($r = .44$, $p \leq .05$). However, when the same children had performed the same tests twelve months earlier, the correlation between the results had been non-significant ($r = .22$ *ns*). On the basis of these results, Gathercole and Adams (1994) suggest that sub-vocal rehearsal strategies needed for memory span tasks are used by children aged five, but not by children aged four.

Support for the Gathercole and Adams (1994) results is provided by Passenger (1997) who reports a non-significant correlation between digit span and articulation rate in children aged four years ($r = .19$, *ns*) which changed to a significant relationship in the same children, using the same tests ($r = .23$, $p \leq .05$) twelve months later. Although the increase in correlation is small, the results converge with the results reported by Gathercole and Adams (1994). These findings, together with the conclusion of Hulme and Roodenrys (1995) that, in older children and adults, articulation rate is a proxy measure for verbal short-term memory, suggest that the relationship between verbal short-term memory and articulation rate may be developmental in nature. An interesting question therefore arises: if children aged four do not use sub-vocal articulation as a means of aiding performance on memory span tasks, what causes the variability in performance?

3.1.5.3 Procedures for measuring articulation rate

Procedures for measuring articulation rate have varied across studies. Participants are generally asked to repeat a word, or sequence of words, a specific number of times. Measurement is either the length of the complete resultant speech stream, or the length of a specific part of the speech stream. Some studies have used stopwatches to record 'live' presentations (for example, Avons & Hannah, 1995; Henry, 1994). Measurement of speech using a stopwatch can be vulnerable to reliability errors, particularly if one tester is both giving the instructions for the test, and operating the stopwatch. It could be argued that the tester's speed of reaction is also being measured, with no control over factors that may influence this. Testing in this way also gives no opportunity to evaluate the quality of speech. Some children may be conscientious about repeating words accurately whereas others may be prepared to sacrifice accuracy for speed. It is possible that, in fact, it is not the same word or phrase that is being measured on each occasion. For example, if the child is asked to repeat the word 'cat', some children may conscientiously do so but others may repeat the word 'cad', 'ca' with a guttural stop, or 'ga'. Some studies have recorded the speech stream so that measurement can take place later (for example, Hulme & Tordoff, 1989). This provides an opportunity for inter-rater reliability testing, and for the quality of articulation to be taken into account.

More recently, computers have been used to record and measure the speech stream, allowing greater accuracy of measurement. Passenger (1997) used computerised sound recording technology to measure the articulation speed of four- and five-year-old children. The children were asked to repeat each stimulus word until told to stop. The whole speech stream was recorded and the time taken to articulate every word was measured. However, only the fastest articulation time for each word was used in analysis. It could be argued that taking the fastest articulation time for each word, rather than the mean articulation time, may provide a distorted picture of each child's general articulation rate. For example, if a child spoke a word at a rate of three words-per-second within a speech stream, this rate would be recorded regardless of the fact that the other six times within the speech stream the word was articulated at a slower rate of two-words per second.

3.1.6 Section summary

Previous research suggests complex inter-relationships between verbal short-term memory, phonological awareness, articulation rate, long-term memory and reading ability.

Several research studies have suggested that performance on verbal short-term memory tests significantly differentiates poor from more able readers (for example, McDougall et al., 1994; Vellutino et al., 1997).

Hulme and his colleagues (Hulme et al., 1995, 1997) claim that verbal long-term memory contributes to verbal short-term memory performance because phonological representations of words in long-term memory are used to refresh decaying phonological traces in short-term memory.

A relationship between verbal short-term memory and articulation rate is thought to exist because sub-vocal rehearsal within the articulatory loop can refresh decaying traces of words in short-term memory. Overt articulation rate is thought to equate to covert articulation rate during the rehearsal process (Baddeley, 1986).

It has been suggested that articulation rate can be considered to be a proxy for verbal short-term memory measurement in older children and adults (Hulme & Roodenrys, 1995). However, there appears to be no significant relationship between articulation rate and verbal short-term memory (measured by digit span) in children aged four years (Gathercole & Adams, 1994; Passenger, 1997). This suggests that variability in verbal short-term memory in children aged four years stems from a different underlying skill deficit to variability in verbal short-term memory in older children and adults.

3.2 Rapid Serial Naming

Several research studies have measured the relationship between rapid serial naming and reading ability. This section will discuss:

- measurement of serial naming
- relationships between serial naming and reading ability
- relationships between serial naming and phonological awareness.

3.2.1 Measurement of serial naming speed

The serial naming test is a measure of how quickly a series of letters, digits, colours or pictured objects can be named. The test was first used by Denckla (1972) and was at that time called the rapid automatised naming (RAN) test. The test, often in its original form, has been used frequently during the past 26 years in studies investigating the association between rapid serial naming and reading (for example, Badian, 1998; Blachman, 1984; Bowers, Steffy & Tate, 1988; Cutting, Carlisle & Denckla, 1998; Manis, Seidenberg & Doi, 1999; McBride-Chang & Manis, 1996; Scarborough, 1998; Wagner et al., 1993, 1994, 1997; Wolf 1991). Participants are presented with a series of visual stimuli, typically between 40 and 80 items, which they are asked to name as quickly as possible. Timing starts at the beginning of articulation of the first word and ends when articulation of the last word is complete. The test is usually timed using a stopwatch.

Several researchers have argued that serial naming speed is predictive of reading ability because both tasks require fast retrieval of phonological codes from memory (Baddeley, 1986; Share, 1995; Wagner & Torgesen, 1987). However, Wolf and Bowers (1999) argue that serial naming is much more than a test of phonological processing skill. These authors describe in detail their perception of the cognitive requirements of the serial naming task. They list these as:

- attention to the stimulus
- visual feature detection/discrimination
- matching of visual information with stored visual representations
- matching of visual information with stored phonological representations
- access and retrieval of phonological labels

- activation of associated semantic and conceptual information
- activation of motoric processes leading to articulation
  (Wolf & Bowers, 1999, p. 417).

Although the demands of the task include some that are phonologically related, Wolf and Bowers argue that naming speed deficits are not simple manifestations of deficits in phonological processing skill, as suggested by Wagner et al. (1997) but represent a second, independent core deficit.

3.2.2 The relationship between speed of serial naming, and reading ability

Although the cause of variability in children's naming speed is not fully understood, converging research evidence suggests that a deficit in serial naming speed is a characteristic of reading difficulty from the early stages of reading (Wolf, Bally & Morrison, 1986) to adulthood (Fawcett & Nicolson, 1994; Felton, 1994; Flowers, 1993; Korhonen, 1995; Wolff et al., 1990). Some studies have found that serial naming of graphological stimuli, such as letters and digits, is more closely associated with reading ability than naming colours or pictured objects (Bowers, Steffy & Tate, 1988; Wolf, 1991). It could be argued that this is unsurprising, given the similarities between reading tasks and tasks that require rapid naming of graphological stimuli. However, other studies have found that rapid serial naming of graphological and non-graphological stimuli, such as colours and pictured objects, are equally associated with reading ability (Denckla & Rudel, 1976; Meyer, Wood Hart & Felton, 1998).

Several authors have suggested that serial naming speed is more predictive of reading ability in samples of poor, or younger, readers, than in samples of normal readers (Scarborough, 1998; Wagner et al., 1997;

Wolf, Bally & Morris, 1986). However, care must be taken in interpreting these findings for two reasons:

1. If the serial naming test items are graphological stimuli, such as letters or digits, measurement could be confounded by large variability in children's secure knowledge of these symbols;

2. It could be argued that daily school reading activities experienced by children who are successful readers are influential in developing rapid serial naming skills. For example, good readers have more practice in scanning text and retrieving phonological codes from memory than poor readers. Good readers may be fast at serial naming simply because they have regular practice in the necessary skills. Therefore, the reciprocal nature of the relationship must be taken into consideration when analyzing and discussing results of research with older children.

Wolf and Bowers (1999) point out that the relationship between serial naming and reading can be highly complex. Relationships appear to vary between different populations (for example, poor and normal reader groups) and at different time periods (for example, younger and older children). It seems that in studies where the sample population comprises average or above average readers correlations tend to be low. However, in samples of poor or younger readers correlations tend to be higher. For example, Meyer, Wood, Hart and Felton (1998) report the results of a longitudinal study of 160 children aged from eight to eleven years, of which 64 children comprised an impaired-reader group. Their results suggest that although serial naming speed does not accurately predict word-level reading ability in normal reader groups or in older children, variance in word-level reading ability of poor readers in fifth and eight grade is predicted from the results of third grade serial naming tests. This is suggested to be the case even when previous reading ability is controlled in the regression equation.

The research discussed in the following section focuses on studies that have investigated the relationship between rapid serial naming and reading ability in younger or less able groups of children.

3.2.3 The relationship between rapid serial naming and reading ability on younger or less able children

Badian, Duffy, Als and McAnulty (1991) carried out a longitudinal study that investigated the relationship between the linguistic skills of children aged five and their subsequent reading ability at age nine. Three serial naming tasks were given at age five: rapid naming of colours, digits and pictured objects. There were 60 participants in the study who were classified into reading groups on the basis of the discrepancy between their standardized reading scores and their intelligence quotients at age nine. Fourteen of the children were classified as dyslexic, 30 as average readers and 16 as good readers. Discriminant function analysis was used to investigate whether it was possible to predict reading group membership at age nine from the results of tests given at age five. The authors conclude that serial naming of digits at age five is one of the most significant predictors of later reading ability, claiming that tests of letter knowledge combined with rapid serial naming predict reading impairment with over 90% accuracy.

The data analysis in the study by Badian and her colleagues (Badian et al., 1991) study did not include a regression analysis, possibly because the numbers in the groups were too small for this statistical technique to be used reliably. Due to the fact that multiple regression was not used it is not possible to establish the amount of variability in later reading that was accounted for by the earlier tasks. A certain amount of shared variance may have become apparent. It is also noteworthy that the study did not include a measure of phonological awareness. Given the extensive research linking phonological awareness to reading ability, it is possible that if a measure of phonological awareness had been included, a different picture would emerge of the most significant early predictors of later reading ability.

In a cross-sectional study, McBride-Chang and Manis (1996) investigated the relationship between serial naming speed and reading ability in a group of 125 children aged eight to ten years. In order to investigate the hypothesis that serial naming has a greater association with reading in poor readers than normal readers, the authors selected children to fit into either a poor reader or normal reader category. The poor reader group comprised 51 children who were at, or below, the 25^{th} percentile on the word attack subtest of the Wide Range Achievement Test (WRAT) (Jastak & Wilkinson, 1984). The normal reader group comprised 74 children who were at or above the 50^{th} percentile on the same test. The authors reported that rapid naming of letters was significantly associated with word reading for poor readers ($r = .50$ $p < .05$) but not for good readers ($r = .03$ *ns*). However, the reliability of using a serial letter-naming task as a measure of serial naming speed in poor readers is again questionable. Results are likely to be confounded by children's lack of secure knowledge of letter names.

Presenting the results of a longitudinal study involving over 200 children, Wagner and his colleagues (Wagner et al., 1997) reported that serial naming of letters and digits was significantly related to concurrent word-level reading ability at age five, six and seven. Correlations ranged from .48 to .66 (all significant at $p \leq .05$). In regression analyses, however, it was found that the predictive influence of serial naming faded with time for readers of all abilities. The authors point out that the gradually weakening predictive relationship between serial naming and reading could be due to the auto-regressive effect of previous reading ability. The autoregressive effect is caused when the results of previous reading ability are entered into a regression analysis as a predictor of later reading ability. In the study by Wagner and his colleagues (Wagner et al., 1997), the autoregressive effect was found to be substantial. Because reading scores over the period of the study were highly stable (children who were good readers at age five continued to be good readers thereafter, and poor readers at age five tended to be poor readers thereafter) there was little scope for any other factor beyond previous reading to exert any predictive influence. It is important to take this fact into account when comparing these results with other studies that may not have included an autoregressive reading variable as a predictor of later reading ability. Only serial naming of graphological stimuli was measured in this study. The authors acknowledge that:

> ...because the naming tasks involved naming either letters or digits, it is possible that these tasks were mere proxies for individual differences in early literacy and print exposure (Wagner et al, 1997, p. 476).

Manis, Seidenberg and Doi (1999) also included the auto-regressive effect of prior reading ability in regression analysis when they investigated the predictive influence of serial naming on reading ability. In this study, the authors used a computational model to examine the contributions of serial naming to the prediction of a variety of reading skills in children over a one-year period from age six to age seven. They found that serial naming speed accounted for independent variance in later reading, even when previous reading skill was controlled. Manis and his colleagues (Manis et al., 1999) used the autoregressive technique but made some interesting observations concerning its impact:

> It is important to note that the autoregression technique factors out both prior reading skill and growth in reading that is predicted from prior reading (expected growth). Therefore only the relation of RAN [rapid automatised naming] and phoneme awareness to unexpected growth in reading is being evaluated in the studies ..... The autoregression studies leave open the possibility that the contribution of RAN and other factors to predictable growth in later reading may be substantial (p. 133).

Wolf and Bowers (1999) suggest that the extent to which serial naming relates to reading ability within different reading ability groups alters as children reach a certain age, typically about seven to nine years. As readers become 'automatic' in their responses to print, naming speed is an increasingly poor predictor of later reading ability. Poor readers reach the level of automaticity later, or not at all. For this reason, serial naming speed continues to be a predictor of reading ability for a longer period of time in poor reader groups.

All of the studies discussed above report significant associations between serial naming speed and reading, but in each case it is graphological stimuli that are reported to be significantly related to reading ability. As discussed above, when young or reading impaired children are asked to rapidly name letters or digits, it is likely that insecurities in existing knowledge of the stimuli will affect performance. The two studies discussed below investigated associations between reading ability and non-graphological stimuli. These studies provide an opportunity to investigate the relationship between serial naming speed and reading when it is not confounded by children's ability to learn associations between verbal and graphological stimuli.

In a longitudinal study, Scarborough (1998) investigated the extent to which rapid naming of pictured objects at age seven could predict reading ability at age thirteen. Her sample of 88 children incorporated a subgroup of 38 children considered to be at risk of reading disability. The reading impaired subgroup was identified retrospectively from reading scores at the end of Grade 2 (age seven to eight) and the autoregressive technique was again used in the regression analyses. For the group of normal readers, regression analyses suggested that reading ability at age seven was the only significant predictor of reading ability at age thirteen. However, for the reading disabled group, the results suggested that reading scores at age seven were less predictive of reading scores at age 13. The predictive power of reading was increased significantly when it was combined with serial naming. The results of the regression analyses, particularly for the reading disabled group, must be treated with some caution because of the small number of children in the subgroups. Nevertheless, the study is of interest because of the reported predictive influence on later reading of serial naming using non-graphological stimuli.

Wimmer, Mayringer and Landerl (1998) conducted a longitudinal study to compare the speed of serial naming of 20 German dyslexic children with a group of 27 age-matched controls. The identification of the dyslexic children took place when they were aged seven, but data on the children had previously been collected when they were aged six. Due to standardized procedures for teaching reading to German children, children were either pre-readers or at the very earliest stages of reading tuition when tested at age six. Wimmer and his colleagues (Wimmer et al., 1998) calculated effect sizes to compare the dyslexic children with the controls on tasks of serial naming, phonological awareness, articulation speed, verbal short-term memory and pseudoword naming. They claim that the two most significant differentiators between the dyslexic and non-dyslexic children are rapid serial naming of digits at grade 2, and rapid serial naming objects at grade 1. The between-group effect sizes for these two tests were 1.55 and 1.33 respectively ($p \leq .01$). They conclude from this evidence that slow serial naming speed for pictured objects cannot simply be a product of poor reading because, at the first time of testing, all of the children were either non-readers or at the very earliest stage of learning to read. As part of this research, children's articulation rate was also measured at age six and age seven. There were two tests of articulation rate. For the first test the children were told three words, such as the German equivalent of dog, cat, mouse (*Hund-Katze-Maus*). They were asked to repeat these words as fast as possible and the number of words per second was calculated. For the second test, the children were asked to count from one to ten as quickly as possible. Again the average number of words per second was calculated. The authors report that there were no significant between-group differences for articulation rate. The dyslexic children performed at a comparable rate to the normal readers at each time of testing, suggesting that differences in serial naming speed could not be attributed to articulation rate even though articulation time is an integral part of serial naming time.

The studies presented above suggest that rapid serial naming of graphological stimuli, such as letters and digits, can be an important indicator of children's current and future reading success. More importantly, the results of the studies by Wimmer and his colleagues (Wimmer et al., 1998) and Scarborough (1998) suggest that rapid serial naming of non-graphological stimuli, such as pictured objects, may be an early indication of reading disability. However, the causes of children's poor performances are not yet clearly understood. Wimmer and his colleagues (Wimmer et al., 1998) suggest that poor serial naming performance is not linked to slow articulation rate. Converging evidence for this was provided by Obregon (1994). In a small-scale study involving 12 children, six of whom were classified as dyslexic, Obregon (1994) used computer analysis of children's rapid serial naming to investigate the three following possible causes of breakdown: slow articulation rate, slow retrieval of phonological labels from memory, and slow transition time from the end of each line to the beginning of the next. He concluded that, in children aged between 12 and 17 years, the element of rapid serial naming that most significantly differentiated normal from dyslexic readers was the length of the 'gaps' between the spoken words. Wolf and Bowers (1999) define each inter-word gap as an 'inter-stimulus interval' (ISI). They describe the ISI as the time taken to 'relinquish processing the previous stimulus and move on to processing the present stimulus (p. 419). The results of the study by Obregon (1994) must be treated with some caution, because of the small number of children involved. Nevertheless, the study is of interest because it appears to be the only study to date that has measured articulation time and ISI time as separate elements of rapid serial naming.

It could be argued that the categorisation of the serial naming time into articulation time and ISI time is an over simplification because participants are likely to be articulating one word at the same time as they are scanning forward and retrieving the next word from phonological memory. Nevertheless, investigation into children's performance on these separate elements of the serial naming test provides additional insight into the possible causes of poor performance.

3.2.4 Investigating variability in serial naming speed

Wide levels of variability in children's serial naming speed have been reported, although there is evidence to suggest that there is stability in the naming speed of individual children over time. In the longitudinal study carried out by Scarborough (1998), the serial naming speed of 68 seven-year-old children was measured at age seven and again at age 13. (See section 3.2.3). At age seven, the stimuli for the naming test were 48, pictured objects. At age 13 the colours and objects stimuli from the RAN test (Denckla & Rudel, 1976) were used. The reported serial naming scores for children aged seven ranged from 33 to 99 seconds. At age 13 the range was 25 to 53 seconds. These results indicate a considerable lack of fluency in some children compared to others in the group. Scarborough (1998) did not investigate the source of this variability. A test-retest correlation of .51 ($p \leq .01$) was reported between the scores at age seven and scores at age 13, indicating that there was significant stability in performance over the six-year period.

A study by McBride-Chang and Manis (1998) also reported large variations in the speed at which children perform serial naming of letters and digits (see section 3.2.3). The authors comment particularly on the amount of variability in the poor reader group:

> Despite the depressed range of reading ability in the poor readers relative to the good readers, they nevertheless exceeded the variability of the good readers on all three naming tasks... This variability is even more remarkable when one considers that the poor reading group had almost one third fewer subjects than the good reader group (p. 335).

The results of the McBride-Chang and Manis (1998) study would seem to provide support for the results of the Scarborough (1998) study but, as discussed previously (section 3.2.3), this study may have confounded serial naming speed with letter knowledge. Although several studies have investigated the links between serial naming speed and reading ability, the levels and causes of variability in children's serial naming speed appear to be a relatively under-researched area.

3.2.5 The relationship between speed of serial naming and phonological awareness

As discussed in previous sections, both serial naming speed and phonological awareness have been found to be significantly associated with reading ability but researchers have generally failed to find significant associations between speed of serial naming and phonological awareness in normal-reader populations (Blachman, 1984; Bowers, 1995; Felton & Brown, 1990).

Wolf and Bowers (1999) argue that serial naming speed and phonological awareness are separable deficits that contribute independently to variability in reading ability. These authors propose that reading disability may be associated with:

- poor phonological awareness alone
- slow serial naming alone
- both poor phonological awareness and slow serial naming.

Individual children who exhibit poor performance in relation to both skills are thought by Wolf and Bowers (1999) to experience a double deficit that is particularly resistant to remediation. Identification of the type of deficit that underlies a child's reading difficulty is considered to be important. As Wolf and Bowers (1999) point out, readers with a phonological awareness deficit will probably benefit from phonological-based interventions, but naming speed deficit and double deficit readers will be 'less comprehensively diagnosed and less fully remediated' by a programme that focuses on phonological awareness deficits (p. 430). These authors suggest that the early identification of children with slow naming speed is necessary if potential reading deficits are to be addressed. Support for this suggestion comes from Byrne and Fielding-Barnsley (1995) who report that training in phonological awareness in pre-school improved accuracy in word-level reading but not fluency in reading several years later.

Manis, Seidenberg and Doi (1999) provide support for the argument of Wolf and Bowers (1999) that phonological awareness and rapid serial naming measure independent skills. The results of their longitudinal study with children aged six to seven years suggest that phonological awareness (measured by a syllable and phoneme elision task) and serial naming (measured by letter naming and digit naming) account for independent variance in later reading. Children with naming speed deficits had slow reading speed and poor reading comprehension but were not impaired on decoding skill. Children with phonological awareness deficits were poor at both word and nonword reading, and on reading comprehension. These findings suggest that a serial naming deficit may be more closely related to reading in older, reading-disabled children, where automatic processing of words for fluency and comprehension is important.

Wagner and his colleagues (Wagner et al., 1997) present an opposing argument concerning the independence of phonological awareness and rapid serial naming. These authors suggest that:

> Serial naming performance is sufficiently correlated with performance on other phonological processing tasks to include it as part of our assessment of children's phonological processing abilities (p. 469)

Wagner and his colleagues (Wagner et al., 1997) report correlations between reading ability and serial naming of letters and digits in children aged five years to be significant ($p \leq .05$). However, as discussed previously, the authors acknowledge that the use of letters as stimulus items in serial naming tasks may jeopardize the validity of results.

3.2.6 Section summary

There has been considerable recent discussion concerning the skills that are measured during serial naming tasks. Wolf and Bowers (1999) suggest that serial naming is a complex task that measures a combination of skills. Serial naming of letters could possibly be confounded by insecure letter knowledge. Therefore, it could be argued that serial naming of pictured objects is a more pure measure of serial naming speed, particularly in younger children.

Wolf and Bowers (1999) argue that rapid serial naming and phonological awareness are separate core deficits and that children who have weaknesses in both areas suffer from a double-deficit that is particularly hard to remediate. However, Wagner and his colleagues (Wagner et al., 1997) argue that serial naming is predominately a measure of phonological processing and that weaknesses can be attributed to a phonological deficit that is measured equally well by other phonological processing tasks, such as phonological awareness or verbal short-term memory.

Although a consistent association between serial naming speed and reading ability in normal populations has not been found, several studies have reported a relationship between serial naming speed and reading ability in poor reader groups. One recent study (Obregon, 1994) has analysed serial naming responses in order to investigate articulation time and ISI time as separate elements of overall serial naming time. The results of this study suggest that ISI time, but not articulation time, differentiates groups of poor and average readers. Although the Obregon (1994) study involved only six children in each reader group, it provides an interesting insight into the elements that comprise the serial naming task that is worthy of further investigation.

3.3 Knowledge of letter names and sounds

The developmental reading models discussed in Chapter 2, section 2.4.1 all include a stage or phase at which knowledge of letters is used to assist reading. Letter knowledge has frequently been found to be a good predictor of reading ability (for example, Adams, 1990; Badian, 1998; Chall, 1967; Gallagher, Frith & Snowling, 2000). This section discusses studies that have investigated the predictive relationship between letter knowledge and reading.

3.3.1 Associations between letter knowledge and reading ability

Several authors report significant associations between the letter knowledge of pre-readers and later reading ability. For example, Gallagher, Frith and Snowling (2000) investigated the relationship between letter knowledge and reading in a group of 63 children who were considered to be genetically at risk of reading disability and a matched control group of 34 children who were not considered at be at risk of reading disability. They reported that letter knowledge at age 45 months was the strongest predictor of reading at age six for both groups. Similarly, Muter, Hulme, Snowling and Taylor (1997) carried out a three-year, longitudinal study with children who were initially four years old. They found that knowledge of letter names at age four correlated significantly with reading ability at age six ($r = .62$, $p \leq .001$). These results converge with a substantial amount of previous research linking weaknesses in letter knowledge to reading disability (Adams, 1990; Badian, 1994; Bond & Dykstra, 1967; Chall, 1967; Share, Jorm, Maclean, & Matthews, 1984)

The research suggests that knowledge of letter sounds and letter names are similarly predictive of later reading ability. There has been considerable interest in the nature of the relationship. Ehri and Wilce (1985) investigated the way in which children use letter knowledge to help them to read words. They found that children who could read only a small number of words, but who knew 77% of the letters of the alphabet, were able to use their knowledge of letter sounds to help them to identify 'words' in which there were regular phoneme/grapheme correspondences. For example, these children could more easily learn that 'scissors' was represented by 'szrs', than by 'qDjK'. Children who knew only 26% of the letters of the alphabet learned the associations between the word 'scissors' and 'qDjK' more easily. On the basis of this evidence, Ehri and Wilce (1985) suggest that children with poor letter knowledge learn to read by noting the visual characteristics of words, whereas children with better letter knowledge automatically use a phonetic strategy. Frith (1985) and Ehri (1995) identify the stage of reading development at which children start to use their knowledge of letter sounds as 'clues' as an important step on the route to successful reading. Share and Stanovich (1995) suggest that once children start to use knowledge of letter sounds and phonological awareness to decode words, they enter a stage of development in which they utilise a self-teaching mechanism that speeds their reading progress.

Research discussed above indicates a longitudinally predictive relationship between letter knowledge and reading ability. The results of research reported by Byrne and Fielding-Barnsley (1989, 1990) support this view, suggesting that children do not automatically acquire letter knowledge through learning to read. However, Gallagher and her colleagues (Gallagher et al., 2000) suggest that the relationship is not a simple one of cause and effect. These authors point out that the poor pre-literate letter knowledge of children who went on to become disabled readers was not due a lack of opportunity to learn. Their study involved the co-operation of parents and they report that the at-risk children spent more time learning letters with their parents than the normal reader group. This finding suggests that there is an underlying deficit that affects the ability to learn the names and sounds of letters. Gallagher and her colleagues (Gallagher et al., 2000) suggest that reading disabled children may have a 'specific verbal learning difficulty such as that which accounts for their slower rate of verbal paired-associate learning' (p. 209).

3.3.2 Section summary

Converging research suggests that knowledge of letters is an important prerequisite of successful reading (Ehri, 1995; Byrne & Fielding Barnsley, 1989, 1990). It has been suggested (Gallagher et al., 2000) that disabled readers may have a specific difficulty in learning associations involving a verbal component. The following section discusses research that has investigated children's ability to quickly learn sound/visual symbol associations.

3.4 Learning sound/visual symbol associations

Although letter knowledge has been reported to be a significant predictor of reading ability, there has been relatively little research investigating children's ability to learn verbal/visual symbol associations. As reported above, Gallagher and her colleagues (Gallagher et al., 2000) found that differences in pre-literate letter knowledge between the groups of children who went on to become either reading disabled or normal readers were significant ($p \leq .001$), even though all children were reported to have spent considerable amounts of time learning letters with their parents. This finding suggests that, for some children, poor letter knowledge may be caused by a difficulty in learning sound/symbol relationships that is not easily compensated for by additional learning experiences. The ability of children to learn sound/symbol associations appears to be an under-researched area. However, two studies that have investigated this skill are discussed below.

Vellutino and Scanlon (1982) report on a series of studies that compared the abilities of average (n = 60) and poor (n = 60) readers to make associations between visual, verbal and non-verbal stimuli. The children involved in the study were aged 10 to 13 years. The authors suggest that poor readers and average readers achieve comparably when learning associations between visual and acoustic but non-verbal material (for example, the association between a printed design and a cough) but that poor readers need significantly more teaching trials to learn to associate visual with verbal stimuli (for example, pictures of letter-like figures with consonant - vowel - consonant nonsense syllables). The reported between-group difference remained significant ($p \leq .01$) when verbal IQ was controlled.

Mauer and Kamhi (1996) identify the cumulative skills that are involved in learning associations between phonemes and graphemes. They define these skills as:

- the ability to recognise and distinguish between letters
- the ability to process phonological information
- the ability to associate specific letters or letter clusters with specific sounds.

Mauer and Kamhi (1996) were particularly interested in processes relating to the third skill – the ability to learn verbal/visual symbol associations. They compared the number of trials needed by two groups of children to learn a series of associations. The first group comprised 20 reading disabled children aged seven to eight years and the second group comprised ten, five-year-old children matched to the reading disabled group on reading age. They found that the reading disabled group needed significantly more trials than the reading-age matched control group to learn the associations. The reading-disabled group needed an average of 8.4 trials (SD = 3.3) to learn sound/symbol associations using sets of stimuli that were phonetically and visually similar. In comparison, the group of reading age-matched controls needed only 3.2 trials (SD = 0.6) to learn the same associations. The between-groups difference was significant at the $p \leq .001$ level. Although the number of children involved in this study was small, the results converge with the results reported by Vellutino and Scanlon (1982).

The studies discussed above suggest that reading disabled children have a specific difficulty in learning verbal/visual symbol associations. However, it is noteworthy that Mauer and Kamhi (1996) also report significant correlations between speed of learning verbal/visual symbol associations and verbal short-term memory ($r = .68$, $p \leq .001$) and speed of learning verbal/visual symbol associations and phonological awareness ($r = .48$, $p \leq .01$). It could be argued therefore, that reported associations between slow speed of learning verbal/visual symbol associations and reading difficulty are underpinned by weaknesses in phonological processing.

3.4.1 Section summary

Although there is not a great deal of research relating to children's ability to quickly learn verbal/visual symbol relationships, the research discussed above suggests that reading-delayed or reading-disabled children may have more difficulty in learning such associations than more able readers.

The results of research by Mauer and Kamhi (1996) suggest that slow speed of learning verbal/visual symbol associations may be a consequence of weaknesses in phonological processing that is equally well demonstrated by poor phonological awareness and poor verbal short-term memory.

3.5 Chapter summary

This chapter has discussed the literature relating to verbal short-term memory, rapid serial naming and its component elements of articulation time and ISI time, letter knowledge and speed of learning verbal/visual symbol associations. Complex inter-relationships between these skills have been identified and relationships with phonological awareness and reading ability have been discussed.

Based on the review of the literature, a longitudinal study was designed to investigate relationships between these skills in children aged 4.0 to 5.5 years, all of whom were non-readers at the beginning of the study. The research questions associated with the subsequent study are discussed in the following chapter. One of the main aims of the study was to investigate the changing relationships between skills as children progressed from being non-readers to readers.

Chapter 4

Summary of Research Aims and Questions

Introduction and chapter overview

Previous chapters have discussed the theoretical background to the study. This chapter will revisit the aims of the current study, review the rationale and state the associated research questions.

4.1 Aims of the study

A study involving children aged 4.0 years to 5.5 years was designed to:

- investigate the development of a carefully selected range of reading related skills
- investigate the evolving relationship of these skills to word-level reading ability.

Specifically the skills to be investigated were:

- phonological awareness
- verbal short-term memory
- speed of serial naming and its component elements: articulation rate and ISI rate
- letter knowledge
- rate of learning sound/symbol associations.

In order to focus the investigation more precisely, the aims were translated into specific questions to be addressed.

4.2 Research Questions

The research questions are presented under the following headings:

- the structure and development of phonological awareness
- serial naming and its component elements
- predicting reading
- the relationship between verbal short-term memory, articulation rate and ISI rate
- the relationship between letter knowledge, speed of learning verbal/visual associations and phoneme awareness.

Each of the following sections addresses the following aspects of the research project:

- summarising the rationale for the research questions
- stating the research questions to be investigated
- identifying links to the relevant sections in the literature reviewed in chapters two and three.

4.2.1 The structure and development of phonological awareness

4.2.1.1 Rationale

The literature presents an unclear picture regarding the conceptual structure of phonological awareness and the relationship of the various tasks used to measure phonological awareness skill to reading ability. The measurement of phonemic awareness predominates in the literature, possibly because most investigations sampled older children for whom the lower linguistic levels might be considered to be too easy. In order to fulfil the aims of measuring development across time and investigating the relationships of each linguistic and task level to later reading ability, it was decided to systematically measure each possible linguistic level/task level combination. Therefore, a series of nine tests was designed to measure blending, segmenting and elision at each of the linguistic levels of syllable, onset-rime and phoneme. In order to maximise the experimental control across tasks that McBride-Chang (1995) identified to be lacking in some previous research, the tests were designed to a common format with only the linguistic level being varied. A tenth phonological awareness test measured rhyme awareness. In order to differentiate global rhyme awareness from onset-rime manipulation, the rhyme awareness test required children only to identify whether two given words rhymed.

Although there is converging evidence of a significant relationship between reading ability and phoneme awareness in children who have already started learning to read, the literature presents an unclear picture regarding the relationship of pre-literate rhyme awareness, syllable awareness, onset-rime awareness and phoneme awareness to the prediction of subsequent reading ability. The current study therefore investigates relationships between a series of phonological awareness tasks and subsequent reading ability.

4.2.1.2 Research questions relating to phonological awareness

Is phonological awareness a unitary construct?	Chapter 2: Section 2.3
How much variability is there in the timing and speed of development of phonological awareness in children aged 4.0 to 5.5 years?	Chapter 2: Section 2.2
Is there a clearly defined order of acquisition of the various stages or levels of phonological awareness?	Chapter 2: Section 2.2
To what extent are the various linguistic and task levels of phonological awareness associated with word-level reading ability?	Chapter 2: Section 2.5

4.2.2 Serial naming speed

4.2.2.1 Rationale

Several studies suggest that slow serial naming is associated with reading disability (Denckla & Rudel, 1976; Scarborough, 1998; Wolf, 1991). Wide variability in the speed at which children can perform serial naming tests has been reported (McBride-Chang & Manis, 1996; Scarborough, 1998) although naming speed in individual children appears to be a relatively stable construct (Scarborough, 1998). Obregon (1994) identifies two elements of the serial naming test as articulation time and ISI time. The current study aims to refine understanding by measuring the children's developing speed of naming over a twelve-month period. Children's responses will be analysed so that speech time and ISI time can be measured separately. The study also aims to discover whether there are significant between-group differences in the serial naming speed of children who are more able or less able readers by age 5.5 years.

Wolf and Bowers (1999) argue that slow serial naming and poor phonological awareness are separable deficits. However, Wagner and his colleagues (Wagner et al., 1997) report that the serial naming speed of letters and digits of children aged five years was significantly related to phonological awareness ($p \leq .05$). These authors therefore suggest that serial naming speed is predominately a measure of phonological processing. The current study will investigate the relationship of articulation rate and ISI rate (measured as elements of the rapid serial naming test) with phonological awareness.

4.2.2.2 Research questions relating to rapid serial naming

Which element of rapid serial naming contributes the greatest variance to overall performance?	Chapter 3: Section 3.2
Does serial naming speed (or its component elements) predict variance in reading ability?	Chapter 3: Section 3.2
Is there a relationship between rapid serial naming (or its component elements) and phonological awareness?	Chapter 3: Section 3.2

4.2.3 Predicting reading

4.2.3.1 Rationale

Previous research has suggested that phonological awareness, verbal short-term memory and letter knowledge are associated with reading ability. It has also been suggested that serial naming speed is associated with subsequent reading disability in populations of younger children and in populations of less able readers. However, the relationship between the component elements of serial naming (articulation time and ISI time) and subsequent reading has not previously been investigated. The current study aims to investigate the association between each of these skills and reading ability longitudinally, so that any changes in relationships as children start to learn to read can be explored.

4.2.3.2 Additional research questions relating to the prediction of reading

How much variance in word level reading at age five years is accounted for by the cognitive skills of phonological awareness, verbal short-term memory, letter knowledge and the component elements of serial naming?	Chapter 3: all sections

4.2.4 The relationship between verbal short-term memory, articulation rate and inter-stimulus interval (ISI) rate

4.2.4.1 Rationale

Hulme and his colleagues (Hulme et al., 1995) suggest that, during verbal short-term memory tests, phonological forms of words stored in long-term memory are accessed in order to refresh items that are gradually decaying in short-term memory. The current study argues that ISI time (measured as an element of the serial naming test) can be regarded as a proxy measure for speed of accessing phonological codes in long-term memory. Support for this theory comes from several researchers who suggest that speed of naming is associated with reading ability because both tasks require fast retrieval of phonological codes from memory (Baddeley 1986; Share, 1995). Wagner and his colleagues (Wagner et al., 1994) explicitly describe serial naming tasks as measures of 'retrieval of phonological codes from a long term store' (p. 75). If ISI time is a measure of speed of retrieval of phonological codes from long term memory and performance on verbal short-term memory tests is thought to be influenced by the ability to refresh decaying phonological traces in short-term memory from phonological forms in long-term memory (as suggested by Hulme et al., 1995) it would follow that there should be an association between verbal short-term memory task performance and ISI rate. The current study aims to investigate this association.

As discussed in Chapter 3, section 3.1.5, converging evidence suggests that there is a relationship between verbal short-term memory (measured by digit span) and articulation rate in older children and adults. Gathercole and Adams (1994) suggest that there is a significant relationship between verbal short-term memory and articulation rate in children aged five, but not in children aged four. The current study uses the measure of articulation rate derived from the serial naming test to longitudinally investigate the relationship between verbal short-term memory and articulation rate in children at age four and age five years.

4.2.4.2 Research question relating to the elements that comprise the serial naming test and verbal short-term memory

Is there a relationship between articulation rate, speed of retrieval of phonological representations from long-term memory (ISI rate) and verbal short-term memory?	Chapter 3: Section 3.1.4 Section 3.1.5

4.2.5 The relationship between letter knowledge and speed of learning verbal/visual associations

4.2.5.1 Rationale

Converging research suggests that letter knowledge is a significant longitudinal predictor of reading ability (for example, Gallagher et al., 2000; Muter et al., 1997). However it could be argued that it is not letter knowledge per se that predicts reading ability, but the ability to learn grapheme/phoneme associations. Mauer and Kamhi (1996) and Vellutino and Scanlon (1982) suggest that reading disabled children have greater difficulty than normal readers in learning verbal/visual symbol associations. The current study investigates relationships between letter knowledge and speed of learning verbal/visual symbol associations and reading ability.

4.2.5.2 Research question relating to letter knowledge and the ability to learn verbal/visual symbol associations

What is the relationship between children's speed of learning verbal/visual symbol associations, letter knowledge and reading ability?	Chapter 3: Section 3.4 and 3.5

4.3 Summary

This chapter has revisited the aims and research questions associated with the current study, stated the rationale underpinning the research questions and identified the relevant links to the literature reviewed in Chapter 2 and Chapter 3. In preparation for the longitudinal study, two small-scale, cross-sectional pilot studies were planned so that the research instruments could be tested with a small group of children aged four years. The pilot studies are described and discussed in the following chapters.

Chapter 5

The Pilot Study: Design and Methodology

Introduction and chapter overview

The previous chapter discussed the aims of the project and the rationale underpinning the research questions. The current chapter will discuss:

- the purpose of the pilot studies
- issues of sampling
- the methodology of the pilot studies.

5.1 The purpose of the pilot studies

Vogt (1999) states that:

> In a pilot, the entire study with all its instruments and procedures is conducted in miniature (e.g., on a small sample) (p. 214).

The piloting phase was a particularly important element of the research design because the participants were only four years of age at the start of the project. As already discussed, a previous study investigating the development of phonological skills in young children reported high levels of participant non-cooperation (Gathercole & Adams, 1993). Therefore, it was considered to be important that the tests for the current study were designed to capture the interest and co-operation of children of this age. Pilot studies also present an opportunity to investigate the reliability and validity of the tests to be used. Cone and Foster (1996) suggest that a pilot study is essential to avoid common research pitfalls. For example, they suggest that:

- procedures may take longer than expected for some participants
- equipment may not work as planned
- participants may not understand instructions.

In the current study, the pilot studies therefore aimed to develop an appropriate and valid range of tests and to check for procedural difficulties.

The first pilot study involved eight children who were selected from a local playgroup after consultation with the playgroup supervisor and the children's parents. All of the children were four years old and they were chosen to represent a varied ability range. The purpose of the study was to investigate the children's attitudes to the tests and the approximate time that each test would take. All of the tests were trialled with all of the children, who were asked which tests they enjoyed and which ones they did not enjoy. Each test was timed and, on the basis of qualitative analysis of the children's responses and the information gained about timing, the second pilot study was planned. The second pilot study involved 25 children aged 4.0 to 5.0 years and its purpose was to investigate the reliability, validity, appropriateness and range of difficulty of each test. The remainder of this chapter discusses the second pilot study.

5.2 Choice and construction of tests

Where suitable tests were available (either as published tests or as used in previous research) these tests were used. However, there were several areas in which it was felt that appropriate tests were not available. In such cases, either existing tests were modified, or new ones were designed.

The choice or design of the tests focused on four key issues: reliability, validity, appropriateness for the age range and level of difficulty. Each of these issues is discussed below.

5.2.1 Reliability

The reliability of a test is concerned with the 'consistency and replicability' of results obtained (Cohen, Manion & Morrison, 2000). Reliability coefficients can be obtained that range from 0 (no consistency) to 1 (perfect consistency). Vogt (1999) states that 'tests with reliability coefficients less than .7 are usually considered unreliable' (p. 245). In the pilot study, the reliability coefficients of the unpublished tests were calculated using Cronbach's alpha (Cronbach, 1951). For the published tests, information about reliability was taken from the test manuals.

5.2.2 Validity

Coolican (1995) comments that:

> A test or effect may well be rated as excellent on reliability but may not be measuring what was originally intended... The validity of a psychological measure is the extent to which it *does* measure what it is intended to measure (p. 52).

Cone and Foster (1996) discuss two aspects of validity that must be addressed at an early stage of the project plan: face validity and convergent validity. Face validity is described as the extent to which the tests appear to be superficially appropriate measures of the construct being tested. Convergent validity is ensured if the tests used are considered to be appropriate by experts in that particular type of research. The face validity and convergent validity of the tests was investigated prior to the pilot study through discussion and by reference to the research literature. A third form of validity, construct validity, defined by Vogt (1999) as 'the extent to which the variables accurately measure the constructs of interest' was investigated later in the research project when results started to become available (Vogt, 1999, p. 53). Construct validity is likely to be questioned if the results do not generally converge with previous research findings.

Each of the tests is discussed in section 5.6 in terms of its design and methodology.

5.2.3 Appropriateness

A third aim of the pilot study was to ensure that each test and the battery of tests as a whole was qualitatively appropriate for the age of the children. Inappropriate tests would be those during which the children showed lack of understanding or motivation. Whenever possible, tests were designed or modified to introduce an interest factor. The aim was to maximise children's interest and attention.

5.2.4 Range and level of difficulty

The range and level of difficulty of the tests was evaluated according to whether they provided results that were normally distributed, suggesting that they effectively discriminated between children within the age range concerned.

5.3 Issues of sampling

Cohen et al., (2000) suggest that decisions about sampling should be made early in the research design process. The samples for the second pilot study and the subsequent, longitudinal study were therefore considered together.

The research questions directly influence the selection of the sample of participants (McQueen & Knussen, 1999). For example, the essential characteristics of children for the current study were that they should be four-year-old non-readers. Cooligan (1994) states, 'Samples should be representative of those to whom results may be generalised' (p. 34). However to obtain a balanced, unbiased sample is not always easy. Aron and Aron (1999) point out that psychological studies are most often conducted with whomever is willing or available to participate:

> At best, a researcher tries to study a sample of individuals who are not systematically unrepresentative of the population in any known way (Aron & Aron, 1999, p.149).

The first stage in selecting the sample for the current study was therefore to find a group of pre-school settings that would be willing to be involved. The second stage was to select from the willing settings a sample of participants who were representative of the target population. In order to do this, screening procedures were built into the design of the study in order to eliminate any child who:

- could read any of the words in the reading test
- had any identified special educational need
- had English as an additional language
- had a speech impairment
- had a standardized receptive vocabulary score below the fifth percentile or above the 95th percentile.

Children of four years of age have not usually started school in the United Kingdom. However, the Nursery Education and Grant-Maintained Schools Act (1996) provides state funding for all four-year-old children in a variety of pre-school settings such as nursery schools, day nurseries and playgroups. At the time that the study began, the majority of four-year-old children in areas local to the study were in part-time, pre-school education.

It was felt that the best way to gain access to the large number of four-year-old children required for both the pilot study and the longitudinal study was through the local, pre-school education network. It was envisaged that one strong advantage in working with children who were receiving pre-school education was that they would be accustomed to working with a variety of adults.

Ethical guidelines set out by Cheltenham and Gloucester College of Higher Education (1997) state that:

> Researchers should attempt to obtain the informed consent of children and their parents and in relation to school children, those in *loco parentis'* (p. 2).

Following these guidelines, together with those issued by the British Psychological Society (1998), the current study could only include children whose parents and pre-school managers were willing for them to be involved. Bearing in mind these ethical considerations, the process of finding an unbiased sample began. As a first step, letters were written to a carefully selected group of pre-school settings. Using knowledge of the local area, twenty settings in a variety of socio-economic areas were contacted. Managers of the twenty pre-school settings were initially asked two questions:

1. Would they like to be involved with the study?
2. Could they provide a room, away from noise and distraction, where the researcher and children could work?

Twenty settings were contacted and nine responded positively. The nine settings that had responded positively were visited to ensure that the 'quiet room' provided a suitable testing environment. The visit was also used to establish how many children of the required age were at each setting. Seven of the nine settings that had volunteered were considered to be suitable. The seven settings were felt to be broadly representative of the range of socio-economic backgrounds, and types of pre-school provision likely to be found within the county. Cohen et al., (2000) describe a sample selected in this way as a 'cluster sample' (p. 101). The procedure is widely used in small-scale research because it is a practically feasible approach that avoids the difficulties attached to working with participants who are geographically widely dispersed.

Of the seven selected settings, three were invited to take part in the pilot study and all were invited to take part in the subsequent longitudinal study. For the pilot study, three pre-school managers were each asked to identify four boys and four girls who had English as a first language, no special education need and were representative of a varied range of ability. The pre-school managers agreed to ask parents of these children for permission for their children to be involved in the pilot project.

5.4 Method

Testing was undertaken in a quiet room at the child's pre-school setting. Each child was seen either three or four times and testing lasted approximately 20 minutes during each visit. Some children needed a little more 'off task' time than others as a prerequisite to settling into the testing procedures. The total time spent with each child was between 60 and 90 minutes. The test battery comprised:

- ten tests of phonological awareness
- two tests of letter knowledge
- two tests of verbal short-term memory
- one test of serial naming
- one test of rate of learning sound/visual symbol associations
- two tests of verbal intelligence.

5.5 Participants

The 24 children in the pilot study were aged from 48 to 58 months. The mean age was 51.3 months and the standard deviation was 2.9 months. The children attended one of three pre-school settings that had agreed to be involved in both the pilot study and the longitudinal study. Participants in the pilot study were twelve boys and twelve girls. All children had English as their first language and had no known special educational need. The socio-economic status of the children was not formally established, but prior discussion with pre-school leaders suggested that a mid-range of socio-economic backgrounds was represented.

5.6 Measurement Instruments

The tests used in the pilot study are discussed below under the following headings:

- source of published test or construction of experimental test
- method
- scoring.

5.6.1 Tests of phonological awareness

Test construction

Nine of the ten tests of phonological awareness were designed to test blending, segmenting and elision at each of the linguistic levels of syllable, onset-rime and phoneme. The tenth test was a test of rhyme awareness. All of the tests were based on designs that were represented in the research literature (see Chapter 2). Examples of each of the nine tests of phonological awareness are shown in Table 1.

Table 1: Examples of the tests of phonological awareness

		Tasks		
		Blending	**Segmenting**	**Elision**
Linguistic Levels	**Syllable**	To blend: 'sis' and 'ter'	To segment: 'dra/gon'	To delete: 'ti' from 'tiger'
	Onset and Rime	To blend: 'g' and 'arden'	To segment: 'c/old'	To delete: 'all' from 'wall'
	Phoneme	To blend: 'c' 'u' and 'p'	To segment: 'd/o/g'	To delete: 't' from 'tap'

A complete list of the words used in each test is contained in Appendix A. An example from the test of rhyme awareness was to ask the children whether the words 'cap' and 'tap' rhymed. A complete list of the words used in the rhyme awareness test is contained in Appendix B. All of the tests, except the rhyming test, had six items. The rhyme awareness test had eight items, each requiring only a yes/no answer.

Method

All of the phonological awareness tests except the rhyming test (which is discussed separately below) used a biscuit as a physical representation of a word. The children were shown how the biscuit could be broken so that it became two or three bits. (Two bits in the case of syllable or onset and rime tests, and three bits in the case of phoneme tests.) The children were shown how the biscuit could 'pretend to be the word - biscuit'. When the (initially) two pieces of the biscuit were taken apart to demonstrate syllable segmenting the word became 'bis....cuit'. When the bits were put back together it became 'biscuit' again. The biscuit then 'pretended' to be other words, which were the practice items for the first test. In this test, children were 'told some broken words' and asked to guess what the word was that had been broken.

The subsequent tests were given in a similar manner. For all blending tests the child was told a 'broken word' and asked to guess what the word was that had been broken. For all segmenting tests, the child was told a whole word and shown how to move the parts of the biscuit apart as they said the 'bits' of the word. For the elision tests, the child was told that 'Naughty Nick sometimes steals bits of words'. When a bit of the biscuit was taken away, the child was asked to say the 'bit of word' that remained. Each test had four practice items followed by the test items. During the four practice items, the child was told the correct word, or bits of word, if they could not provide it. For the subsequent test items the correct answers were not given. If the child gave either a correct or an incorrect response the tester said, 'That's a good try. Let's try another one'. If the child did not give a response, the tester said, 'Let's try another one'. The nine phonological awareness tests described above were always given in the same order: syllable blending, syllable segmenting, syllable elision, onset/rime blending, onset/rime segmenting, onset/rime elision, phoneme blending, phoneme segmenting, and phoneme elision. A maximum of three of these tests was given at any one testing period.

For the rhyme awareness test, the children were shown pairs of pictures in a 'rhymes book'. For each practice and test item, the tester said the two words represented by the pictures. Children were told that they 'can hear whether words rhyme by listening to the sounds in the middle and at the ends of words to see if they sound the same'. The four practice pairs were then shown, one pair at a time, and the child was asked to say 'yes' if they heard rhyming words, and 'no' if they heard words that did not rhyme. During the practice phase, the tester corrected incorrect responses and the words were repeated so that the child could hear them again. The eight test pairs of words were then presented with no corrections of incorrect responses.

Scoring

In all phonological awareness tests, a correct response scored one point and an incorrect response, or no response, scored 0 points.

5.6.2 Tests of letter knowledge

Test construction

Two tests of letter knowledge were given: letter sound identification and letter sound production. There were fourteen test items for each test. It was felt that to test children on all 26 alphabet letters might overburden them, especially as it was expected most of the children would know few letters at this age. The literature search revealed four studies that had previously investigated letter knowledge in pre-readers (Coleman 1970; Huxford, 1993; Passenger, 1997; Stuart, 1987). The four studies showed considerable agreement concerning the order in which children learn letters. From these three studies it was possible to identify seven letters that were generally learned early and seven letters that were generally learned later. These 14 letters were used in this study. The earliest learned letters were d, s, m, p, o, a, and f. The latest learned letters were u, w, l, e, b, g, and v.

Method

Each set of seven letters was included on a three by four grid, with the remaining five letters on each grid being letters that were not being tested. A set of model puppies helped the children to 'play this game'. For the letter identification test, the tester said the sound of a letter and the child was asked to help the puppy to find it. For the letter production test, the child was told that 'one of the puppies hadn't learned the sounds of any letters yet, but would like to learn some now if the child would help'. Therefore, when the puppy went to sniff at a letter, the child was asked to tell him the sound that was usually associated with the letter if it was in a word.

Scoring

One point was scored for each letter correctly identified.

5.6.3 Tests of verbal short-term memory

Two tests of verbal short-term memory were given.

Source of published tests

The pilot study included two published tests of verbal short-term memory:

- The British Ability Scales digit-span subtest (long form) (Elliott, Murray & Pearson, 1983)
- The Children's Test of Nonword Repetition (Gathercole, Willis, Baddeley & Emslie, 1994).

Method

The tests were given according to the instructions in the test manuals. For the digit span test the child listened to strings of digits, of gradually increasing length, presented at half-second intervals. Each digit string had to be repeated back to the tester. There were five test items at each string length, with the shortest length being two digits. For interest and motivation the children were told that the digit strings were the telephone numbers of people who wanted to come to a party. During the nonword repetition test the children heard 40 nonwords of two, three four and five syllables. The children were asked to repeat each word back to the tester.

Scoring

In the digit span test, each correctly repeated test item scored one point. In the nonword repetition test, one point was scored for each word repeated correctly.

5.6.4 Test of speed of learning sound/visual symbol associations

Test construction

This was an experimental test designed to measure the speed at which children could learn to associate 'letter-like' symbols to regular, consonant-vowel-consonant (CVC) nonwords. A computer program was designed to present three letter-like symbols and three associated nonwords to the children. For interest, the symbols were presented as snakes and the nonwords were the names of the snakes (Zag, Tig and Nog). The symbols and names are presented in Appendix C.

Method

During a simple introduction, each child was shown each of the three symbols and told each of the three names once. The test was presented in story format. The children were asked to help Jungle Bird to find the snake for which the tester asked. For each test item the three snakes appeared on the screen in random places. As each snake appeared, the computer said the corresponding name. The tester then said 'Jungle Bird wants to play with [name]', and the child was asked to point to the correct snake.

Scoring

One point was scored for every correct response. In order to maintain motivation, if an incorrect response was made, the child was given a second, and then, if necessary, a third opportunity to find the correct snake, but no points were scored. This allowed each child to be eventually successful on each test item and provided the same amount of positive reinforcement to each child regardless of whether or not they scored a point.

5.6.5 Test of rapid serial naming

Source of published test

The serial naming test used in the current study was taken from the Dyslexia Early Screening Test (DEST) (Nicolson & Fawcett, 1996). The DEST is specifically designed for children between the ages of 4.5 and 6.5 years, and the serial naming test comprises 40, pictured line drawings of objects as the stimulus items. The test was not designed to be used by children aged below 4.5 years and the length of the test was an issue of concern. It was considered possible that some children might lose concentration during the 40-item test. It was decided to halve the number of items in the array of objects to be named. This was easily done, as the published test requires children to name each of twenty pictured objects twice. The current study required them to name each pictured object once.

Method

The test was given following the instructions in the DEST (Nicolson & Fawcett, 1996) manual. The tester and child looked at the 20 pictures and the tester told the child the names of the pictured objects. The child was then asked to name the pictures in untimed conditions and the tester reminded the child of any words on which they hesitated. When the tester was confident that the child was familiar with the phonological labels for each picture, the child was asked to 'say all of the words as fast as you can'. The instructions for giving the DEST (Nicolson & Fawcett, 1996) test suggest measuring the time taken to name the items with a stopwatch. However, in order to maximize reliability and measure the individual elements of articulation time and ISI time, it was necessary to record children's responses to computer so that they could be analysed in detail. For this purpose, a notebook computer with a boom microphone was used. The computer was preloaded with the Soundforge Professional

Recording System (Sonic Foundry, 1991) so that the children's responses could be recorded for later analysis. Using the computer programme to aid the analysis it was possible to hear each spoken word and simultaneously view the sound wave that was produced. A picture of sound waveforms and an example of a highlighted ISI is contained in Appendix D.

Scoring

The test was scored when the sound files were retrospectively analysed. Three measurements were taken:

- the time to articulate each of the twenty words
- the ISI time between each two consecutive words
- the time to complete the overall serial naming test (comprising the two measurements above).

5.6.6 Tests of verbal intelligence

Two tests of verbal ability were given for screening purposes.

Source of published tests

The British Picture Vocabulary Scale (BPVS II) (Dunn, Dunn, Whetton & Burley, 1997) and the BAS Similarities Test (Elliott, Murray & Pearson, 1983) were included in the study as screening measures. The BPVS (Dunn et al.,) is primarily a test of receptive language, but the test manual states that it may additionally be 'viewed as a screening test of scholastic aptitude (verbal ability or verbal intelligence)' (p. 2). It is standardized for children with chronological ages from three to fifteen years. The BAS Similarities Test (Elliott et al., 1983) is standardized for children from five to seventeen years.

The inclusion of these tests allowed comparison of the sample with a normally distributed population. As discussed in section 5.3, the research sample was chosen with the aim of maximizing 'generalisability' to the target population. It was decided therefore to exclude any child whose vocabulary score was below the fifth percentile (standardized score 75) or above the ninety-fifth percentile (standard score 125).

Method

The tests were given according to the instructions in the user manuals. For the BPVS (Dunn et al., 1997) each test item requires the child to look at a set of four line drawings and choose the drawing that best corresponds to a word given by the tester. For example, the first page of the tests shows pictures of a hand, a duck, a cup and a trolley. The child is asked 'Can you find...hand?'

In the Similarities Test (Elliott et al., 1983) the child listens to a list of three words and is asked to think of another word to add to the list. For example, the tester says: 'skirt, hat, trousers... What would go with these?' The child is then asked to say how the named items are similar. For example, after 'skirt, hat, trousers' the child is expected to explain that the items are all 'clothes' or 'things that people wear'. The test manual gives several examples of acceptable and unacceptable answers.

Scoring

For the BPVS (Dunn et al., 1997), items are scored as correct if the child is able to indicate the most appropriate drawing for the word spoken by the tester. The items are graded in difficulty and testing is discontinued when the child makes eight errors in any set of twelve items.

For the Similarities Test (Elliott et al., 1983) one point is scored for each test item where the child can give a satisfactory reason why the listed items go together. No account is taken of whether the child can add another word to add to the list, as this is described in the test manual as being a focusing element of the test. The test items are graded in difficulty and testing is discontinued after four incorrect responses.

5.6.7 Hearing Test

Source of published test

The Hearing Test Cards (Reed & Iliffe, 1987) were used to screen for hearing difficulties.

Method

The test was given twice. Firstly, according to the instructions in the user guide. The child was shown a set of four pictures and asked to point to each in turn. On successful completion of this test, the test was given again using a different set of four pictures. At the second time of testing, the tester used a voice much quieter than would be used in normal conversation. The purpose of the second test was for the tester to feel confident that each child had normal hearing. During the pilot study, all children completed both tests successfully.

5.7 Order of testing

The tests were given in a fixed order following the schedule below:

Time 1: hearing test
tests of syllable awareness
test of rhyme awareness
verbal ability tests

Time 2: tests of onset/rime awareness
tests of verbal short-term memory
tests of letter knowledge

Time 3: tests of phoneme awareness
test of learning sound/visual symbol associations
test of serial naming

In cases where children's limited concentration span made it impractical to keep to the schedule, the tests were spread over four visits but the order of presentation remained the same.

5.8 Summary

This chapter has discussed the purpose of the pilot studies, issues of sampling, the design of each test that was used, the methodology for each test and details of how the test was scored. The following chapter discusses the analysis of the data from the pilot study.

Chapter 6

Pilot Study: Data Analysis

Introduction and chapter overview

The previous chapter discussed the design and the methodology of the pilot studies. The current chapter continues to discuss the piloting phase under the following headings:

- analysis of the results of the main pilot study data
- influence of the pilot study results on the design of the subsequent longitudinal study.

6.1 Analysis of the results of the main pilot study

Analysis of the results of the pilot study had several objectives:

- to establish an order of difficulty for the items within the phonological awareness tests and for the phonological awareness tests themselves
- to investigate the normality and linearity of scores
- to investigate the reliability and validity of tests
- to evaluate the qualitative appropriateness of the tests and children's levels of attention and motivation.

Each of these objectives is discussed below.

6.1.1 Order of difficulty of the phonological awareness tests

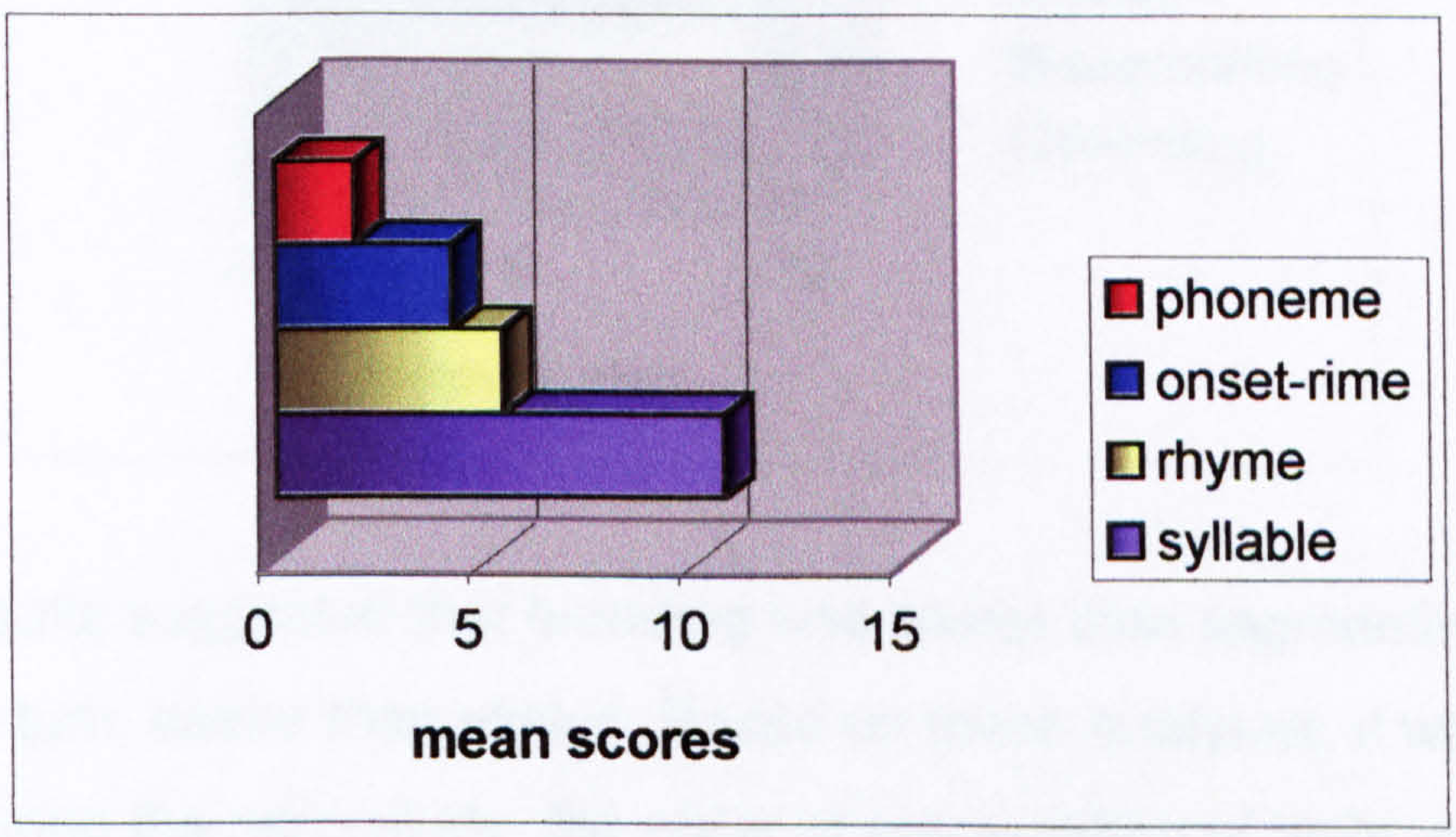
Each phonological awareness test comprised four practice items and six test items with the exception of the rhyme awareness test, which had four practice items and eight test items. It was considered that discontinuation criteria should apply because of the age and possible limited concentration span of the children. To ensure the reliability and validity of tests in the main study it was important that, when tests were discontinued, the tester was confident that the child was very unlikely to be able to answer any more items correctly. It was important, therefore, that an order of facility was established.

As a first step in determining an order of facility, mean scores for each linguistic level and each type of task were calculated. The maximum scores at each linguistic level were:

- rhyme 8
- syllable 18
- onset-rime 18
- phoneme 18.

Figure 1 compares the mean scores obtained at each linguistic level.

Figure 1: Mean phonological awareness score at each linguistic level



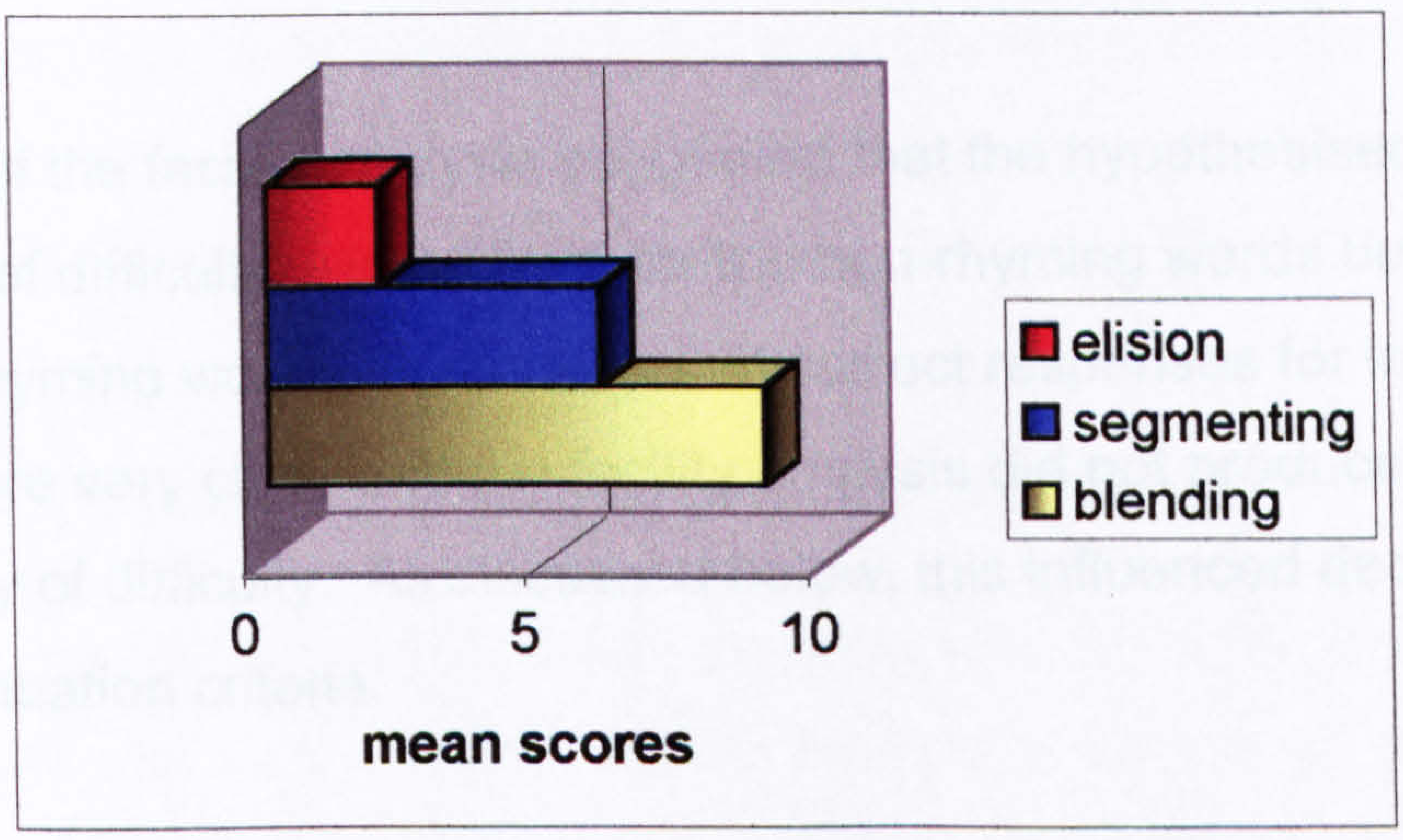
The results suggest that syllable awareness tasks were the easiest, followed by rhyme awareness tasks, onset-rime awareness tasks and phoneme awareness tasks, which were the most difficult. These findings converge with previous research by Treiman (1992), but conflict with the findings of Seymour and Evans (1994) who found that onset/rime awareness tasks were generally found to be more difficult than phoneme awareness tasks.

An investigation of the facility of the tasks (blending, segmenting and deletion) for syllables, onset/rimes was then carried out. The maximum scores for each type of task were:

- blending 18
- segmenting 18
- elision 18.

Figure 2 compares the mean scores obtained for each type of task.

Figure 2: Mean phonological awareness score for each type of task



The results suggested that blending was easier than segmenting, which was, in turn, easier than elision. Based on these analyses, it was decided that, during the main study, the order of presentation of tests would be based on facility of linguistic level. Therefore, all of the syllable tests would be given first, followed by the rhyme awareness test, followed by all of the onset-rime awareness tests, followed by all of the phoneme awareness tests. Within each linguistic level, the blending test would be given first, followed by the segmenting test, followed by the elision test.

The next stage of the facility ordering process was to order the items within each test according to difficulty. Therefore, within each test, the number of correct responses for each item was calculated. This information was used to decide the order of items within each test during the longitudinal study. The full list of test items, ordered after facility indexing, is contained in Appendix A.

For the test of rhyme awareness, it was considered that the level of difficulty of the test items could be affected in two ways:

- for the rhyming pairs, the length and complexity of the words used might be influential
- for the non-rhyming pairs, the number and similarity of non-shared sounds might be influential.

Results of the facility analysis suggested that the hypothesised influences on level of difficulty were correct for the non-rhyming words but incorrect for the rhyming words. Percentages of correct responses for individual test items were very close and the facility analysis did not produce a clear hierarchy of difficulty. As discussed below, this influenced decisions about discontinuation criteria.

Discontinuation of tests of syllable, onset-rime and phoneme awareness

Strict rules were followed to ensure that discontinuation criteria were not applied too early. As each test had six test items that were presented in order of difficulty, it seemed reasonable to assume that after three consecutive incorrect responses the child would be unable to answer any further test items correctly. Therefore, individual tests could be discontinued after three consecutive items had been answered incorrectly, or not answered at all.

The set of nine tests incorporated three linguistic levels (syllable, onset-rime and phoneme) and three task levels (blending, segmenting and elision). It was felt that four failed tests were necessary in order for the tester to ascertain that failure had occurred at more than one linguistic level and with all types of task. Therefore, testing in phonological awareness could be discontinued if four consecutive tests had been discontinued.

Example 1

The syllable blending test could be discontinued if the child was unable to successfully blend the first three consecutive items 'brek - fust' (breakfast), 'sis - ter' (sister) and 'car-pit' (carpet).

Example 2

If the tests of syllable blending, syllable segmenting, syllable elision and onset/rime blending were all discontinued, the child would be given no further phonological awareness tests until the next time of testing.

Discontinuation of tests of rhyme awareness

It was decided not to apply discontinuation criteria for the rhyme awareness test, as the results did not produce a clear hierarchy. It was decided that, during the main study, all of the children would attempt all eight test items.

6.1.2 Normality and linearity

The pilot study provided an opportunity to investigate the normality and linearity of score distributions. It was expected that some children would be at floor level on several of the phonological awareness measures and in tests of letter knowledge, as the tests were chosen or designed to measure changes over time during the longitudinal study. Tabachnick and Fidell (1996) suggest that data screening is an essential process before data analysis takes place. Therefore, data screening techniques were used to investigate the accuracy, normality and linearity of the pilot study data. Norusis (1999) suggests that, in univariate analysis, descriptive statistics, histograms and boxplots should be obtained for each variable. Descriptive statistics and histograms can be inspected to check for non-normal distributions of data and boxplots can identify outlying scores. Tabachnick and Fidell, (1996) warn that non-normal distributions and outlying scores can be a threat to the reliability of parametric analyses such as correlation and regression. It was planned that both correlation and regression would be used in the analysis of the main study data. Therefore it was important to find out whether the pilot study tests were producing scores that would meet the assumptions of parametric, multivariate analysis.

The linearity of scores is also an important pre-requisite of reliable analyses using correlation and regression. (The statistical techniques used in the longitudinal study are discussed in Chapter 7.) According to Tabachnick and Fidell (1996) 'the assumption of linearity is that there is a straight line relationship between two variables' (p. 78). Prior to correlational analysis, the linearity of variables was investigated by inspecting bivariate scatterplots, plotting regression lines and checking that the points clustered in an approximately oval shape along the regression line. The results of the data screening and data analyses are presented below.

6.2 Results

This section presents results and discussion relating to the tests used in the pilot study. For each test, or group of tests, descriptive statistics are followed by discussions of normality, linearity, reliability and validity. The implications of the pilot study results for the main, longitudinal study are then discussed. Results and discussion are presented under the following headings:

- phonological awareness
- letter knowledge
- verbal short-term memory
- speed of learning verbal/visual symbol associations
- rapid serial naming
- verbal intelligence.

6.2.1 Phonological awareness

Ten tests of phonological awareness were given as previously described.

Descriptive statistics

Descriptive statistics for the phonological awareness tests are shown in Table 2. A composite phonological awareness score is also shown (composite PA). This score represents the total of all of the phonological awareness tests with the exception of rhyme. It was decided to keep rhyme awareness as a separate measure so that its unique contribution to the prediction of reading ability could be investigated (Muter et al., 1997; Bryant, 1998). The split-half reliability coefficient for each experimental test, calculated using Cronbach's alpha (α), is also shown. Cronbach's alpha (Cronbach, 1951) is defined by Vogt (1999) as 'a measure of internal reliability or consistency of the items in an index' (p. 64). In this context an 'index' is defined further by Vogt as 'a group of individual measures that, when combined, are meant to indicate some more general characteristic' (p. 138). In addition to reliability coefficients for the individual phonological awareness tests, Cronbach's alpha for the composite phonological awareness score was calculated using the results of the nine individual syllable, onset-rime and phoneme awareness tests in the analysis.

Table 2: Descriptive statistics for the phonological awareness tests used in the pilot study

Variable (No. of test items)	Mean	SD	Min	Max	α
Syllable blending (6)	4.96	2.03	0	6	.9
Syllable segmenting (6)	4.09	2.23	0	6	.87
Syllable elision (6)	1.57	2.15	0	6	.93
Onset/rime blending (6)	2.43	2.25	0	6	.91
Onset/rime segmenting (6)	2.94	2.06	0	6	.93
Onset/rime elision (6)	0.70	0.30	0	3	.85
Phoneme blending (6)	1.95	1.39	0	6	.89
Phoneme segmenting (6)	0.59	0.7	0	5	.89
Phoneme elision (6)	0.17	0.58	0	2	.85
Composite PA (54)	18.74	9.05	0	42	.88
Rhyme (8)	5.39	3.18	2	8	.85

The results of the individual phonological awareness tests (with the exception of rhyme) were affected by floor effects. This was expected as the range of tests had been designed for use in the longitudinal study with children aged 4.0 to 5.5 years. The more difficult tests were too difficult for most of the younger children. However, composite scores across the nine phonological awareness tasks showed a distribution that was closer to normal. The distribution of scores for the composite test was wider because the composite test comprised 54 test items, whereas each individual test comprised only six items. Since one of the aims of the project was to investigate the growth in phonological awareness over a longer time period, it was necessary to retain the easiest and most difficult measurement instruments in order to fully discriminate between children's abilities at each time of testing.

Reliability and validity

The internal reliability of each of the phonological awareness tests was at or above the .85 recommended by Hills (1981).

The validity of the tests was considered to be high because of the high level of similarity between the tests designed for the current study and tests used in previous research. It was also felt that having tests of consistent design strengthened validity: children did not have to contend with new sets of instructions for each type of test. Consequently measurement of phonological awareness was less likely to be confounded by children's inability to understand the verbal instructions for the task.

The results suggested that the tests would be a reliable and valid measure of phonological awareness in children aged 4.0 to 5.5 years. The order of the phonological awareness tests was modified to take account of the previously described investigations into the order of facility, but was otherwise unchanged for the subsequent longitudinal study.

6.2.2 Knowledge of letter sounds

Two tests of letter knowledge were given, as described in Chapter 5: section 5.5.2.2.

Descriptive statistics

Descriptive statistics for the tests are shown in Table 3.

Table 3: **Descriptive statistics for the tests of letter knowledge used in the pilot study**

Variable (No. of test items)	Mean	SD	Min.	Max.	α
Letter sound identification (14)	4.87	2.7	0	14	.93
Letter sound production (14)	3.56	2.5	0	14	.9

As expected, several children scored at floor level on the letter sound identification and letter sound production tasks. Consequently, the distribution of scores was positively skewed. It was noted that some children were more able to provide letter names than letter sounds. During the pilot study, letter names or letter sounds were counted as correct. However, it was decided to retain a consistent measure throughout the main study and accept letter sounds only as correct. Letter sounds are more closely linked to the decoding process associated with reading ability than are letter names (Treiman, Tincoff, Rodriguez, Mouzaki & Francis, 1998).

Reliability and validity

The internal reliability of the two tests of letter knowledge was .92 for letter sound identification and .95 for letter sound or name production. The correlation between the two tests was .96. These analyses indicated a high level of internal and external reliability. The validity of the tests was considered to be high because:

- the children were highly motivated to perform the tasks because they were 'helping the puppies'
- the tasks were very similar to others used in previous research

- the tasks were simple in design, with little scope for measurement error.

The results suggested that the tests would be a reliable and valid measure of letter knowledge in children aged 4.0 to 5.5 years. The tests were unchanged for the subsequent longitudinal study.

6.2.3 Verbal short-term memory

The pilot study contained two measures of verbal short-term memory: digit span (Elliott et al., 1983) and non-word repetition (Gathercole & Adams, 1993).

Descriptive statistics

Descriptive statistics for the two tests of verbal short-term memory are shown in Table 4.

Table 4: Descriptive statistics for the tests of verbal short-term memory used in the pilot study.

Variable (No. of test items)	Mean	SD	Min.	Max.	α
Digit span	3.0	1.23	0	6	.83
Nonword repetition (40)	10.0	4.6	0	16	.63

The scores on the digit span test were normally distributed but scores on the nonword repetition test showed six outlying scores, two of which were more than two standard deviations below the mean. Taking into account that the range of scores on the nonword repetition test was from 1 to 16, from a possible score of 40, the number of outlying scores was a cause for concern.

Reliability and validity

The reliability coefficients for the tests were taken from the user manuals. The correlation between the two tests was non-significant (r = -.19, *ns*). This was surprising and suggests either that the two tests were not measuring the same construct or that the results of one of the tests were unreliable. At a qualitative level, it was found that the children appeared to find the non-word repetition task rather threatening. Gathercole and Adams (1993, 1994) used a simpler 20-nonword test for children aged two and three years, but the longer 40 nonword test for children aged four years and above. The digit span test, on the other hand, is standardized for use with children aged 2 to 16 years and showed good levels of discrimination, with a distribution of scores that was close to normal. On this basis of these findings it was decided to use only the digit span test to measure verbal short-term memory in the longitudinal study.

6.2.4 Speed of learning sound/visual symbol associations.

This test was given using a specially written computer programme, which has previously been described in section 5.6.4. The descriptive statistics are reported in Table 5.

Descriptive statistics

The descriptive statistics for the test of speed of learning verbal/visual symbol associations are shown in table 5.

Table 5: The descriptive statistics for tests of speed of learning verbal/visual symbol associations used in the pilot study

Variable (No. of test items)	Mean	SD	Min.	Max.	α
Speed of learning verbal/visual symbol associations (12)	6.4	4.1	1	12	.95

The distribution of scores on this test was close to normal and there was a good level of internal consistency.

Reliability and validity

It was hypothesized that there would be a significant correlation between scores on this measure and scores on letter knowledge, since letter knowledge also relies on children's ability to learn sound/symbol associations. The correlations are reported in Table 6.

Table 6: Correlations between speed of learning verbal/visual symbol associations and letter knowledge

	Letter sound identification	Letter sound production
Rate of learning verbal/ visual symbol associations	.63**	.55**

**p ≤ 01

The results suggested that there were significant correlations ($p \leq .01$) between speed of learning verbal/visual symbol associations and letter knowledge. The significance of the association was thought to validate the experimental test.

6.2.5 Serial naming speed

Serial naming and the component elements of articulation time and inter-stimulus interval (ISI) time were measured.

Descriptive statistics

Table 7 contains the descriptive statistics for serial naming and its component elements: articulation time and ISI time.

Table 7: **Descriptive statistics for the test of serial naming and its component elements used in the pilot study**

Variable (No. of test items)	Mean	SD	Min.	Max.	α
Overall speed of serial naming (secs.)	33.62	7.52	19.90	68.00	.80
Speech time (secs.)	12.8	2.2	9.8	17.5	.76
ISI time (secs.)	23.6	9.3	9.5	58.6	.83

It is noteworthy that there were large variations in children's overall scores, which appeared to be mainly attributable to variations in ISI time.

Reliability and validity

The overall test of serial naming showed a wide range of scores with two outlying cases. However, seven of the recordings could not be analysed for a variety of reasons. On three occasions the child's voice was too quiet for the microphone to record and on two occasions there was too much background noise from an adjoining room. Two children also declined to do the test. The reported results are for the 17 successful tests. Children's inter-stimulus interval (ISI) scores showed much wider variability than the articulation scores. The wide distribution of scores was expected as this has been reported in previous research (McBride-Chang & Manis, 1996; Scarborough, 1998). Steps were taken to make the computer equipment more reliable and the tester more confident before the longitudinal study began. This involved thoroughly checking the equipment and organizing an additional small pilot study with a group of six four-year-old children from a local primary school.

6.2.6 Tests of verbal intelligence

Verbal intelligence was measured using two tests: The British Picture Vocabulary Scale (Dunn et al., 1997) and the BAS Similarities Test (Elliott et al., 1983). Raw scores were converted to standardized scores and the descriptive statistics are reported in Table 8.

Table 8: **Descriptive statistics for the tests of verbal intelligence used in the pilot study**

Variable (No. of test items)	Mean	SD	Min.	Max.	α
BPVS	97.83	9.64	78	119	.89
Similarities	96.93	8.61	80	122	.84

Scores on both tests were normally distributed. The reliability coefficients are calculated from the results of samples of pre-school children and are reported in the test manuals. The validity of the tests is well established.

6.3 Summary

This chapter has presented an analysis of the pilot study data and discussed the extent to which the tests were considered to be appropriate for the subsequent longitudinal study. Following analysis of the data, it was decided that most of the tests were reliable, valid and suitable for the age range. Only a very few modifications were thought to be necessary before the longitudinal study. These are summarized below:

- The nonword repetition test was removed from the test battery
- The order of item presentation within the phonological awareness tests was changed as a result of the facility analysis
- The computer software for recording the serial naming responses was reloaded and thoroughly tested for technical reliability

- A test of reading ability was included in the test schedule at Time 1 and Time 3. The reading test is discussed in Chapter 7.

The following chapter discusses the design and methodology of the main study.

Chapter 7
The Main Study

Introduction and chapter overview

The previous chapter presented the pilot study and discussed the ways in which the analysis of results influenced decisions about the tests to be used in the main study. The current chapter will present and discuss the main study under the following headings:

- the design of the main study
- the sample size
- selecting the sample
- methodology
- data screening prior to analysis
- the statistical techniques to be used.

7.1 The design of the main study

The current study was designed to be longitudinal so that the development of individual children could be measured over time. Longitudinal studies take measurements from a group of participants over a period of time and are frequently used to investigate aspects of human development (Cohen, Manion & Morrison, 2000).

7.1.1 Advantages of longitudinal research

Cohen and his colleagues (Cohen et al., 2000) identify several advantages of longitudinal studies:

- They are useful for establishing causal relationships and making reliable inferences

- They show how the changing properties of individuals fit into systematic change
- They are useful for charting growth and development
- They enable change to be analysed at the individual level and enable the dynamics of change to be caught (p. 178).

A longitudinal design was considered to be appropriate for the current study because one of the major aims was to investigate variability in the timing and speed of development of phonological awareness. However, as Cohen and his colleagues (Cohen et al., 2000) point out, there are also disadvantages to the longitudinal methodology.

7.1.2 Disadvantages of longitudinal research

Principal among the disadvantages of longitudinal studies and particularly relevant to the current study are issues of time consumption, attrition rate and continued access to participants. These issues are discussed below.

It was anticipated that the current study would be time consuming because, during the main, longitudinal study, each child would have to be visited at least seven times during a twelve-month period. To a large extent, the number of visits required was due to the anticipated limited concentration span of the young participants. Furthermore, all of the children would be unfamiliar with traditional educational or psychological procedures for measuring attainment. During the longitudinal study, every child would transfer from pre-school to primary school. New headteachers would have to be contacted and the project would need to be explained to each new headteacher and class teacher in order to gain continued access to the children.

Another possible disadvantage of longitudinal studies is high attrition rate. Attrition rate refers to the number of children who start the project but are unable to complete it. There may be a variety of reasons for this. For example, parents may move home or children may decide that they no longer wish to participate. It was planned that if children moved home within the area every effort would be made to keep the children in the project by contacting new educational settings. However, if children moved away from the area, resources would not be available to cover the costs of long distance travel to visit them.

7.1.3 The programme of testing

The programme for the longitudinal study was as follows:

- Time 1 of testing: May and June 1999
- Time 2 of testing: October and November 1999
- Time 3 of testing: May and June 2000.

At Time 1, each child was visited either three or four times. Each period of testing lasted between 15 and 25 minutes. At Time 2, each child was visited either two or three times with each period of testing lasting between 20 and 30 minutes. At Time 3, most children were visited only once, although a few were visited twice. Each period of testing at time 3 lasted either 20 or 40 minutes. A summary of the approximate time spent testing each child is shown below:

- Time 1 60 – 75 minutes
- Time 2 60 minutes
- Time 3 40 minutes

Decisions relating to how many visits each child should have were made solely on the basis of the concentration ability of the child. The aim was to maximize validity by ensuring that it was the intended construct that was being measured and not merely the child's ability to concentrate for a given period of time.

7.2 Participants

As discussed in the previous chapter, pre-school settings were contacted before the pilot study in order to identify a suitable sample of children for testing. Decisions about the number of children to include in the project were made with reference to the research methodology literature.

7.2.1 The sample size

Cohen et al., (2000) advise that there are no clear-cut answers to questions abut sample size. They suggest two ways in which the sample size can be determined:

- by using a table which, from a mathematical formula, indicates the appropriate size of a random sample from a given number of the wider population
- by the researcher exercising prudence and ensuring that the sample represents the wider features of the population with the minimum number of cases.

For the current study, an investigation of formulae to determine sample size, based on power analysis (Rudestam & Newton, 1992) generated the conclusion that a sample size of approximately 250 children for each 1000 children in the population would be necessary. However it was considered impossible to determine the size of the target population, as this would depend on the geographical radius under consideration. Furthermore, the resources available for this single-researcher study made it impractical to consider using such a large number of children in a longitudinal study. Cohen et al. (2000) advise that:

> A sample size of 30 is held by many to be the minimum number of cases if researchers plan to use some form of statistical analysis on their data (p. 93).

This number was considered to be too small for the current study as multiple regression was to be used. When using multiple regression, Tabachnick and Fidell (1996) recommend a minimum number of 50 cases, plus eight extra cases for each independent variable to be used in regression analyses. (The statistical techniques used in the current study are described in section 7.8 of this chapter.) It was decided to recruit a sample of 74 children. The need to use information from correlation tables as criteria for selecting possible predictor variables to enter into regressions was noted. Several recent, similar research projects have reported using samples of this size, or smaller (for example, Nation & Hulme, 1997; Muter & Snowling, 1998). Given that this number of cases was smaller than might be expected according to power analysis formulae, it was considered important to take steps to maximize the representativeness of the sample through the selection procedure. Allowing for a 10% attrition rate over the twelve-month period of the longitudinal study, it was therefore anticipated that approximately 82 children should be included in the first phase of the project.

7.2.2 Obtaining parental consent

For the longitudinal study, parents were asked to provide written permission for their children to be included in the project. The reasons for this are outlined below.

1. The programme of testing represented a considerable time commitment on the part of children.

2. A more formal application for permission to be involved would provide an opportunity to fully explain the nature of the project to parents and for parents to discuss participation in the project with their children.
3. The more formal application for permission would also provide an opportunity to encourage parents to consider whether they would be staying in the area for the twelve-month duration of the project. It was hoped that this strategy would lower the attrition rate.
4. As the children transferred to primary school, the headteachers would need to be reassured that parents had given permission for their children to be involved and would probably ask for evidence of written permission.

Letters were sent out to 130 parents from the seven suitable settings that had previously been identified. Letters were not sent to children identified by pre-school staff as having a speech or hearing impairment, any other form of special educational need, or who were able to read any word other than their own name. Only parents of children who would be aged between 48 and 54 months when the project was due to begin were contacted. Eighty-four signed permission slips were returned and, as one parent had twins, this provided a possible 85 children. The researcher met the 85 children and carried out two screening tests. Children were tested for hearing ability using the Hearing Test Cards (Reed & Iliffe, 1987), and tested on receptive vocabulary using the British Picture Vocabulary Scale (Dunn et al., 1997), following the procedures described in Chapter 5. Children were also tested on the first ten words of the British Ability Scales Test of Single Word Reading (Elliott et al., 1983). As a result of these screening procedures, it was decided that seven children were not suitable for the project:

- one child could not successfully complete the hearing test
- two children could read several words in the reading test

- two children indicated that they did not want to take part
- two children appeared willing to take part but would not speak.

7.2.3 The sample

The sample for Time 1 of testing therefore comprised 78 children: 42 boys and 36 girls. Unfortunately, between Time 1 and Time 3 of testing, ten children left the area. Consequently, full sets of data from 68 children (32 girls and 36 boys) were used in the analyses. The age range of the 68 children at Time 1 was 48 – 54 months. The mean age was 50.5 months and the standard deviation was 1.9 months. Discussion with pre-school managers suggested that the children were broadly representative of the larger population of local, four-year-old children receiving pre-school provision. The seven pre-school settings were in geographically varied areas:

- the nursery attached to a large primary school serving a market town
- a nursery attached to a small rural primary school
- a rural, private nursery school
- three playgroups on different city housing estates
- a playgroup serving a market town.

7.3 Method

Apart from the changes identified in Chapter 6, section 6.3, the procedures for testing during the longitudinal study were identical to those for the pilot study. Additional tests of reading ability were added to the set of tests given to the children at Time 1 and Time 3. All testing was carried out by the researcher in a quiet room at the child's pre-school setting. By Time 2, the children had transferred from their pre-school settings to a total of 21 primary schools. The headteachers of the primary schools were contacted and asked for permission for the research programme to be continued in school. All headteachers agreed. The full set of tests used in the longitudinal study is shown in Table 9. The asterisks indicate when each test was given. It can be seen that some of the tests were given at each time of testing, whilst others were given once or twice.

Table 9: Summary of tests given during the longitudinal study

Test	Preliminary visit	Time 1	Time 2	Time 3
Hearing test	*			
Phonological awareness tests		*	*	*
Tests of letter knowledge		*	*	*
Digit span		*	*	*
BPVS	*			
Similarities		*		*
Rate of learning		*		*
Serial Naming		*	*	*
Single word reading		*		*

7.3.1 Measuring Reading Ability

At Time 1, children were tested on the first ten words of the Single Word Reading Test from the British Ability Scales as a screening procedure (Elliott et al., 1983). Any child who was able to read any of the words did not proceed with the study. At Time 3, a test that could discriminate between non-readers and children at the very earliest stages of learning to read, showing normally distributed results, was required. Several published reading tests were considered, but none of them fitted the required criteria. An experimental word-reading test was therefore designed specifically for the study.

The test was designed to measure a combination of differing types of word-level reading: regular words, non-regular words and nonwords. The National Literacy Strategy (DfEE, 1999) provides a list of suggested words to be taught to children during the reception year and Year 1 of primary school. It was decided to make some use of this list of key words to design a reading test that would be suitably discriminatory. The test designed for this study comprised:

- ten phonetically regular words that are suggested key words for the National Literacy Strategy (DfEE, 1999)
- ten phonetically irregular words that are suggested key words for the National Literacy Strategy (DfEE, 1999)
- ten regular words that are not suggested by the Literacy Strategy
- ten irregular words that are not suggested by the Literacy Strategy
- ten nonwords taken from the Non-Word Reading Test (Snowling, Stothard, & McLean, 1996).

The sets of words were matched as far as possible on number of letters (ranging from three to five) and likely familiarity. The nonwords were also matched with the words on number of letters. The five lists of words are given in Appendix E.

Children were tested on the five lists of words during the final session of testing when they were aged 5.0 to 5.5. Each set of words was presented in a book. Each book had a colourful character on the front cover and the children were told that the character had brought the words for the child to read. However, some characters were said to be not very good at choosing words, leading to the possibility that some of the words might be very easy to read and some of the words might be quite hard to read. The purpose of this strategy was to provide motivation and to encourage the children to feel comfortable about the testing procedure. The ten nonwords were said to have been 'brought by an alien from outer-space'. Because he was 'rather silly' he had brought a book containing the names of his friends. The children were told that the alien's friends had rather strange names although most of them were quite easy to read. Previous studies have reported that children are reluctant to read nonwords, fearing that they must be making mistakes because the nonwords are meaningless. The 'alien' was used as a strategy to encourage children to feel confident about decoding meaningless nonwords. No discontinuation criteria were used for the word-reading tests. All of the children were encouraged to attempt to read all of the words.

7.4 Data Screening

The research methodology literature suggests that, before results are analysed, it is necessary to follow a procedure of data screening. Following the recommendations of Tabachnick and Fidell (1996) the processes outlined below were followed.

7.4.1 Checking for missing, or incorrectly entered data

The raw data and the descriptive statistics generated by the data analysis programme were visually scrutinized to check for missing or incorrectly entered data.

7.4.2 Checking for univariate outliers

Univariate outliers are extreme scores on any variable. Aron and Aron (1999) warn that:

> A single outlier, if it is extreme enough, can cause a statistical test to give a significant result even when the other scores would not (p. 460).

To check for outlying scores, boxplots (SPSS, 1998) were computed for each variable. Examination of the boxplots showed that the serial naming task had produced time scores with wide variability, leading to several extreme outlying cases. Computation of z scores confirmed that some scores were in excess of the 3.29 (p. <001) threshold that Tabachnick and Fidell (1996) recommend should not be exceeded. Following the recommendations of these authors, square root transformations were applied to each of the serial naming variables, including the articulation and ISI variables that were derived from the serial naming variables. Tabachnick and Fidell (1999) suggest that:

> Unless there are compelling reasons not to transform data it is probably better to do so (p. 78).

The transformations significantly improved the distribution of the scores, but two outlying scores remained. The outlying scores were removed for all analyses involving correlation or regression.

7.4.3 Checking for normality of distribution

Histograms and probability plots were examined to check for normality of distribution. Data from some of the individual phonological awareness tests and from the letter knowledge tests at Time 1 were skewed because of floor and ceiling effects. Although the individual phonological awareness tasks were skewed, the composite phonological awareness scores showed a near normal distribution. Transformations were computed for all variables with non-normal distributions. In most cases the transformations improved the distributions of scores, but the distributions of scores for the individual phonological awareness tasks were not improved by transformations. Therefore, when individual phonological awareness tests were used in subsequent correlational analyses, non-parametric techniques were used. Individual phonological awareness tests were not used in regression analyses.

7.4.4 Checking for multivariate outliers

Multivariate outliers are extreme scores on any two variables. The data was screened for multivariate outliers by computing Mahalanobis distances. This is 'a measure of the distance of a case from the average values of all the independent variables' (Norusis, 1999. p. 397). It was found that, after individual variables had been transformed and remaining univariate outliers removed, there were no multivariate outliers. It was also found that there were no significant multivariate outliers in untransformed data when the extreme univariate outliers associated with the serial naming test had been removed.

7.4.5 Multicollinearity and singularity

Tabachnick and Fidell explain that:

> When variables are multicollinear or singular, they contain redundant information and they are not all needed in the same analysis (p. 84).

This can occur when variables contain information that is partly contained within other variables and is particularly likely to occur when variables are derived from other variables. For example, in the full data set used in this study, the scores from nine phonological tasks were combined into a composite phonological awareness variable and serial naming time was comprised of articulation time and ISI time. Care was taken during analysis to make sure that derived variables were never used in the same analysis as the variables from which they are derived. Indeed, it would not have made logical sense to do so. Examination of correlation matrices using a) all untransformed variables and b) transformed variables and variables that did not need to be transformed showed that there were no correlations higher than the .9 which Tabachnick and Fidell (1999) suggest might lead to problems in statistical analysis.

7.5 Statistical techniques used in data analysis

This section describes the main statistical analyses methods used in the current study.

7.5.1 Correlational Analyses

Correlation is a measure of association between two variables. The strength of the association is reflected in the reported statistic that ranges from –1 to +1. For example a correlation of .6 indicates a stronger association than a correlation of .4. The direction of association is indicated by a plus or minus sign. A positive association indicates that, as the scores on one variable increase, scores on another increase correspondingly. A negative association indicates that as one set of scores increases the other set of scores decreases correspondingly. The significance level of the correlation is determined by consulting significance tables. Significance varies according to the strength of the relationship and the size of the sample. An important assumption of correlational analysis is that the relationships between variables are linear. Linearity was checked visually by looking at scatterplots before correlational analyses.

7.5.2 Test-retest reliability

The issue of internal reliability was addressed in the discussion of the pilot study results in Chapter 5. However, the pilot study did not investigate test-retest reliability as each test was only given once. Test-retest reliability is...

> ...a correlation between scores on two administrations of a test to the same subjects (Vogt, 1999, p.290).

A significant correlation at the $p \leq .05$ level is generally considered to indicate reliability (Cohen et al., 2000). Test-retest reliabilities for tests used in the main study were investigated through correlational analysis. The results are shown in Table 10.

Table 10: Test-retest correlations

Variable	Time 1/Time 2	Time 2/Time 3	Time 1/Time 3
Phonological awareness	.76**	.84**	.66**
Rhyme identification	.59**	.46**	.37*
Letter knowledge	.81**	.73**	.60**
Digit Span	.75**	.79**	.71**
Rate of learning verbal/visual symbol associations	-	-	.41*
Serial Naming	.66**	.60**	.43**
Articulation rate	.44**	.22*	.08
ISI rate	.61**	.56**	.56**

* p < .05 ** p < 01

As expected, correlations were lower between Time 1 and Time 3 when the test-retest interval was twelve months. The skills of phonological awareness, letter knowledge, digit span and ISI rate all showed considerable reliability and stability over time. The lowest correlation (ns: .08) was between Time 1 and Time 3 for articulation rate. The low correlation could have been caused by unreliable measurement, or because the skill itself is variable when measured in children of this age. To check the reliability of measurement, a professional colleague was asked to reanalyze 45 of the children's recorded responses (15 from each time of testing). The responses had been recorded to computer and all had been saved in their original form. Correlations were calculated between the original scores and the reanalysed scores. All of the correlations were greater than $r = .9$ ($p \leq .001$), suggesting that the measurements were reliable.

7.5.3 Regression

Regression analysis is...

> ...a way of explaining or predicting the variability of a dependent variable using information about one or more independent variables (Vogt, 1999 p. 240).

Aron and Aron (1999) make the point that correlations are not always truly predictive of variance in the dependent variable, particularly when several variables are significantly correlated with the dependent variable and with each other. This is because of the probability that...

> ...part of what makes any one predictor variable a successful predictor of the dependent variable overlaps with what makes the other predictor variables successful in predicting the dependent variable (Aron & Aron, 1999: p. 118).

Multiple regression more clearly shows predictive relationships in multivariate analysis because the unique, distinctive contribution of each predictor variable is calculated. The current study used multiple regression to predict the variance in reading ability explained by combinations of independent variables. Velleman (1998) lists the conditions that should be 'approximately true' for multiple regression (p. 300):

- The relationship between the dependent and predictor variables should be linear
- The true residuals should be mutually independent. (This is easily violated by data measured sequentially over time)
- The true residuals should have the same variance for all values of the dependent variable (homoscedasticity)
- The true residuals should have a normal distribution.

In addition to the univariate screening described above, normality, linearity and homoscedasticity of regression models was checked through analysis of residuals as described by Norusis (1999).

7.5.4 Factor Analysis

Factor analysis is a statistical method of determining the degree to which test items are measuring the same construct (Bryman & Cramer, 1997). The current study used ten different tests of phonological awareness. Factor analysis was used to investigate the construct of phonological awareness, aiming to discover whether the ten tests were measuring a unitary construct. Factor analysis is sensitive to outlying cases, non-normality of distribution, and homoscedasticity (Tabachnick & Fidell, 1999). The size of the sample in relation to the number of variables entered into the analysis is also considered to be important, although there is a lack of consensus concerning the appropriate ratio. Comrey and Lee (1992) suggest that data should contain at least 100 cases but a more generally accepted level appears to be between five and ten cases per variable with a minimum of about 50 cases. The process of factor analysis is described by Tabachnick and Fidell (1996):

> Variables that are correlated with one another, but largely independent of other subsets of other variables are combined into factors. Factors are thought to reflect underlying processes that have created the correlations between variables (p. 635).

The factor analysis process extracts consecutive factors, with each consecutive factor accounting for less variance that the previous one. The total variance in a correlation matrix is equal to the number of variables that it contains (Tabachnick & Fidell, 1986). The amount of variance accounted for by each extracted factor is measured according to its eigenvalue. Therefore, the sum of the eigenvalues is equal to the number of factors in the analysis.

After the factor analysis process, the researcher has the responsibility of deciding:

- how many of the identified factors are significant
- what the identified factors represent and how they should be named.

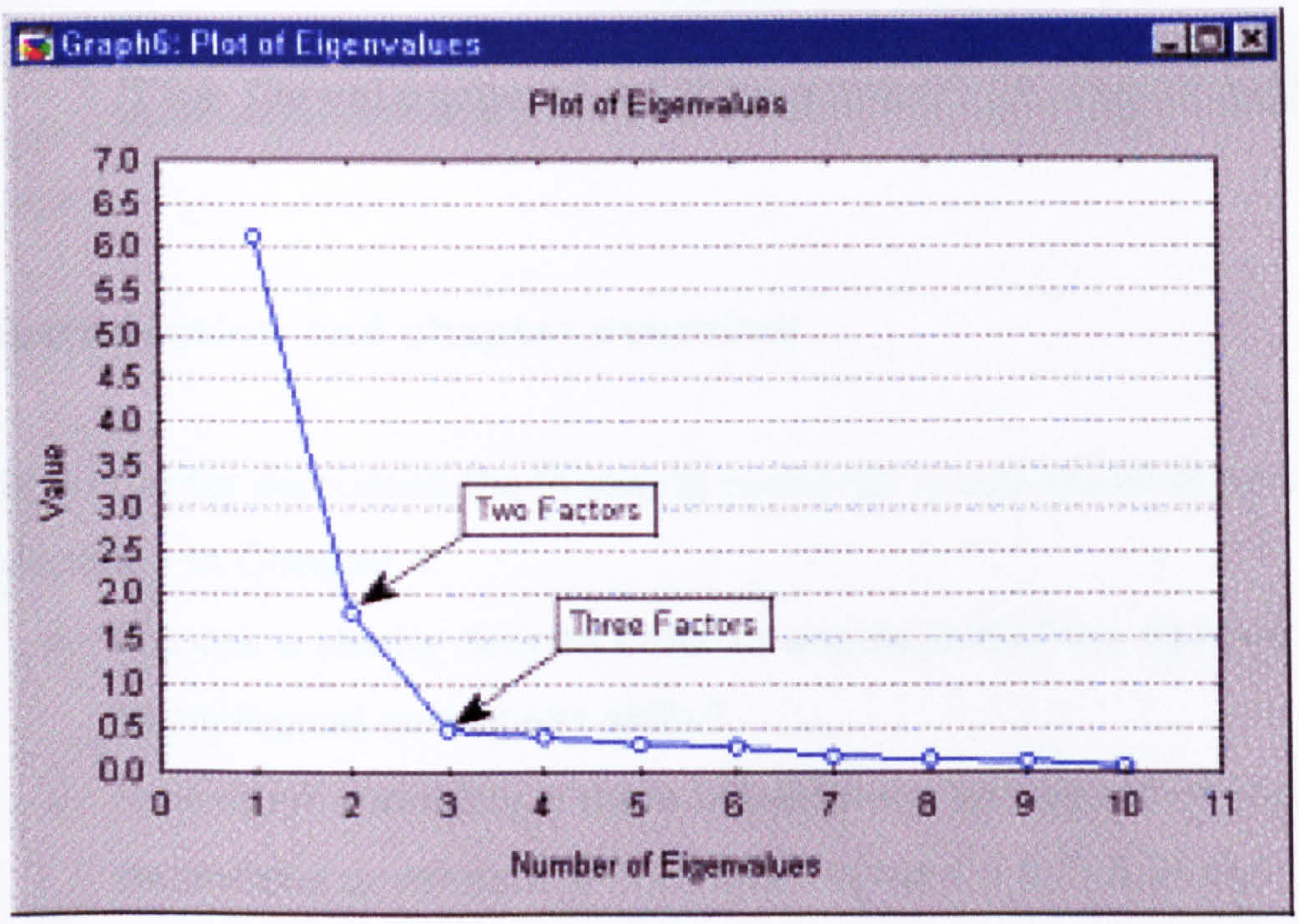
There are two, alternative procedures for deciding how many of the extracted factors are considered to be large enough to be retained.

1. The Kaiser criterion (Kaiser 1974).
2. The scree test (Cattell, 1966).

The Kaiser (1974) criterion suggests retaining only factors with eigenvalues greater than 1. Factors with an eigenvalue of less than 1 are usually not retained because they extract less than the equivalent of one of the individual variables entered (Vogt, 1999).

The scree test (Cattell, 1966) is a graphical process of determining how many factors are retained. The eigenvalues of the consecutively extracted values are plotted on a simple line plot. The graph is thought to resemble geological scree, which is an accumulation of stones or rubble found at the bottom of a steep hill (Vogt, 1999). Cattell (1966) suggests that significant factors can be identified by finding the place where the slope of the graph begins to 'level off'. Only factors above this point are considered to be large enough to be retained. An example of a scree plot is shown in Figure 3.

Figure 3: An example of a scree plot



In the current study, decisions about which factors to retain were made after consideration of both the Kaiser criterion and the scree plots.

7.6 Summary

This chapter has:

- discussed the design of the main study and described how the participants were selected
- discussed the methods used to measure reading ability
- discussed data screening procedures
- described the statistical techniques used in the data analysis.

The following chapters will discuss how the data was used to investigate the research questions that were identified in Chapter 4.

Chapter 8

The Development of Phonological Awareness

Introduction and chapter overview

This chapter discusses the following research questions that were identified in Chapter 4:

- Is there a clearly defined order of acquisition of the various phonological awareness skills?
- How much variability is there in the timing and speed of phonological awareness development in children aged 4.0 to 5.5 years?

The research questions are addressed under the following headings:

- summary of rationale
- summary of methodology
- results
- discussion.

8.1 Summary of Rationale

A plethora of research studies suggest that children who lack phonological awareness are likely to become poor readers (for example, Bradley & Bryant, 1983; Wagner et al., 1994, 1997; Vellutino & Scanlon, 1987). As discussed in Chapter 2, phonological awareness is typically measured at one or more of four linguistic levels (rhyme, syllable, onset-rime and phoneme) and using one or more of three types of task (blending, segmenting, and elision). McBride-Chang (1995) points out that the accumulated research includes phonological awareness tasks at a variety of different levels with experimental control lacking across tasks.

Blachman (1997) suggests that more information is needed about the speed and timing of phonological awareness development in normal populations in order to identify children who are not following normal developmental patterns. The research literature presents a confused picture concerning development of the component skills of phonological awareness in individual children over time (see Chapter 2, section 2.2). The literature is particularly lacking in empirical evidence concerning the developing phonological awareness skills of children aged four to five years. This chapter aims to add to existing knowledge concerning the development of phonological awareness in young children as they progress from being non-readers to readers.

8.2 Summary of Methodology

In the present study, the phonological awareness of 68 children was measured at three equidistant time points over a twelve-month period. All of the children included in the study were aged between 4.0 and 4.5 years when the longitudinal study began. Information from previous research, discussed in Chapter 2, was used to design a range of tests with inbuilt discontinuation criteria so that testing would be wide-ranging, rigorous and appropriate for the age range of participants. Full details of the methodology are given in Chapter 5: section 5.6.1. In summary, nine of the ten tests used to measure phonological awareness tested blending, segmenting and elision at syllable, onset-rime and phoneme levels. These nine tests used consistent methodology in order to achieve experimental control across tasks. The tenth test of phonological awareness was a rhyme identification test. The longitudinal design of the study enabled a picture to emerge of the development of phonological awareness over time in children aged 4.0 to 5.5 years.

8.3 Results

The results of the study are reported under the following headings:

- descriptive statistics
- the order of facility of phonological awareness skills
- the order of acquisition of phonological awareness skills for faster and slower developing children.

8.3.1 Descriptive statistics

Descriptive statistics for the ten phonological awareness tests, at each time of testing, are contained in Tables 11, 12 and 13.

Table 11: Descriptive statistics for the ten phonological awareness tasks at Time 1

Task	Median	Mean	SD	Min	Max
Rhyme awareness	4.5	5.0	1.7	1	8
Syllable blending	4.5	4.2	2.2	0	6
Syllable segmenting	5.5	4.5	2.2	0	6
Syllable elision	0	1.2	1.9	0	6
Onset-rime blending	2	2.3	2.1	0	6
Onset-rime segmenting	0	1.4	2.2	0	6
Onset-rime elision	0	.5	1.3	0	0
Phoneme blending	0	1.1	1.7	0	5
Phoneme segmenting	0	.18	.85	0	5
Phoneme elision	0	0	0	0	0

It can be seen that, at Time 1, the scores of many children were close to floor level on tests of syllable segmenting and on all onset-rime and phoneme awareness tests. However, it is also noteworthy that some children scored close to ceiling on most tests except onset-rime elision and phoneme elision. No child scored at all on either onset-rime or phoneme elision at Time 1.

Table12: Descriptive statistics for the ten phonological awareness tasks at Time 2

Task	Median	Mean	SD	Min	Max
Rhyme awareness	6	5.8	1.9	2	8
Syllable blending	6	5.7	.9	0	6
Syllable segmenting	6	5.7	1.0	0	6
Syllable elision	3	2.6	2.3	0	6
Onset-rime blending	4.5	4.1	1.9	0	6
Onset-rime segmenting	3	2.9	2.2	0	6
Onset-rime elision	0	1.6	2.2	0	6
Phoneme blending	2.5	2.7	2.0	0	6
Phoneme segmenting	0	1.2	2.1	0	6
Phoneme elision	0	.78	1.45	0	5

Between Time 1 and Time 2 of testing, most children had improved their performance on all tasks, although mean and median scores on onset-rime elision, phoneme segmenting and phoneme elision suggest that most children are still finding these tests difficult.

Table13: Descriptive statistics for the ten phonological awareness tasks at Time 3

Task	Median	Mean	SD	Min	Max
Rhyme awareness	6	6.2	1.5	2	8
Syllable blending	6	5.9	.4	3	6
Syllable segmenting	6	5.9	.38	3	6
Syllable elision	5.5	4.2	2.3	0	6
Onset-rime blending	6	5.2	1.7	0	6
Onset-rime segmenting	6	5.1	1.8	0	6
Onset-rime elision	4	3.4	2.4	0	6
Phoneme blending	5	4.4	2.1	0	6
Phoneme segmenting	6	4.2	2.4	0	6
Phoneme elision	3	2.6	2.4	0	6

The median and mean scores at Time 3 indicate a continued increase in children's ability to perform all tasks. The results overall indicate that there were considerable floor and ceiling effects but these were not unexpected. In order to fully investigate the development of phonological awareness skills in individual children over time, it was considered important to test a wide range of skills at each time of testing.

The reliability of measurement had been investigated during the second pilot study and was investigated further by calculating the test-retest correlation coefficients for each test. Non-parametric correlations were calculated because several sets of data showed non-normal distributions. The test-retest reliability coefficients are shown in Table14.

Table 14: Test–retest reliability coefficients for each of the phonological awareness tests

Test	Time 1/Time 2 coefficient	Time 2/Time 3 coefficient	Time 1/Time 3 coefficient
Rhyme awareness	.60	.61	.58
Syllable blending	.61	.64	.52
Syllable segmenting	.63	.72	.61
Syllable elision	.63	.62	.54
Onset-rime blending	.73	.65	.55
Onset-rime segmenting	.67	.67	.58
Onset-rime elision	.68	.73	.59
Phoneme blending	.65	.72	.52
Phoneme segmenting	.66	.68	.57
Phoneme elision	-	.56	-

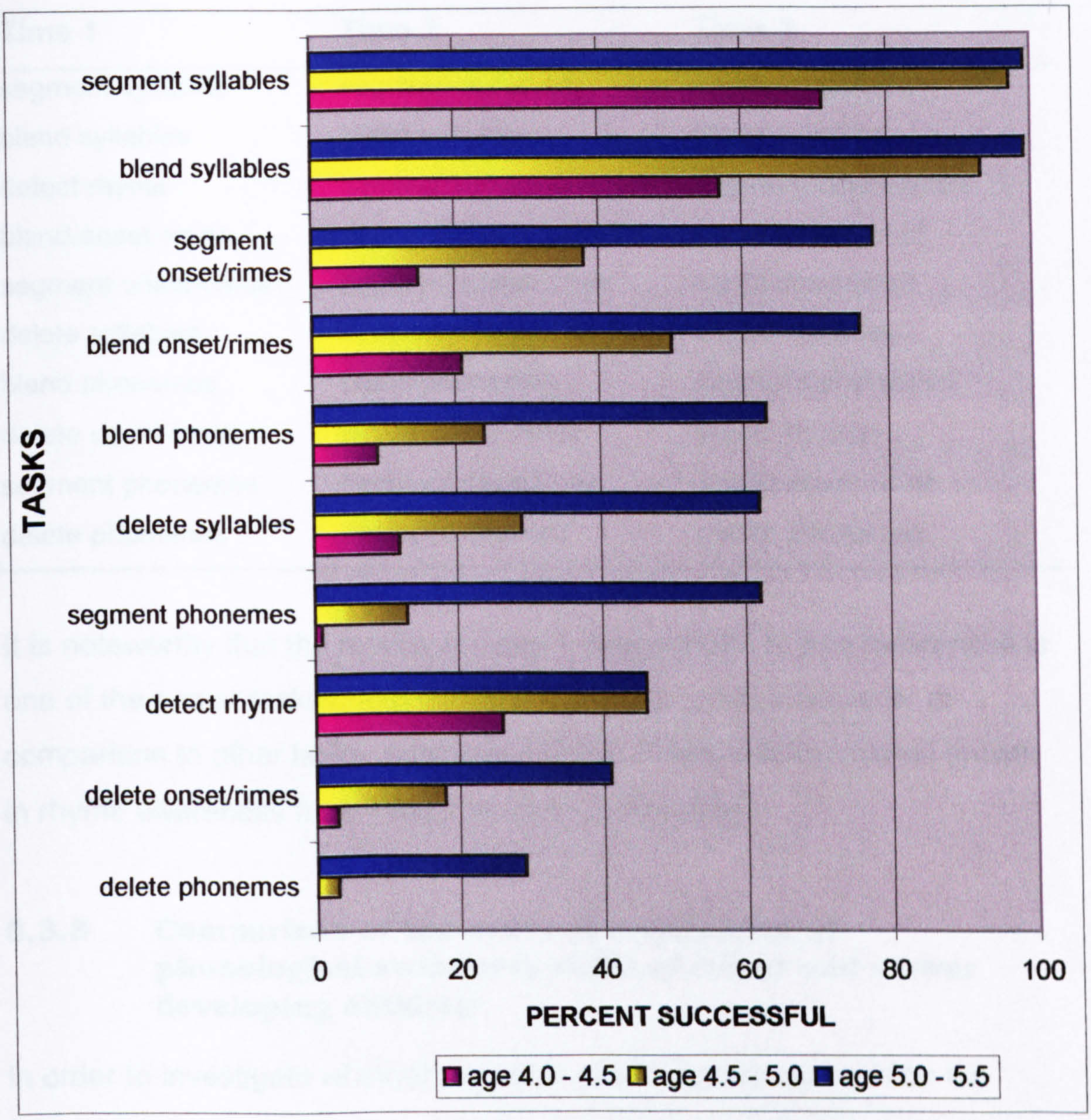
All correlations are significant at the $p \leq .01$ level

The test/re-test coefficients were all significant at the $p \leq .01$ level, suggesting that the tests were reliable measures of children's phonological awareness.

8.3.2 Order of facility of phonological awareness skills

The order of facility of the ten phonological awareness tasks was initially investigated during the pilot study (see Chapter 6). The longitudinal study provided an opportunity to investigate the order of facility of skills more thoroughly and to investigate differences between faster and slower developing children. The order of facility was established by calculating the percentage of children who could successfully perform each task. In this analysis, a 'successful' performance was defined as all, or all but one, test items correct. Figure 4 shows the percentage of children who could successfully perform each task at each time of testing.

Figure 4: **Percentage of children who could successfully perform each of the ten phonological awareness tasks**



The results suggest that children steadily improved their performance on all tasks over the time period but improvement in performance of some tasks was greater than improvement in other tasks. A comparison of the order of facility between the three times of testing is shown in Table 15.

Table 15: **The order of facility of phonological awareness tests at each time of testing**

Time 1	Time 2	Time 3
segment syllables	segment syllables	segment syllables
blend syllables	blend syllables	blend syllables
detect rhyme	blend onset-rimes	segment onset-rimes
blend onset-rimes	detect rhyme	blend onset-rimes
segment onset-rimes	segment onset-rimes	blend phonemes
delete syllables	delete syllables	delete syllables
blend phonemes	blend phonemes	segment phonemes
delete onset-rimes	delete onset-rimes	detect rhyme
segment phonemes	segment phonemes	delete onset-rimes
delete phonemes	delete phonemes	delete phonemes

It is noteworthy that the results at Time 1 suggest that rhyme awareness is one of the easier tasks but by Time 3 it appears to have become, in comparison to other tasks, relatively difficult. There was no overall growth in rhyme awareness from Time 2 to Time 3 of testing.

8.3.3 Comparison of the order of acquisition of phonological awareness skills of faster and slower developing children

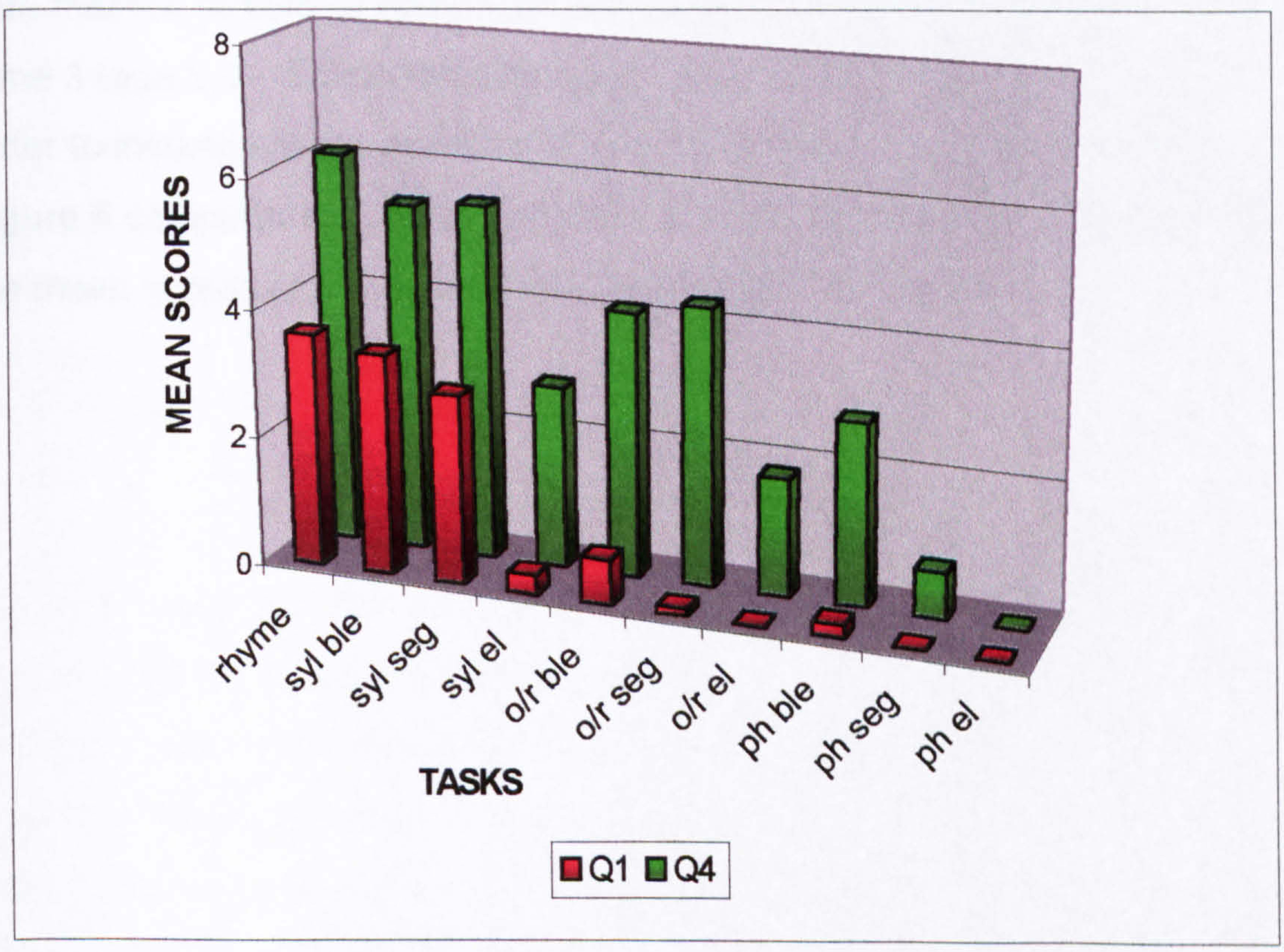
In order to investigate whether the order of acquisition was similar for faster and slower developing children, two subgroups were established through the following process:

- cases were sorted according to children's composite phonological awareness scores at Time 3;
- the lowest and highest quartiles of children were identified;
- the lowest quartile (Q1) comprised the 17 children with the lowest phonological awareness scores and the highest quartile (Q4) comprised the 17 children with the highest phonological awareness scores;

- the mean Time 1 score for the and highest quartile of children, for each of the ten tasks, was calculated;
- the mean Time 1 score for the highest quartile of children, for each of the ten tests, was calculated.

Figure 5 shows the mean Time 1 scores for each task for the lowest and highest quartiles of children (Q1 and Q4). The ceiling score for all tasks except rhyme awareness was six. The ceiling score for rhyme awareness was eight.

Figure 5: **A comparison of the mean scores of the lowest (Q1) and highest (Q4) quartiles of children on the phonological awareness tests at Time 1 (age 4.0 – 4.5)**



Key

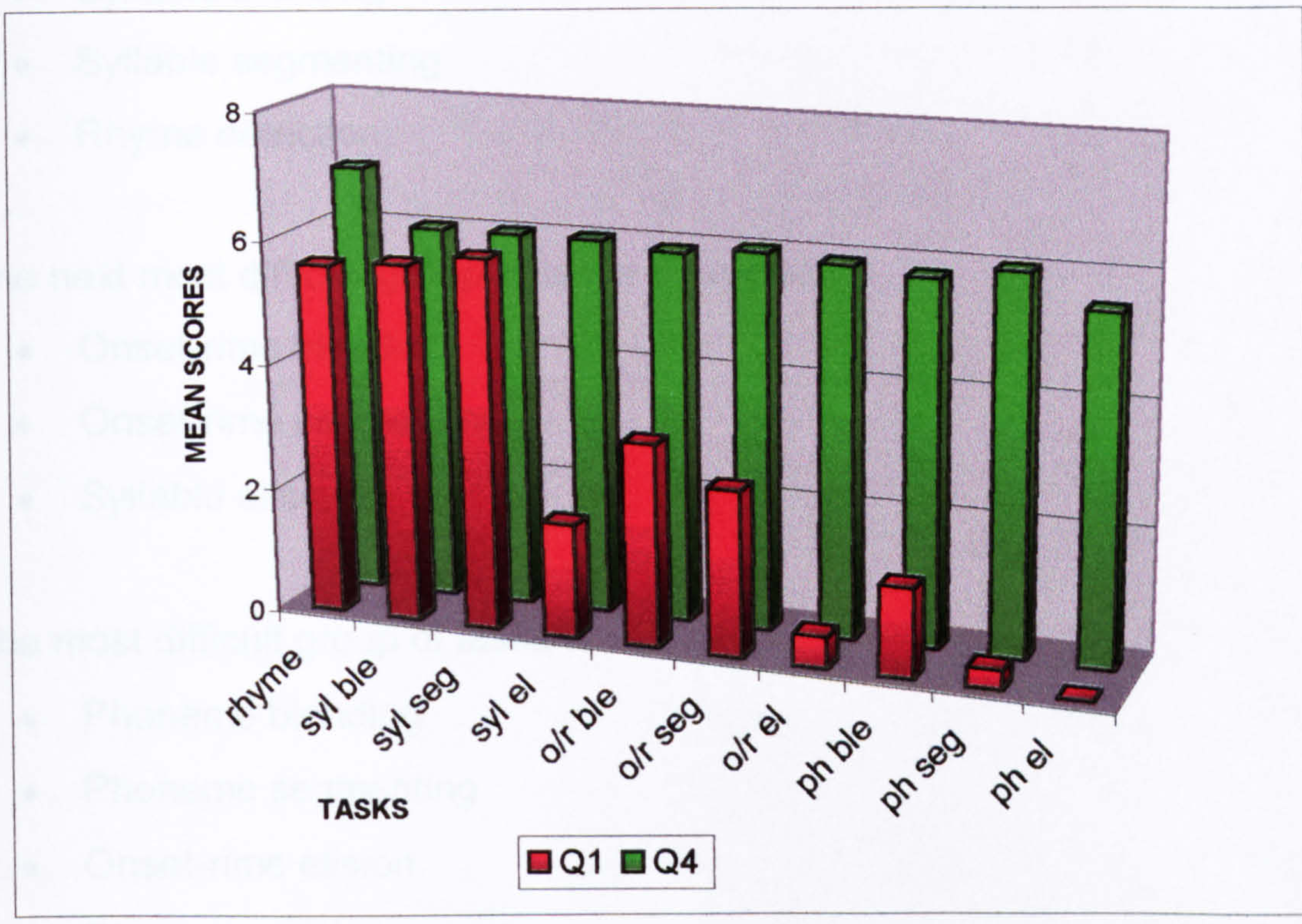
syl ble = syllable blending
syl seg = syllable segmenting
syl el = syllable elision
o/r ble = onset-rime blending
o/r seg = onset-rime segmenting
o/r el = onset-rime elision
ph ble = phoneme blending
ph seg = phoneme segmenting
ph el = phoneme elision

Figure 5 suggests that the lowest quartile of children performed moderately at syllable blending, syllable segmenting and rhyme awareness. However they scored close to floor level in tests of syllable elision and on all onset-rime and phoneme awareness tasks.

The highest quartile of children had already gained a good level of awareness of syllables and rhyme, scoring close to ceiling on these tests. They had moderately good awareness of onset-rimes and of phoneme blending. However they scored close to floor level on tests of phoneme segmenting and phoneme elision.

Bearing in mind that the lowest quartile of children was established according to Time 3 phonological awareness scores, it is interesting to note that the pattern of comparatively poor phonological awareness at Time 3 (age 5.0 – 5.5) is already apparent at Time 1 (age 4.0 to 4.5). In order to investigate the patterns of development for each test further, Figure 6 compares the mean scores of the lowest quartile of children with the mean scores of the highest quartile of children at Time 3.

Figure 6: **A comparison of the mean scores of the lowest and highest quartiles of children on phonological awareness at Time 3 (age 5.0 – 5.5)**



Key

syl ble = syllable blending	o/r ble = onset-rime blending	ph ble = phoneme blending
syl seg = syllable segmenting	o/r seg = onset-rime segmenting	ph seg = phoneme segmenting
syl el = syllable elision	o/r el = onset-rime elision	ph el = phoneme elision

Figure 6 suggests that, at Time 3, the mean scores for the highest quartile of children for all tasks are close to ceiling. The lowest quartile of children nearly matches the performance of the highest quartile of children on syllable blending, syllable segmenting and rhyme awareness. However there appear to be significant differences between the groups on all other tests. In the test of onset-rime elision, and in all phoneme awareness tests, the lowest quartile of children was still scoring close to floor level.

Figures 4 and 5 indicate that, for both subgroups of children, the three easiest tasks are:

- Syllable blending
- Syllable segmenting
- Rhyme detection.

The next most difficult group of tasks comprise:

- Onset-rime blending
- Onset-rime segmenting
- Syllable elision.

The most difficult group of tasks is:

- Phoneme blending
- Phoneme segmenting
- Onset-rime elision
- Phoneme elision.

There are no notable differences between the subgroups in terms of order of acquisition of skills but it is noteworthy that at age 5.0 – 5.5 years, the slower developing children (Quartile 1) have not reached the levels of performance that the faster developing children (Quartile 4) had achieved at age 4.0 – 4.5 years.

8.3.4 Which phonological awareness tasks significantly differentiate slower and faster developing children?

Figures 4 and 5 above suggest that some tasks more clearly differentiate slower developing from faster developing children. For example, it appears from the charts that the syllable blending and segmenting tests are not as effective at differentiating the subgroups as the onset-rime blending or segmenting tests. In order to investigate the effectiveness of the various tasks for differentiating the subgroups further, Mann-Witney U tests were carried out to investigate statistically the between-group differences at Time 1 and Time 3. The Mann-Witney U test is a non-parametric test of 'the statistical significance of differences between two groups' (Vogt, 1999, p. 168). The results of the Mann-Witney U tests using Time 1 and Time 3 data are presented in Table 16 and Table 17 respectively.

Table 16: Comparing the lowest and highest quartiles of children on phonological awareness tests at Time 1

Test	Q1PA (n = 17) M	SD	Q4PA (n = 17) M	SD	Z value	p
Rhyme identification	3.65	0.86	6.06	1.95	-3.77	.000
Syllable blending	3.35	2.34	5.35	1.32	-2.96	.003
Syllable segmenting	2.94	2.61	5.53	1.28	-3.29	.001
Syllable elision	0.29	0.99	2.82	2.16	-3.76	.000
Onset-rime blending	0.71	1.49	4.12	1.58	-4.39	.000
Onset-rime segmenting	0.12	0.49	4.29	2.08	-4.94	.000
Onset-rime elision	0	0	1.82	2.07	-3.63	.000
Phoneme blending	0.24	0 .66	2.76	1.95	-4.17	.000
Phoneme segmenting	0	0	0.71	1.61	-1.79	.074
Phoneme elision	0	0	0	0	-	-

The results suggest that the tests that best differentiated the groups at Time 1 ($p \leq .001$) are:

- rhyme identification
- syllable segmenting and elision
- onset-rime blending, segmenting and elision
- phoneme blending.

The results of the Mann Witney U tests using Time 3 data are presented in Table 17.

Table 17: A comparison of the effectiveness of individual tasks to differentiate phonological awareness subgroups at Time 3

	Q1PA (n = 17)		Q4PA (n = 17)			
Test	M	SD	M	SD	Z value	p
Rhyme identification	5.59	1.66	6.94	1.09	-2.75	.010
Syllable blending	5.71	0.77	6.00	0.00	-1.78	.390
Syllable segmenting	5.94	0.24	6.00	0.00	-1.00	.317
Syllable elision	1.82	2.30	6.00	0.00	-4.62	.000
Onset-rime blending	3.18	2.35	5.88	0.49	-4.06	.000
Onset-rime segmenting	2.65	2.40	6.00	0.00	-4.61	.000
Onset-rime elision	0.53	1.01	5.88	0.33	-5.34	.000
Phoneme blending	1.41	1.77	5.82	0.39	-4.87	.000
Phoneme segmenting	0.29	0.69	6.00	0.00	-5.54	.000
Phoneme elision	0	0	5.47	0.80	-5.42	.000

At Time 3, the tests that best differentiate the subgroups ($p \leq .001$) are:

- syllable elision
- onset-rime blending, segmenting and elision
- phoneme segmenting, phoneme elision.

8.4 Discussion

The results suggest that the order of acquisition of the skills needed to perform phonological awareness tasks is quite clearly defined and is consistent for both faster and slower developing children. However, there appears to be considerable variability in the speed at which the skills develop in individual children. Three issues of particular relevance to the current study are discussed below. These are:

- the place of rhyme awareness in the order of acquisition of skills;
- the place of onset-rime awareness in the hierarchy of difficulty;
- the issue of developmental lag (Francis, Shaywitz, Stuebing, Shaywitz & Fletcher, 1996).

8.4.1 Development of rhyme awareness

The results presented in section 8.2 suggest that rhyme identification, like syllable blending and syllable segmenting, is an early developing skill for the majority of children. The results also suggest, however, that the skill of rhyme identification develops less rapidly than other phonological awareness skills, such as onset-rime awareness. The reason for the apparent lack of progress in rhyme awareness could lie in the design of the rhyme awareness task.

The design of the rhyme awareness test has previously been described and is summarised here. There were four practice items and eight test items. Each child was shown a series of pairs of pictured objects. As the child looked at the pictures, the tester spoke the two associated words (for example, cat, hat). The child was asked to say whether or not the words rhymed. The practice items aimed to clarify the concept of rhyme by demonstrating to children that the words that rhymed had 'the same sounds in the middle and at the end' whereas the non-rhyming pairs did not 'have the same sounds in the middle and at the end'. During the practice items, children's incorrect responses were corrected and their attention was drawn to the shared sounds, or lack of shared sounds, in the middle and at the ends of the words.

The test was designed to incorporate developing difficulty with the earlier items being easier than the later items. The identification of non-rhyming words was made more difficult by using pairs of words that shared initial and middle sounds, although not final sounds. For example, an easier test item asked children whether 'dig' and 'bag' rhymed. A more difficult test item asked children whether 'pen' and 'peg' rhymed. The first pair of non-rhyming words has only one phoneme in common but the second pair of non-rhyming words has two phonemes in common. Although the second pair of words does not rhyme, the words are 'globally similar'. Following the second pilot study, the test items had been ordered by facility after calculating which test items had been answered correctly most frequently. In the longitudinal study, all of the children attempted all of the test items.

The results suggest that the majority of children can answer the easier test items but that they find it harder to give correct responses to test items that require a more explicit level of analysis. The increased levels of difficulty as test items changed from testing global rhyme awareness to more explicit rhyme awareness could explain why the mean score at Time 1 was 5.0 (from a maximum of eight items) but moved up to only a mean score of 6.2 twelve months later. Only fifteen children scored at ceiling.

The results converge with previous research suggesting that rhyme awareness develops early (Bradley & Bryant, 1983; Goswami & Bryant, 1990) but also provide support for the suggestion put forward by Cardoso-Martins (1994) that 'the ability to detect rhyme may be best defined in terms of a judgement of global phonological similarity' (p. 39). It would appear that where 'global similarity' occurs in the absence of rhyme, many children experience confusion.

8.4.2 The place of onset-rime awareness in the hierarchy of difficulty

Several researchers, such as Adams (1990) and Treiman and Zukowski (1991), suggest that children refine their awareness of word segments of gradually decreasing length as they get older and start to develop reading skills. This theory is supported by the results of a study by Wood and Terrell (1998) who report that onset-rime awareness develops later than syllable awareness and earlier than phoneme awareness. The results of the current study provide support for Treiman and Zukowski (1991) and Wood and Terrell (1998) that, as children get older and start to learn to read, they gradually gain awareness of word segments of decreasing length. For the whole group and for the lowest quartile and highest quartile subgroups, the skills of onset-rime blending, segmenting and elision were acquired after the corresponding skills at syllable level and before the corresponding skills at phoneme level.

The results of the current study are contradictory to the finding by Seymour and Evans (1994) that children aged from five to seven years generally find phoneme segmentation to be easier than onset-rime segmentation. It has been suggested by Goswami (1999) that the instructions used in the Seymour and Evans (1994) study caused some confusion to the children, who were asked to 'speak like robots' and segment words and nonwords into two parts. The statistics reported by Seymour and Evans (1994) indicate that 28% of the responses of the five-year-old children and 42% of the responses of the six-year-old children were incorrect even though they had followed the instructions and segmented the word into two parts. Commenting on their results, Seymour and Evans (1994) note that:

> These analyses suggest that the apparent inferiority of onset-rime division reflects a difference in the scope for production of alternative segmentations, which is high for two parts but more constrained for three parts (p. 236).

In the current study, it was also noted that some children had a tendency to segment words at an 'incorrect' boundary. However, the use of the biscuit as a visual aid directed children's attention to the fact that the onset was a small part at the beginning of the word. Furthermore, the current study did not include test items with initial phoneme clusters. Both of these aspects of the methodology may have minimised the opportunity for error cause by insecure understanding of the requirements of the test.

Nation and Hulme (1997), reporting on the segmenting ability of children aged five to nine years, state that there was no correlation between the ability to segment onsets from rimes and age. However, they suggest that at both age five and age seven, the children found onset-rime segmentation easier than phoneme segmentation. The authors note that the procedures for giving the tests are 'based on those adopted by Seymour and Evans (1994)' (p. 159). It is interesting therefore that different results emerged. Although Nation and Hulme report that 'all age groups performed onset-rime segmentation at a similar level' (p.155), it is noteworthy that there was a slight upward trend and that it was only the nine-year-old cohort that found phoneme segmentation to be easier than onset-rime segmentation.

8.4.3 Developmental lag and developmental deficit

Using individual growth curve analysis, Francis and his colleagues (Francis et al., 1996) investigated developmental lag versus developmental deficit in reading in a large-scale, longitudinal study with 403 children aged six to sixteen. These authors compared the relative progress of reading disabled children and normally developing readers. They concluded that the reading disabled group did not reach the same plateau of skill as the normal reader group, even though they continued to make progress for as long as the normal reader group. On the basis of these finding they suggested that

> The developmental course of reading skills in children with reading disability is best characterised by deficit as opposed to lag models (p. 3).

The issue of developmental lag versus developmental deficit is pertinent to the current study and to the investigation of differences in the timing and speed of individual children's phonological awareness development. The results of the current study suggest that children's phonological awareness steadily improves between the ages of 4.0 and 4.5 years. However, it can be seen from Figure 4 and Figure 5 in this chapter that the lowest quartile of children at Time 3 does not reached the level of phonological awareness of the highest quartile of children at Time 1. In other words, the slower developing children are already lagging more than twelve months behind their faster developing peers by the age of five and a half years.

Although the lowest quartile of children demonstrate considerable developmental lag, they continue to make steady progress in rhyme awareness, syllable awareness and onset-rime awareness over the time of the investigation. The limited time span of the study does not make it possible to discover at what level their skills plateau: i.e. cease to develop further. A fuller investigation of development lag versus developmental deficit in phonological awareness would be an interesting area for future research. In the meantime, the finding that such a large developmental lag exists at such an early age is an interesting contribution to knowledge about the timing and speed of development of phonological awareness in young children. It is current educational practice to wait for children to develop reading delay before they are considered for learning support or to be included in intervention programmes. Increased knowledge about normal and delayed development of phonological awareness might assist the identification of children who need support at a younger age.

8.5 Summary

- The results of the current study suggest that the development of phonological awareness follows a generally consistent pattern regardless of the speed of its development in individual children. The results support the theory put forward by Adams (1990) and Treiman and Zukowski (1991) that children gain a gradually more refined awareness of word segments of decreasing length.

- Global awareness of rhyme is apparent in children below 4.5 years but, where global similarity appears in the absence of rhyme, children show confusion (Cardoso-Martins, 1994).

- Developmental lag (Francis et al., 1996) in phonological awareness can be identified in children as young as four and a half years of age. By the age of five and a half years, some children are as much as twelve months behind their faster developing peers.

Chapter 9

The Conceptual Structure of Phonological Awareness

Introduction and chapter overview

The previous chapter discussed the development of phonological awareness in children aged 4.0 to 5.5 years and suggested that children follow similar developmental patterns regardless of their speed of development. The current chapter discusses the following question that was identified in Chapter 4.

- Is phonological awareness a unitary construct?

This chapter reports and discusses the data under the following headings:

- summary of rationale
- summary of methodology
- results
- discussion.

9.1 Summary of rationale

Chapter 2, section 2.3, discussed several studies that have investigated the structure of the phonological awareness construct. It was noted that none of the studies had included tests at all linguistic levels (rhyme, syllable, onset-rime, and phoneme) in the same investigation and only one study (Muter et al., 1997) had included children as young as four years of age. Understanding of the conceptual structure of phonological awareness is relevant to educational practice. If phonological awareness is found to be a developmental, unitary construct, as suggested by Schatschneider and his colleagues (Schatschneider et al., 1999) it might be beneficial to explicitly develop young children's early phonological awareness skills (such as rhyme and syllable awareness) in order to facilitate later developing phonological awareness skills, such as phoneme awareness.

9.2 Summary of methodology

As previously described in Chapter 5, ten tests of phonological awareness were used in the current study. The three linguistic levels of syllable, onset-rime and phoneme were measured with three types of task: blending, segmenting and elision. Rhyme awareness was measured using a rhyme identification task.

The statistical technique of factor analysis was used to investigate the phonological awareness construct (see Chapter 7). Factor analysis investigates patterns in correlations between several variables in order to determine the extent to which the variables are measuring the same construct (Bryman & Cramer, 1997). In the current study, a series of factor analyses was carried out to investigate whether the tasks at each of the linguistic levels (rhyme, syllable, onset-rime and phoneme) and at each level of difficulty (blending, segmenting and elision) combined to form a single unitary construct, or separated into two or more independent factors. A similar analysis was carried out by Stahl and Murray (1994) but their study focused on onset-rime and phoneme awareness and the level of complexity was determined by the number of phonemes in the word. The longitudinal nature of the current study enabled factor analyses to be carried out for Time 1 and Time 3 data, so that results at different stages of children's development could be compared.

In order to carry out the factor analyses, the original data was used to derive twelve new variables. Table 18 shows how the derived variables were calculated.

Table 18: **The derived variables for the principal components analysis**

New Variable	Derived from
Syllable awareness at Time 1	The Time 1 variables of syllable blending, syllable segmenting and syllable elision
Syllable awareness at Time 3	The Time 3 variables of syllable blending, syllable segmenting and syllable elision
Onset-rime awareness at Time 1	The Time 1 variables of onset-rime blending, onset-rime segmenting and onset-rime elision
Onset-rime awareness at Time 3	The Time 3 variables of onset-rime blending, onset-rime segmenting and onset-rime elision
Phoneme awareness at Time 1	The Time 1 variables of phoneme blending, phoneme segmenting and phoneme elision
Phoneme awareness at Time 3	The Time 3 variables of phoneme blending, phoneme segmenting and phoneme elision
Blending at Time 1	The Time 1 variables of syllable blending, onset-rime blending and phoneme blending
Blending at Time 3	The Time 3 variables of syllable blending, onset-rime blending and phoneme blending
Segmenting at Time 1	The Time 1 variables of syllable segmenting, onset-rime segmenting and phoneme segmenting
Segmenting at Time 3	The Time 3 variables of syllable segmenting, onset-rime segmenting and phoneme segmenting
Elision at Time 1	The Time 1 variables of syllable elision, onset-rime elision and phoneme elision
Elision at Time 3	The Time 3 variables of syllable elision, onset-rime elision and phoneme elision

Using the twelve new variables, plus the existing rhyme identification variable, four factor analyses were carried out. Table 19 shows the derived variables that were entered into each analysis.

Table 19: **The variables that were entered into each of the four principal components analyses**

Factor analysis 1	Rhyme awareness, syllable awareness, onset-rime awareness and phoneme awareness at Time 1
Factor analysis 2	Rhyme awareness, syllable awareness, onset-rime awareness and phoneme awareness at Time 3
Factor analysis 3	Blending, segmenting and elision at Time 1
Factor analysis 4	Blending, segmenting and elision at Time 3

The statistical technique of factor analysis returns four important measurements.

1. The number of factors that emerge.
2. The eigenvalues of the factors that emerge.
3. The loading weight of each variable on the emerging factors.
4. The amount of variance explained by the emerging factors.

The significance of each of these measurements has previously been described in Chapter 7, section 7.5.4.

9.3 Results

Table 20 shows the results of the first two factor analyses. In each analysis only one factor emerged with an eigenvalue greater than 1, which is the level at which factors are considered to demonstrate statistical significance (Vogt, 1999). The lower part of the table shows the eigenvalue of the emerging factor and the amount of variance accounted for in the analysis. The top part of the table shows the loading of each test on the factor that emerged. According to Vogt (1999), 'the higher the loading, the closer the association of the item with the group of items that make up the factor' (p. 109).

Table 20: **The results of factor analyses at Time 1 and Time 3. Variables were entered for each of the four linguistic levels: rhyme, syllable, onset-rime and phoneme**

Variables	Time 1	Time 3
	Factor loadings	
rhyme awareness	.46	.44
syllable awareness	.65	.64
onset-rime awareness	.82	.85
phoneme awareness	.62	.86
Variance accounted for	64%	65%
Eigenvalue	2.6	2.6

The results suggest that, at both Time 1 and Time 3, the four linguistic levels of phonological awareness form a unitary construct. It is noteworthy that, at Time 1, the strongest element of the factor is onset-rime awareness and that, at Time 3, the strongest elements of the factor are onset-rime and phoneme awareness.

Table 21 shows the results of the second two factor analyses. The results are presented in the same form as the previous table, but in these analyses the variables that are entered are for the tasks of blending, segmenting and elision. As in the previous two analyses, it can be seen that only one factor emerged with an eigenvalue greater than 1.

Table 21: **The results of factor analyses at Time 1 and Time 3. Variables were entered for each of the three types of task: blending, segmenting and elision**

Variables	Time 1	Time 3
	Factor Loadings	
Blending	.68	.87
Segmenting	.72	.89
Elision	.62	.75
Percentage of variance	67%	83%
Eigenvalue	2.0	2.5

The results presented in Table 21 suggest that, at Time 1, the segmenting tasks align most strongly with the emerging factor. At Time 3, both blending and segmenting tasks align strongly.

The results suggest that, whether variables were grouped by linguistic level or by task, phonological awareness emerges as a unitary construct. The scree plots (Cattell, 1966) associated with each of the four analyses are shown in Appendix H.

9.4 Discussion

The results support the conclusions of Stanovich and his colleagues (Stanovich et al., 1984) and Stahl and Murray (1994) that phonological awareness is a unitary construct. There is no support for the finding by Wagner and his colleagues (Wagner et al., 1993) that blending and segmenting are separate factors. Bearing in mind that both Wagner and his colleagues (Wagner et al., 1993) and Schatschneider and his colleagues (Schatschneider et al. 1999) found the two emerging factors of blending and segmenting to be highly correlated, it is possible that the number of emerging factors is determined by comparatively minor variations in the correlations between the variables.

The results provide support for the theory of Schatschneider and his colleagues (Schatschneider et al., 1999) that phonological awareness is best regarded as a developmental, unitary construct. In the current analyses, early-acquired tasks such as rhyme and syllable awareness align more weakly with the overall construct. It is possible that if measurement of phonological awareness took place in children aged three-to four years, rhyme and syllable awareness would be appropriate tests to use and would align more strongly with the phonological awareness construct. An interesting focus for future research would be an investigation of the phonological awareness construct in younger children.

9.5 Summary

- Principle components analysis suggests that phonological awareness is a unitary construct regardless of whether the data is analysed by linguistic level or type of task. This finding converges with results reported by Stahl and Murray (1994) and Stanovich et al. (1984).

- The results of the current study suggest that, at Time 1, the linguistic level of onset-rime aligns more strongly with the phonological awareness construct than the other three linguistic levels. At Time 3, the linguistic levels of onset-rime and phoneme align more strongly with the phonological awareness construct than the linguistic levels of rhyme and syllable awareness. At both Time 1 and Time 3, the task levels of blending and segmenting align more strongly with the phonological awareness construct than elision, but the alignment is stronger at Time 3 than at Time 1. Overall, the results support the theory put forward by Schatschneider and his colleagues (Schatschneider et al., 1999) that the various phonological awareness tasks are differentially sensitive measures of a developmental but unitary construct.

Chapter 10

The Relationship Between Phonological Awareness And Word-Level Reading Ability

Introduction and chapter overview

Results discussed in the previous two chapters suggest that the various linguistic levels and types of task that are frequently used to measure phonological awareness combine to form a unitary, developmental construct. The current chapter presents results and discussion relating to the following research question that was identified in Chapter 4.

- To what extent are the various linguistic and task levels of phonological awareness associated with word-level reading ability at age 5.0 to 5.5 years?

The chapter addresses the research question under the following headings:

- summary of rationale
- summary of methodology
- results
- discussion

10.1 Summary of rationale

As discussed in Chapter 2, research over the past 20 years suggests that phonological awareness is significantly associated with reading ability (for example, Adams, 1990; Brady & Shankweiler, 1991; Wagner et al., 1997) but the relationship between reading and phonological awareness skills at different linguistic levels is still unclear (Hatcher & Hulme, 1999). It could be argued that one of the principal reasons for this lack of clarity is unspecific definitions of 'phonological awareness'. The current study aims to add to existing knowledge concerning the relationship between reading ability and specific phonological awareness skills by investigating developing relationships in children aged 4.0 to 5.5 years.

Chapter 2 discussed a second aspect of the relationship between phonological awareness and reading that is debated in the research literature: the direction or cause of any relationship between phonological awareness and reading ability. Four theories have been considered:

- that good phonological awareness is predictive of successful reading (for example, Lundberg, Frost & Petersen, 1988)
- that successful reading is predictive of good phonological awareness (for example, Scholes, 1998)
- that the relationship between phonological awareness and reading ability is reciprocal (for example, Share & Stanovich, 1995)
- that both skills depend on the quality of underlying phonological representations held in lexical memory (for example, Elbro et al., 1998).

The current study argues that phonological awareness is a unitary, developmental construct. Therefore, a clear understanding of the relationship between phonological awareness and reading is unlikely to emerge until there is a refined and shared understanding of the relationship between the component phonological awareness skills with both prospective and concurrent reading. For this reason, the current study investigates the developing relationship between phonological awareness and reading ability in individual children at pre-literate (Time 1) through to early-literate (Time 3) stages of their development.

The definition of reading ability used in the present study is word-level reading ability. This is considered to be the most appropriate measure of reading to use with children aged 5.0 to 5.5 years and has theoretical validity in the research literature. Torgesen and Wagner (1998) comment that:

> The first breakthrough in the search for the primary causes of reading disabilities came with the recognition that the most severe reading problems of children with reading disabilities lie at the word, rather than the text, level of processing (p. 221).

10.2 Summary of methodology

The design and methodology associated with the tests of phonological awareness used in the current study were described in Chapter 5. In summary, there were ten tests of phonological awareness comprising blending, segmenting and elision at the linguistic levels of syllable, onset-rime and phoneme and a test of rhyme detection. In order to maximize experimental control across tasks, which has been identified as lacking in many studies (McBride Chang, 1995), tests of blending, segmenting and elision at each of the linguistic levels of syllable, onset-rime and phoneme were designed to be of consistent methodology, with only the linguistic level being varied.

The design and methodology associated with the test of reading ability used in the current study was discussed in Chapter 7. In summary, the test comprised five subtests, each of ten words or nonwords. The reading test was given at Time 3 of testing when the children were aged 5.0 to 5.5 years. No discontinuation criteria were used: all children were encouraged to attempt to read every word.

10.3 Results

The data was initially analysed by calculating correlations and then investigated further through graphical representations. The statistical technique of multiple regression was considered but rejected because of floor and ceiling effects in the data from the ten phonological awareness tests. The results of the study are reported under the following headings:

- descriptive statistics
- the relationship between pre-literate (Time 1) phonological awareness skills and subsequent reading ability
- the relationship between early-literate (Time 3) phonological awareness skills and concurrent reading ability
- a comparison of test performance for below average and above average readers.

10.3.1 Descriptive statistics

Descriptive statistics for the reading test are shown in Table 22.

Table 22: Descriptive statistics for the reading test given at Time 3

	Median	M	SD	Min	Max
Test of word-level reading	14	18.1	8.3	0	50

A square-root transformation of the composite reading scores was successful in producing normally distributed results. Descriptive statistics for the tests of phonological awareness were presented in Chapter 8, section 8.3.1.

10.3.2 The longitudinal relationship between pre-literate (Time 1) phonological awareness skills and subsequent reading ability

The relationship between reading ability and each of the ten tests of phonological awareness was investigated through correlational analyses. Non-parametric correlations were calculated because of the non-normal distributions in the phonological awareness test data. Non-parametric statistics use rank-order transformations and are therefore more suited to data with non-normal distributions. Aron and Aron (1999) comment that rank-order transformations 'have the effect of spreading the scores out evenly' (p. 470). The results of the correlations are presented in Table 23.

Table 23: Correlations between pre-literate phonological awareness (tested at Time 1: children aged 4.0 to 4.5 years) and subsequent reading ability

Test	Correlation with subsequent reading ability
onset-rime segmenting	.53**
onset-rime blending	.49**
onset-rime elision	.45**
syllable segmenting	.44**
rhyme detection	.44**
syllable elision	.37**
phoneme blending	.35**
phoneme segmenting	.17
syllable blending	.15
phoneme elision	No child scored on this test

* p ≤ .05 **p ≤ 01

The results presented in Table 23 suggest that the pre-literate phonological awareness tasks that significantly correlate with subsequent reading ability ($p \leq .01$) are:

- onset-rime segmenting, blending and elision
- syllable segmenting and elision
- rhyme detection
- phoneme blending.

The linguistic level that appears to have the strongest relationship with subsequent reading ability is onset-rime awareness, demonstrated by the ability to blend, segment and delete onsets and rimes. It is noteworthy that phoneme segmenting and phoneme elision are not significantly associated with subsequent reading ability.

10.3.3 The relationship between phonological awareness skills (Time 3) and concurrent reading ability

Table 24 reports the non-parametric correlations between reading ability and the ten tests of phonological awareness. The results presented in Table 24 suggest that the phonological awareness tasks that significantly correlate with concurrent reading ability in children aged 5.0 to 5.5 years are:

- phoneme elision, blending and segmenting
- onset-rime elision and segmenting
- syllable elision.

The linguistic level that appears to have the strongest relationship with concurrent reading ability is phoneme awareness, demonstrated by the ability to blend, segment and delete phonemes.

Table 24: **Correlations between phonological awareness (tested at Time 3: children aged 5.0 to 5.5 years) and concurrent reading ability**

Test	Correlation with concurrent reading ability
phoneme elision	.75**
phoneme blending	.68**
phoneme segmenting	.56**
onset-rime elision	.53**
onset-rime segmenting	.47**
syllable elision	.47**
rhyme detection	.33*
onset-rime blending	.29*
syllable blending	.15
syllable segmenting	.14

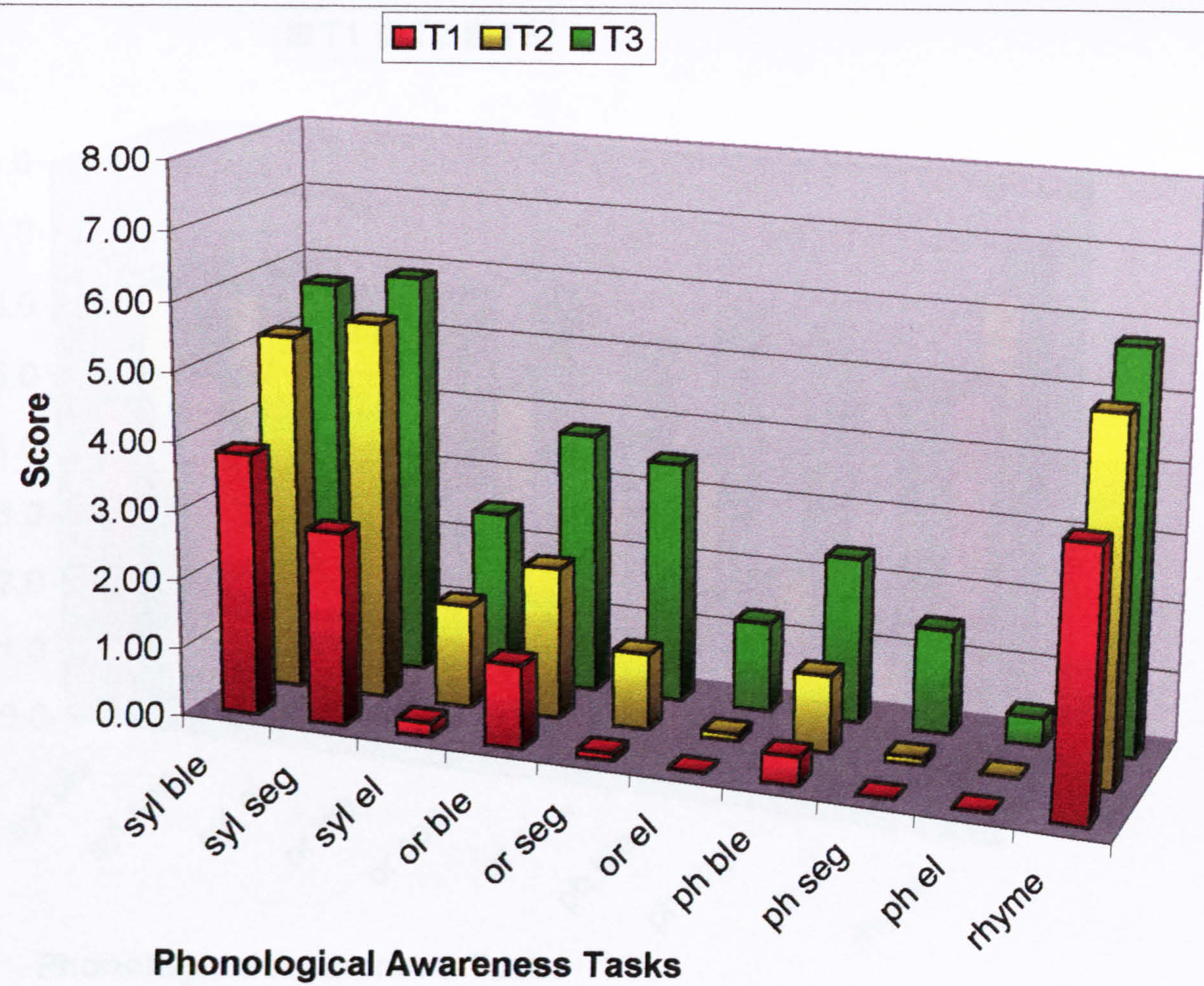
* $p < .05$ **$p < 01$

10.3.4 A comparison of phonological awareness task performance for above average and below average readers

A further analysis of the data investigated the differences in performance of the lowest and highest quartiles of readers. The quartiles were established by ordering the reading scores of the children at Time 3 and forming subsets of children based on the highest and lowest reading scores. There were seventeen children in each subset. The reading scores of the lowest quartile (Q1) ranged from 0 to 4 and the reading scores of the highest quartile (Q4) ranged from 35 – 50.

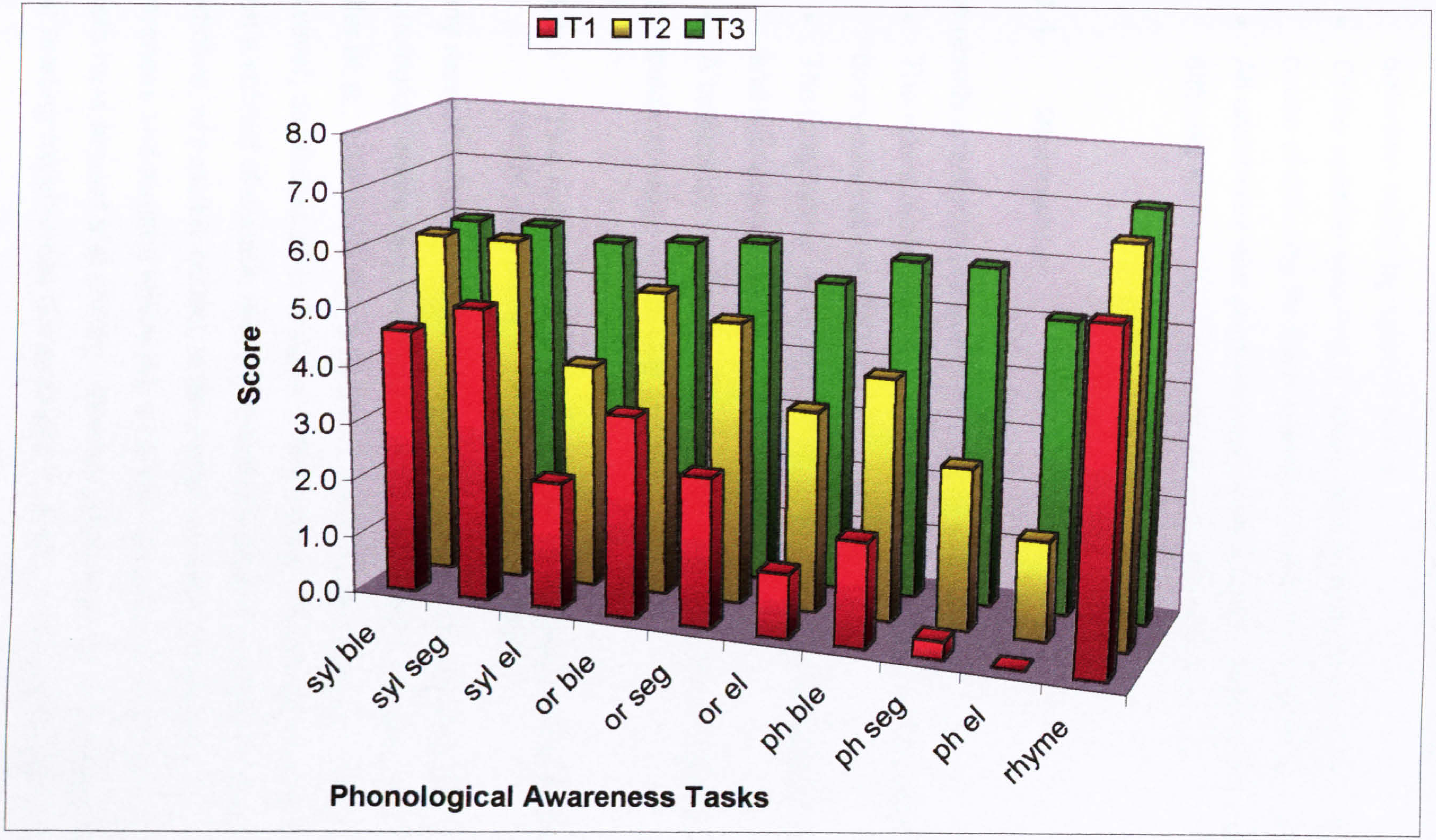
Figure 7 shows the performance of the lowest quartile of readers on each of the phonological awareness tests at each time of testing. Figure 8 shows the performance of the highest quartile of readers on each of the phonological awareness tests at each time of testing.

Figure 7: Scores on phonological awareness tests for the lowest quartile of readers at each time of testing



Key: syl = syllable; or = onset-rime; ph = phoneme; ble = blending; seg = segmenting; el = elision

Figure 8 : **Scores on phonological awareness tasks for the highest quartile of readers at each time of testing**



Key: **syl = syllable; or = onset-rime; ph = phoneme; ble = blending; seg = segmenting; el = elision**

Visual analysis of Figure 7 and Figure 8 suggests that:

- Both higher and lower quartile readers made steady progress in rhyme detection and all children developed similar levels of rhyme detection ability by age 5.0 to 5.5
- Of the syllable awareness tasks, only syllable elision was still a cause of difficulty for lower quartile children by age 5.0 to 5.5 years
- All onset-rime and phoneme awareness tasks remained a cause of difficulty for the lower quartile readers at age 5.0 to 5.5.

10.4 Discussion

The results are discussed under the following headings:

- The relationship between phonological awareness skills and concurrent reading ability
- The longitudinal relationship between phonological awareness skills and subsequent reading ability
- A comparison of the developing phonological awareness skills of below average and above average readers.

10.4.1 The relationship between phonological awareness skills and concurrent reading ability

Many researchers have reported significant associations between phonological awareness and reading ability (Bradley & Bryant, 1983; Muter et al., 1997; Vellutino & Scanlon, 1987; Wagner et al., 1997). However, as discussed in Chapter 2, the nature of the relationship has been a subject of debate. Many researchers have argued that there is a predictive, or possibly causal, relationship between phonological awareness and reading ability (for example, Wagner et al., 1997) whilst others have argued that children develop phonological awareness through their reading experiences (for example, Scholes, 1998). It has also been suggested that children use 'pictured spelling' as a means of performing phonological awareness tasks (Stuart, 1990).

The current study differed from much previous research in two respects:

- the study set out to investigate relationships between reading ability and phonological awareness at four linguistic levels
- the study set out to investigate longitudinal relationships between phonological awareness and reading ability as they developed in individual children between the ages of 4.0 to 5.5 years.

In line with much previous research, the results of the current study suggest that there are significant relationships ($p \leq .01$) between phonological awareness and concurrent reading ability in children aged 5.0 to 5.5 years. Phonological awareness at the linguistic level of phonemes appears to be most strongly associated with concurrent reading ability, but onset-rime awareness syllable elision and rhyme detection also show a predictive relationship with concurrent reading. It is noteworthy that the significant relationships were found in relation to tasks at each linguistic level. Previous research has tended to focus on relationships between phoneme awareness and reading, possibly because there is a logical, direct link between the processes of phoneme manipulation and decoding. The finding that other linguistic levels of phonological awareness are also significantly related to concurrent reading ability refines current knowledge and supports the argument presented in Chapter 9 that phonological awareness is a unitary construct. However, the results of the Time 3 investigation do not clarify understanding about the direction of the relationship between phonological awareness and reading ability. It is possible that, at any of the linguistic levels of phonological awareness, children may have used pictured spelling (Stuart, 1990) to help them to perform tasks. For example, children may have used an ability to read words by sight to help them to

delete syllables from words, and may have used their ability to decode written words to help them to segment words into phonemes.
As suggested by Goswami and Bryant (1990), a valid means of establishing the relationship between phonological awareness and reading ability is to investigate phonological awareness skills in children before they have learned to read so that correlations between pre-literate phonological awareness and subsequent reading ability can be calculated. In studies using this design, the longitudinally predictive nature of the relationship between phonological awareness tasks and reading can be clarified because non-readers cannot use reading ability to help them to perform phonological awareness tasks.

10.4.2 The relationship between pre-literate phonological awareness skills and subsequent reading ability

The current study measured the phonological awareness of non-readers aged 4.0 to 4.5 and then investigated relationships with subsequent reading ability at age 5.0 to 5.5.

The results of the current study suggest that phonological awareness at the linguistic level of onset-rime appears to be most strongly associated with subsequent reading ability, but syllable segmenting and elision, rhyme detection and phoneme blending also show a longitudinally predictive relationship with reading.

Cardoso-Martins (1994) suggests that global rhyme awareness should be differentiated from rhyme awareness that requires a more explicit awareness of the onset and rime segments of words. The current study attempted to differentiate these skills and tested rhyme detection ability as a measure of rhyme awareness and onset-rime blending, segmenting and elision skills as measures of onset-rime awareness. The results suggest that, although rhyme awareness in preliterate children is significantly associated with subsequent reading ability, it is less strongly associated with reading than onset-rime segmenting and blending.

Several researchers, such as Bradley and Bryant (1983) and Goswami and Bryant (1990) suggest that rhyme awareness is a significant predictor of later reading ability in pre-literate children but this view has recently been challenged by Muter and her colleagues (Muter et al., 1997) who argue that the relationship between rhyme awareness and reading is weaker than previous research has suggested. As discussed above, results from the current study support this conclusion.

Muter and her colleagues (Muter et al., 1997) suggest that 'segmentation', measured by tests classified as phoneme identification and phoneme elision, is a better predictor of subsequent reading ability than rhyme awareness. The study on which this hypothesis is based (Muter et al., 1997) was a longitudinal study involving 38 children who were four-year-old non-readers when the study began. The phoneme identification test used in the study required children to add the last phoneme to a word. For example, the child looked at a picture of a horse, the tester said 'hor' and the child was expected to supply the final phoneme, /s/. The phoneme deletion test used in the study required children to delete single phoneme onsets from monosyllabic words (for example, delete /m/ from 'meat'). The test of phoneme deletion might therefore be better classified as a test of onset elision. By reclassifying the tests used in the Muter et al. (1997) study to make them more descriptive of the skills actually tested, it appears that pre-literate phoneme segmenting and onset elision are significantly predictive of subsequent reading. Results from the current study support the view that onset elision is significantly associated with subsequent reading ability but do not support the view that phoneme segmentation is significantly associated with subsequent reading. Most of the pre-literate children in the current study found phoneme segmentation a difficult task to perform, because they were asked to segment three phonemes within each word. The Muter et al. (1997) study only required children to supply one missing phoneme. It could be argued that it was not, therefore, a true test of children's ability to segment phonemes because only their ability to provide the final phoneme in a word was measured.

The results of the current study are contrary to the results of two recent studies that suggest that onset-rime awareness is not associated with reading ability (Seymour & Evans, 1994; Nation & Hulme, 1997). However, as discussed in Chapter 2, a lack of explicit task instructions in the Seymour and Evans (1994) study may have influenced the results. The investigation by Nation and Hulme (1997) was cross-sectional and pre-literate phonological awareness was not measured. Commenting on the limitations of their study, Nation and Hulme (1997) suggest that:

> It would be of considerable interest to investigate to what extent preschool assessments of onset-rime awareness as measured by a segmentation test predict later literacy skills (p. 165).

The current study suggests that onset-rime segmenting is significantly associated with subsequent reading ($r = .53$ $p \leq .01$).

The research literature has generally not found a significant association between reading ability and syllable awareness. For example, Badian (1998) reported that syllable awareness was not a significant predictor of later reading ability when measured with a syllable-tapping task. However, in Badian's (1998) study the children were aged five years at the first time of testing. The current study provides support for the Badian (1998) study in that no significant association was found between syllable awareness at Time 2 of testing (when children were aged five) and later reading. However, a significant relationship ($p \leq .01$) <u>was</u> found at age four.

Previous chapters have argued that phonological awareness is a developmental but unitary construct. Therefore, the finding that syllable awareness is significantly associated with later reading ability in children aged four, but not in children aged five is unsurprising. As suggested by Schatschneider and his colleagues (Schatschneider et al., 1999) it is possible that the stage of development of the children is influential in determining the strength of statistical relationships.

The results from the tests of children's pre-literate phonological awareness at age 4.0 to 4.5 and subsequent reading ability at age 5.0 to 5.5 suggest that the unitary, developmental construct of phonological awareness is longitudinally predictive of subsequent reading ability, with the linguistic level of onset-rime awareness being the strongest predictive element. However, this conclusion does not rule out two related hypotheses:

- that the causal influence underlying the longitudinally predictive relationship is the quality of phonological representations that a child is able to store in memory (Elbro, Neilson & Petersen, 1994; Hulme & Snowling, 1992; Swan & Goswami, 1997)
- that reading ability has a reciprocal influence on phonological awareness (Share & Stanovich, 1995).

10.4.3 A comparison of the phonological awareness test performances of below average and above average readers.

Figure 7 and Figure 8 in this chapter show the abilities of the lowest and highest quartiles of readers on each phonological awareness task at each of the three times of testing. The results suggest that the lowest quartile of readers show considerable developmental lag in phonological awareness compared to the highest quartile of children. The results discussed in this chapter support previous research in suggesting that the developmental construct of phonological awareness is significantly associated with reading ability. Therefore, the information presented in Figure 7 and Figure 8 is unsurprising. The lowest quartile of readers performed poorly on syllable elision and on all onset-rime and phoneme awareness tasks at Time 1, Time 2 and Time 3. In contrast the highest quartile of readers performed poorly on these tasks at Time 1 but showed rapidly developing skills thereafter to become proficient by Time 3. The results suggest that children demonstrating delay in their phonological awareness development can be identified between their fourth and fifth birthdays by monitoring their performance on 'lower level' phonological awareness tasks such as syllable elision and onset-rime awareness.

10.5 Summary

- The results of the current study suggest that phonological awareness is significantly related to concurrent reading ability in readers aged 5.0 to 5.5. The linguistic level of phonological awareness most strongly related to concurrent reading ability appears to be phoneme awareness. This finding converges with previous research findings that phoneme awareness is significantly associated with concurrent reading ability (for example, Wagner et al, 1997). The correlation between phonological awareness and concurrent reading ability does not give information about the direction of the predictive relationship (Goswami & Bryant, 1990).

- Pre-literate phonological awareness in children aged 4.0 to 4.5 appears to be significantly related to subsequent reading ability at age 5.0 to 5.5. The pre-literate linguistic level of phonological awareness that seems most strongly associated with subsequent reading ability is onset-rime awareness, which has a stronger association with subsequent reading ability than simple rhyme awareness. This finding supports the hypothesis of Cardoso Martins

(1994) that a global awareness of rhyme should be differentiated from onset-rime manipulation skills. The results support the conclusion of Muter and her colleagues (Muter et al., 1997) that the association between rhyme awareness and subsequent reading is weaker than has previously been supposed, but does not support the suggestion that by these authors that the phoneme segmentation ability of four-year-old pre-readers is longitudinally predictive of reading ability.

- The results of the current study suggest that poor readers demonstrate considerable developmental lag in phonological awareness and are approximately twelve months behind their more able peers by the age of 5.5 years.

Chapter 11

The Development of Rapid Serial Naming and Relationships with Reading Ability

Introduction and chapter overview

The rapid serial naming test is a measure of how quickly a series of letters, digits, colours or pictured objects can be named. This chapter presents results and discussion relating to the following research questions that were identified in Chapter 4:

- Which element of rapid serial naming contributes the greatest variance to overall performance?
- Does serial naming speed predict variance in reading ability?
- Is there a relationship between serial naming speed and phonological awareness?

The chapter is organized under the following headings:

- summary of rationale
- summary of methodology
- results
- discussion

11.1 Summary of rationale

Wolf and Bowers (1999) discuss the cognitive and linguistic processes that combine to enable fluent serial naming (see Chapter 3, section 3.2.1). They suggest that serial naming speed is independent of phonological awareness and that children who show a deficit in both skills are likely to have more severe reading disabilities than children who have a deficit in only one of the skills. These authors differentiate the articulation element of the test from the inter-stimulus interval (ISI) element of the test. The ISI's are the gaps between the articulated words. The current study measures articulation time and ISI time as component elements of serial naming at three time points. Developmental changes over time and the relationships of both the articulation and ISI elements of the test with reading ability and phonological awareness are investigated.

Several studies report wide variability in children's naming speed (McBride-Chang & Manis, 1998; Scarborough, 1998) but the cause of this variability has not been investigated. The current study compares the individual contributions of articulation time and ISI time to overall serial naming time. The extent to which each element contributes to variability in overall speed is investigated.

Following a small-scale study involving 12 teenage children, of whom six were designated as dyslexic and six were designated as normal readers, Obregon (1994) reported significant between-group differences in ISI time. Commenting on the results of the study by Obregon (1994), Wolf and Bowers (1999) suggest that:

> Such differences [in ISI time] presumably reflect the extra time taken by dyslexic participants to relinquish processing the previous stimulus and to move on to processing the present one (p. 418).

Several other studies also suggest that there is an association between serial naming speed and reading ability (for example, Manis, Seidenberg & Doi, 1999; Scarborough, 1998). As discussed in Chapter 3, some studies have reported an association between serial naming of letters with reading ability, but it could be argued that serial naming of letters confounds letter knowledge with serial naming fluency, particularly in younger children.

Therefore, the current study uses a test of rapid serial naming of pictured objects (Nicolson & Fawcett, 1996).

As discussed in Chapter 3, section 3.3, several authors have suggested that speed of serial naming is more predictive of reading ability in groups of poor readers than in groups of normal or high reading ability (McBride-Chang & Manis, 1996; Scarborough, 1998; Wolf & Bowers, 1999). The current study therefore investigates between-group differences in serial naming speed by comparing the overall speed of naming times, articulation times and ISI times for the lowest and highest quartiles of readers.

11.2 Summary of methodology

The testing methodology for the serial naming test was fully described in Chapter 5, section 5.6.5. In summary, children were shown an array of 20 pictured objects and asked to name the objects as quickly as possible. After a practice test, responses were recorded as digital audio files. The sound recordings and the visual waveforms were analysed and scores were calculated for overall speed of naming, articulation time and inter-stimulus interval (ISI) time. An example of the visual waveforms for the 20 words of the serial naming test, with an inter-stimulus interval highlighted between the waveforms for two words, is contained in Appendix D.

11.3 Results

This section presents descriptive statistics for overall serial naming, articulation time and ISI time, followed by results associated with the specific research questions that were identified at the beginning of the chapter.

11.3.1 Descriptive statistics

Descriptive statistics for the tests at Time 1 and Time 3 are contained in Table 25. Raw scores were converted to word or interval per second scores for ease of comparison and to make higher scores indicative of better performance. Both the raw scores and the word/interval per second rates are reported.

Table 25: Descriptive statistics for overall serial naming, articulation rate and inter-stimulus interval rate.

	M	SD	Min	Max
	Overall speed of naming			
Time 1				
Raw scores	32.5	11.2	19.0	79.8
Words per second	.67	.18	.25	1.05
Time 3				
Raw scores	25.7	7.8	12.6	56.7
Words per second	.84	.22	.35	1.6
	Articulation			
Time 1				
Raw scores	12.6	2.1	8.6	19.0
Words per second	1.6	.2	1.0	2.3
Time 3				
Raw scores	11.2	2.1	7.2	16.5
Words per second	1.8	.3	1.2	2.7
	Inter-stimulus interval			
Time 1				
Raw scores	20.2	10.7	7.1	67.3
ISI's per second	1.1	.5	.28	2.6
Time 3				
Raw scores	14.5	6.9	4.4	40.2
ISI's per second	1.6	.71	.47	4.27

The data screening process identified one outlying score in overall speed of naming, and four outlying cases in the inter-stimulus interval scores at Time 1. Standardised scores for the cases concerned were calculated to establish how extreme the outlying scores were. Following the advice of Tabachnick and Fidell (1996) one case containing an outlying score more than two standard deviations above the mean was removed from the data set when the data were being analysed using correlation or multiple regression. The outlying score was returned to the data set for other investigations. With the outliers removed and after square root transformations all tests showed normal distributions.

11.3.2 Investigating variability in serial naming speed

The descriptive statistics suggest that there is considerable variability in children's overall serial naming performance that appears to be primarily attributable to variability in inter-stimulus rate. Figure 9 shows the variability in performance at Time 1 by comparing the mean, minimum and maximum times for both ISI time and articulation time.

Figure 9: **Variability in performance on ISI time and articulation time at Time 1 of testing**

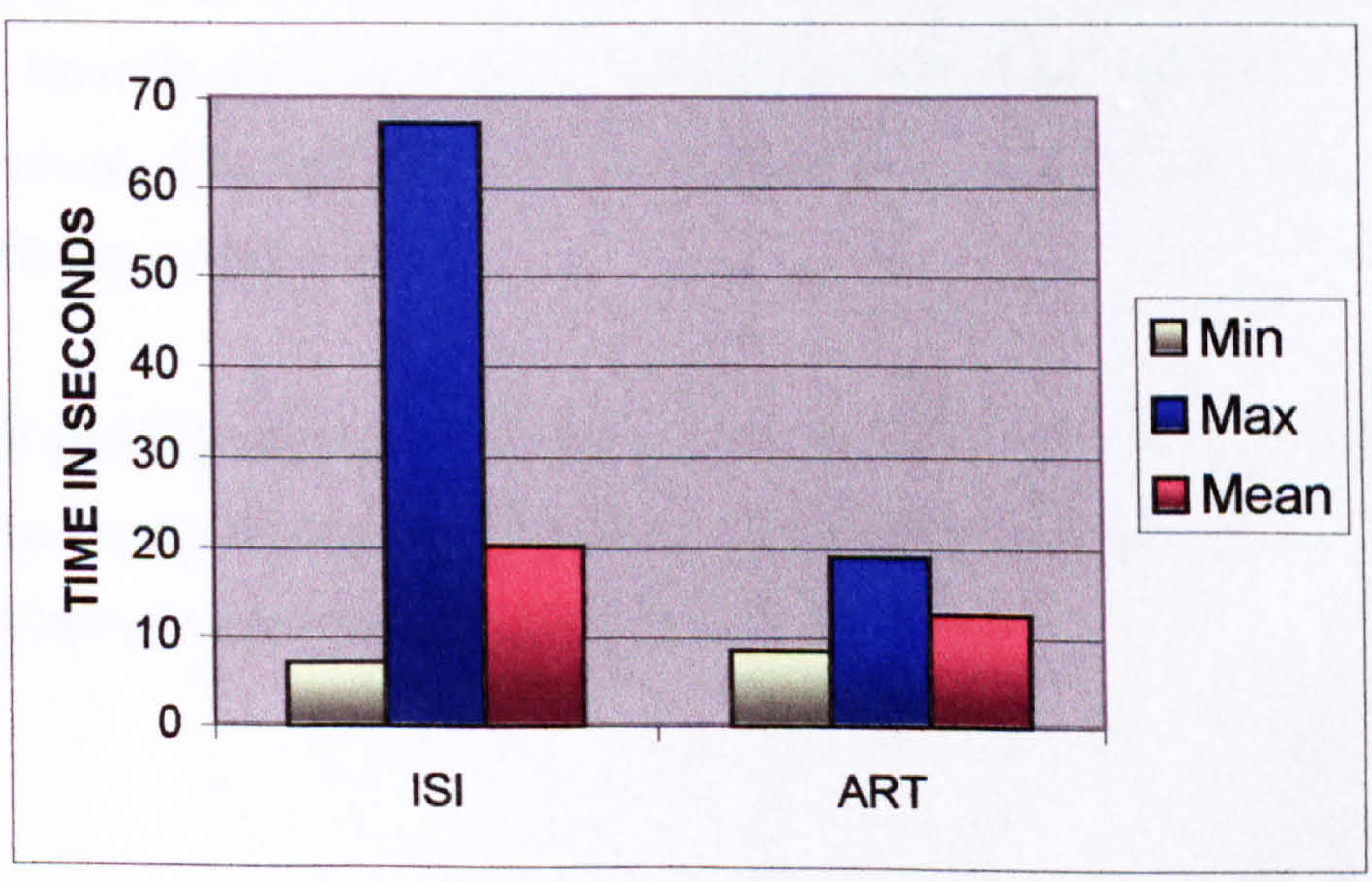


Figure 9 demonstrates that there was wide variability in the speed at which children could recall the names of the objects at age 4.0 to 4.5 years. There was comparatively little variability in the speed at which children could articulate the words.

Figure 10: **Variability I n performance on ISI time and articulation time at Time 3 of testing**

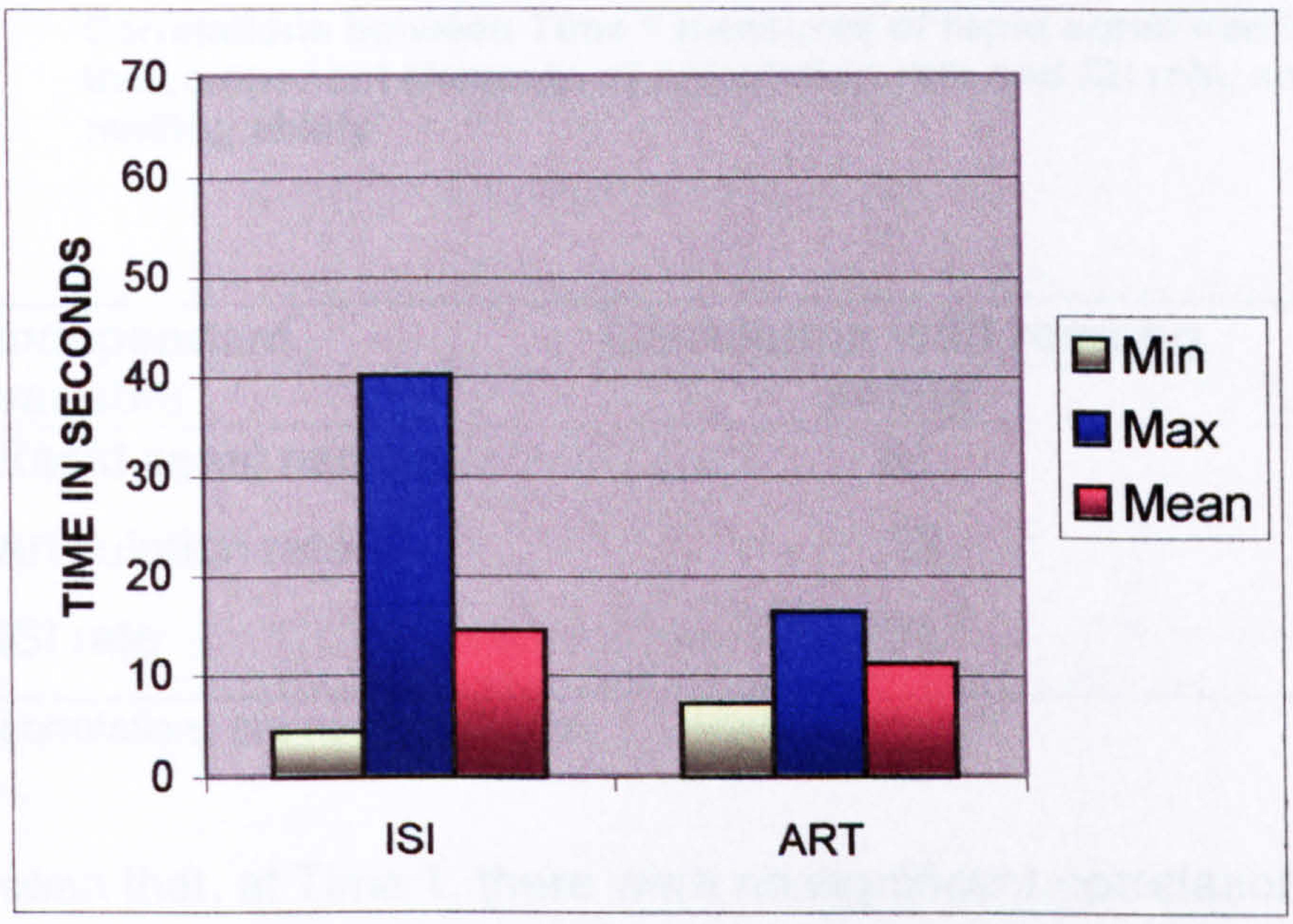


Figure 10 demonstrates that, at Time 3 of testing, there was less variability in the speed at which children could recall the names of the objects than at Time 1. Nevertheless, the variability is still wide. There continued to be comparatively little variability in the speed at which children could articulate the words.

Figure 9 and Figure 10 indicate that gradual decreases in time taken to complete the serial naming test as children become older are predominately caused by decreases in ISI time.

11.3.3 Investigating the relationship between serial naming speed and reading ability?

The relationship between rapid serial naming and reading ability was investigated through correlational analysis. The results of analysis based on the Time 1 measures are shown in Table 26. The results of analysis based on Time 3 measures are shown in Table 27.

Table 26: Correlations between Time 1 measures of rapid serial naming and the component elements of articulation rate and ISI rate, and reading ability

Independent variable	Correlation with reading ability
Rapid serial naming	.01
Articulation rate	-.22
ISI rate	.04

All correlations are non-significant

It can be seen that, at Time 1, there were no significant correlations between any of the elements of the serial naming test and subsequent reading ability.

Table 27: Correlations between Time 3 measures of rapid serial naming and the component elements of articulation rate and ISI rate, and reading ability

Independent variable	Correlation with reading ability
Rapid serial naming	.24*
Articulation rate	-.06
ISI rate	.28*

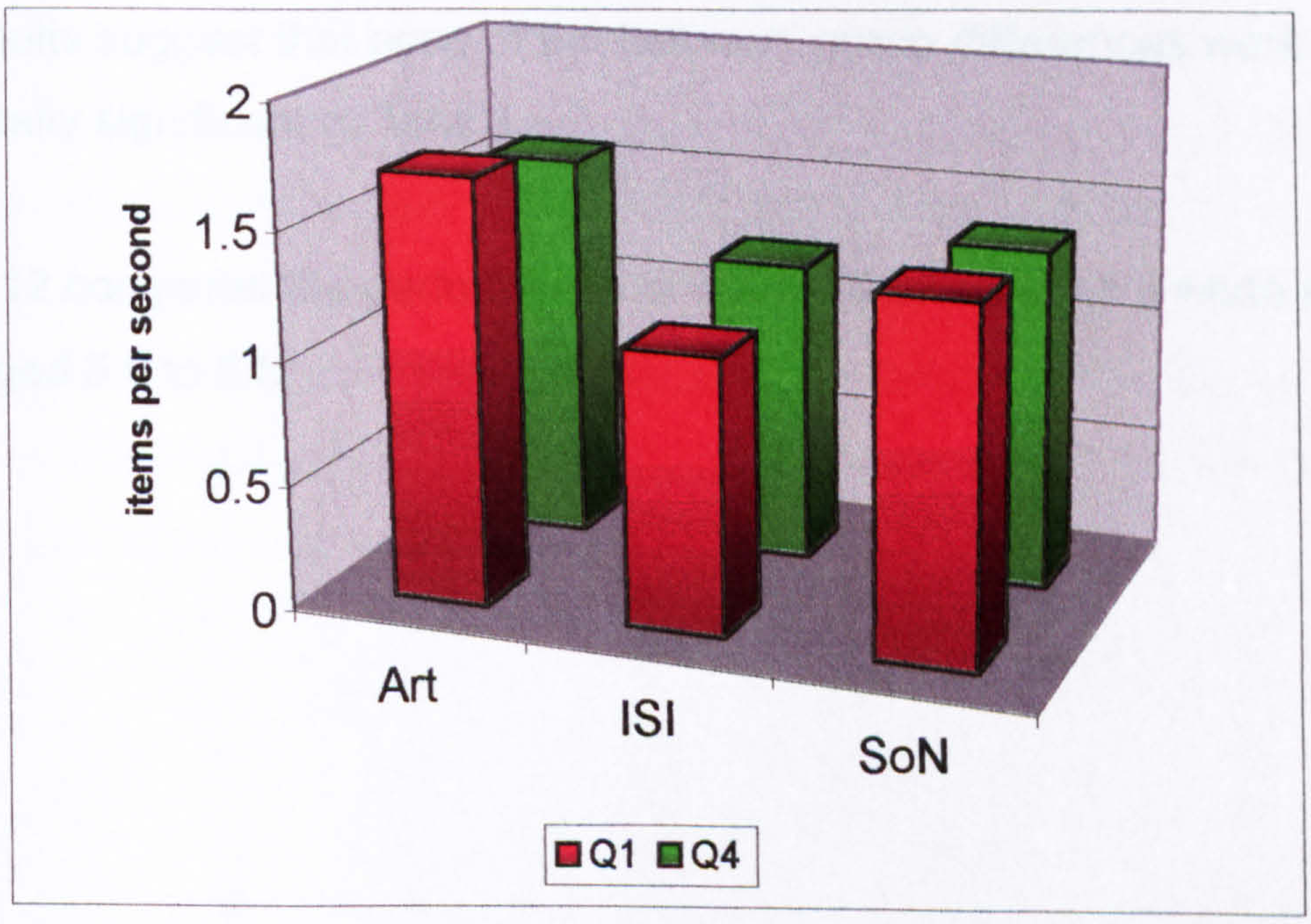
* $p \leq .05$

At Time 3, the results suggest a modestly significant association between rapid serial naming and concurrent reading ability that appears to be a consequence of an association between ISI time and reading ability.

11.3.4 A comparison of the speed of serial naming of above and below average readers

Based on Time 3 reading scores, the lowest and highest quartiles of readers were identified. Each subgroup comprised 17 children. The range of reading scores for the lowest quartile was from 0 to 4 words and the range of scores for the highest quartile was from 35 to 50 words. A further analysis of the data compared the performance of lower and higher quartiles of readers. Figure 11 compares the performance of the children at Time 1 when they were aged 4.0 to 4.5.

Figure 11: **Scores of the lowest (Q1) and highest (Q4) quartiles of readers on speed of naming, articulation rate and ISI rate at Time 1**



The chart suggests that the greatest between-group difference was in ISI time. The statistical significance of the between-group differences was investigated using an independent t test. The results of the independent t test are show in Table 28.

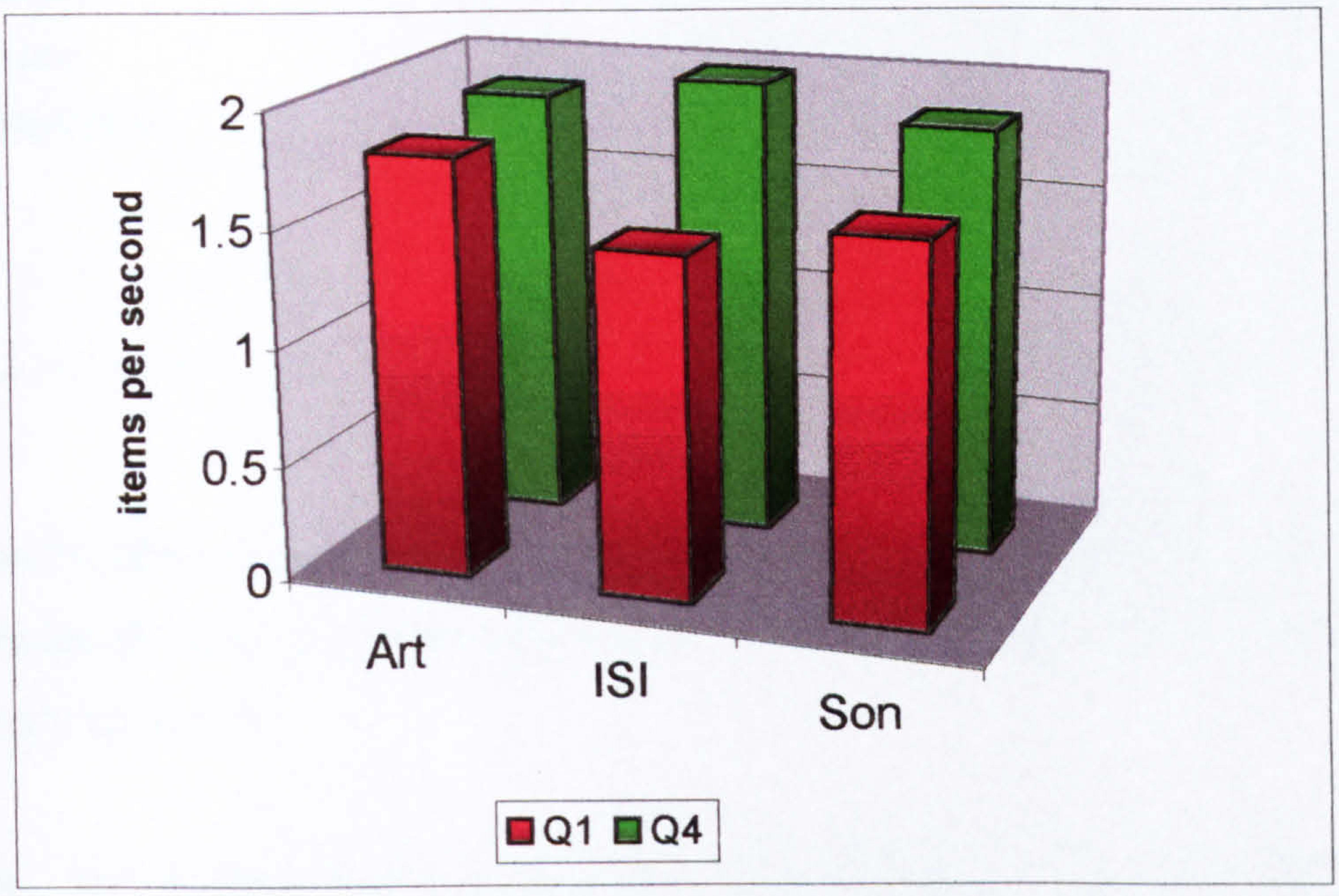
Table 28: A comparison of the lowest and highest quartiles of readers on overall serial naming time and the component elements of articulation time and ISI time at Time 1

	Q1 reading		Q4 reading			
Test	**M**	**SD**	**M**	**SD**	**t value**	**p**
			Time 1			
Overall serial naming rate	.64	.2	.68	.18	-.68	.49
Articulation rate	1.69	.22	1.57	.19	1.62	.11
ISI rate	1.07	.56	1.21	.47	-.75	.45

The results suggest that none of the between-group differences were statistically significant at Time 1.

Figure 12 compares the performance of the children at Time 3 when they were aged 5.0 to 5.5.

Figure 12: **Scores of the lowest (Q1) and highest (Q4) quartiles of readers on speed of naming, articulation rate and ISI rate at Time 3**



The chart suggests that, at Time 3, the more able readers had faster serial naming speed than the less able readers. As at Time 1, differences in performance were more attributable to differences in ISI speed than to differences in articulation speed. Independent t tests were again carried out to investigate the statistical significance of between-group differences. The results of the t tests are shown in Table 29.

Table 29: A comparison of the lowest and highest quartiles of readers on serial naming time, articulation time and ISI time at Time 3

	Q1 reading		Q4 reading			
Test	M	SD	M	SD	t value	p
Overall serial naming rate	.79	.24	.97	.39	2.25	.03*
Articulation rate	1.79	.15	1.88	.37	-.67	.51
ISI rate	1.46	.69	1.99	.8	-2.01	.05*

* $p \leq .05$

The results of the independent t tests suggest that the between-group differences at Time 3 in overall speed of serial naming and ISI speed were significant ($p \leq .05$).

11.3.5 Investigating the relationship between serial naming speed and phonological awareness?

The relationships between phonological awareness, overall serial naming speed and the component element of articulation rate and ISI rate were explored through correlational analysis. In these analyses the composite phonological awareness score is used. The results of the analysis using Time 1 data are shown in Table 30.

Table 30: The relationship between phonological awareness, overall serial naming speed and the component element of articulation rate and ISI rate at Time 1

Independent variable	Correlation with phonological awareness
Rapid serial naming	.14
Articulation rate	-.01
ISI rate	.16

All correlations non-significant

These results suggest that there is no significant relationship between serial naming and phonological awareness in children aged 4.0 to 4.5 years. The results of the analysis using Time 3 data are shown in Table 31.

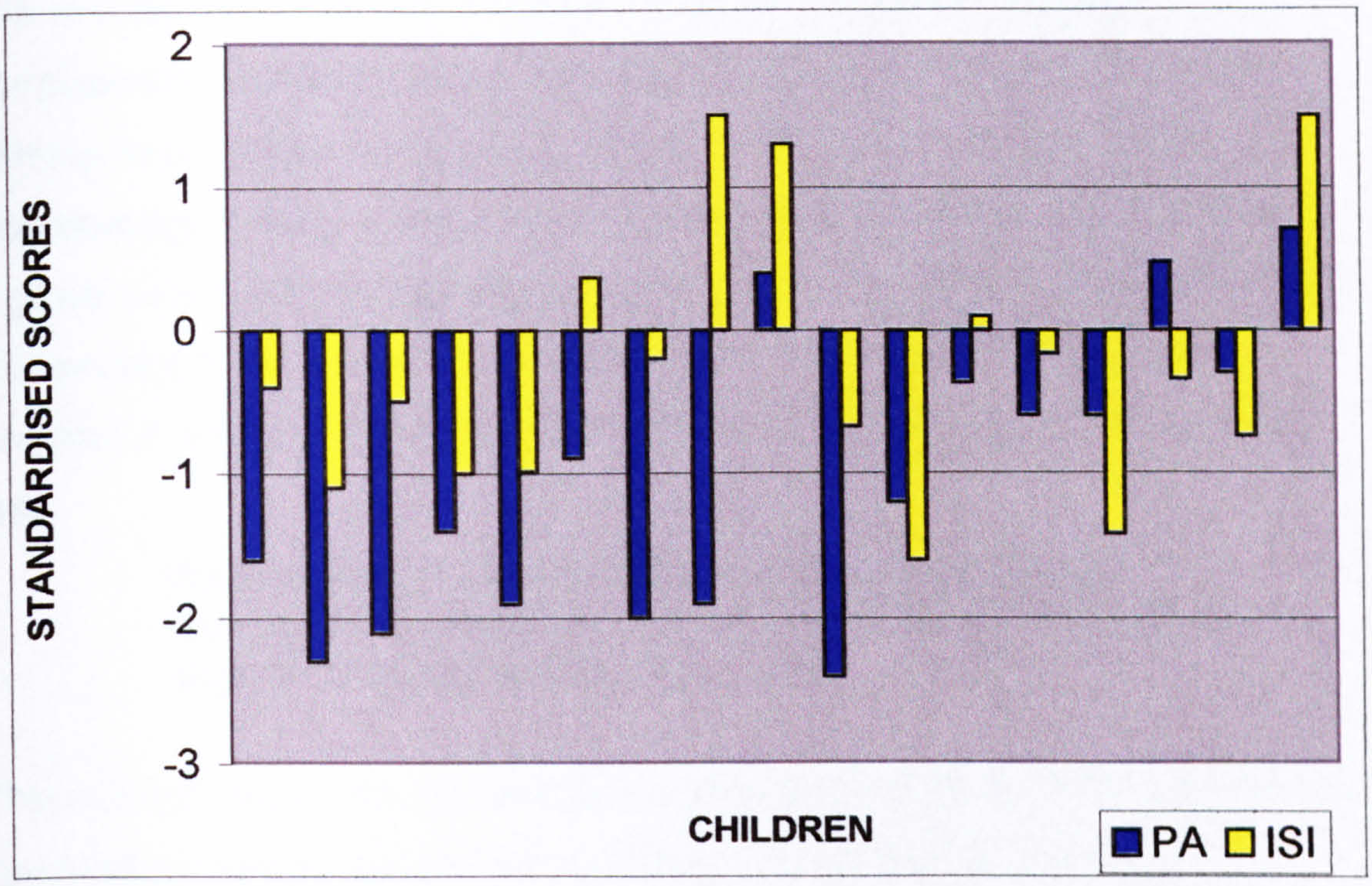
Table 31: The relationship between phonological awareness, overall serial naming speed and the component element of articulation rate and ISI rate at Time 3

Independent variable	Correlation with phonological awareness
Rapid serial naming	.27*
Articulation rate	.02
ISI rate	.28*

* $p \leq .05$

These results suggest that there is a modestly significant relationship between serial naming speed and phonological awareness at Time 3. The relationship appears to be attributable to ISI rate. In further investigation, the performance of the lowest quartile of readers on both phonological awareness and ISI time was investigated by calculating standardized scores for both variables. The standardized scores for the lowest quartile of readers, based on Time 3 data, are shown in Figure 13.

Figure 13: **Standardised scores for each of the lowest quartile of readers on phonological awareness and ISI rate at Time 3**



It is noteworthy that four of the lowest quartile of readers had both phonological awareness scores and ISI scores at one standard deviation below the mean. Eleven of the 17 children in the lowest quartile of readers had scores in both phonological awareness and ISI time that were below the mean. It is noteworthy that some children scored below the mean on phonological awareness but above the mean on ISI rate (or vice versa).

11.4 Discussion

The results are discussed under the following headings:

- Variability in performance on the serial naming test
- The relationship between serial naming speed and reading ability
- The relationship between serial naming speed and phonological awareness.

11.4.1 Variability in performance on the serial naming test

The results converge with previous research findings that there is considerable variability in the time that children take to perform serial naming tasks (McBride-Chang & Manis, 1996; Scarborough, 1998). Scarborough (1998) measured serial naming speed of pictured objects in a group of 88 children aged seven years. She reports scores ranging from 33 seconds to 99 seconds. McBride-Chang and Manis (1996) (see Chapter 3, section 3,2,4) do not report the range of scores but comment that:

> What appears to be most important about speeded naming in the present study is the variability poor readers show in such naming tasks (p. 335).

The current study extends previous understanding by providing evidence suggesting that the cause of variability in overall serial naming performance in children aged 4.0 to 5.5 years is variability in inter-stimulus interval time. There was little variability in articulation rate.

11.4.2 The relationship between serial naming speed and reading ability

McDougall et al. (1994) report a significant relationship between articulation rate and reading ability in children aged 7.5 to 9.5 years. However, the current study found no significant association between the articulation speed element of rapid naming and subsequent reading ability at any time of testing. It is possible that articulation speed, measured as an element of the serial naming test, is a qualitatively different measure to articulation speed measured when asking participants to simply repeat a series of words out of context. In the serial naming test, speech rate may be influenced by the other cognitive demands of the task. This suggests an interesting avenue for future research. It is noteworthy that there were no significant correlations between articulation time and ISI time at any time of testing.

At Time 3 of testing, the results suggest a significant relationship between ISI time and reading ability. These results provide support for the findings of Obregon (1994) who reports that ISI time differentiates average from dyslexic readers. The comparison of the lowest and highest quartiles of readers on rapid serial naming, articulation rate and ISI rate adds support for the hypothesis that ISI rate is associated with reading ability, as there are significant between-group differences.

Obregon (1994) measured articulation rate and ISI rate as separate elements of rapid serial naming, but a search of the literature found no other study that had measured these elements separately. The current study therefore adds considerably to existing knowledge. The finding that ISI time significantly differentiates between poor and more able reader groups at age five years, when children are at the earliest stages of reading, suggests that differences between the subgroups are not caused by a lack of reading experience which may themselves affect fluency. None of the children in the present study had sustained reading experience as twelve months previously they had all been non-readers.

11.4.3 The relationship between serial naming speed and phonological awareness

The results presented in Figure 13 suggest that the five weakest readers at Time 3 all have both slow serial naming and poor phonological awareness. This finding provides some support for the hypothesis of Wolf and Bowers (1999) that children who have both slow serial naming and poor phonological awareness are likely to have particular difficulty in learning to read. The modestly significant relationship between serial naming speed and reading ability at Time 3 appears to be attributable to a relationship between ISI rate and reading ability, as there was no significant relationship between articulation rate and reading ability. Wolf and Bowers (1999) suggest that poor phonological awareness and slow serial naming are independent deficits. However, Torgesen and Wagner (1998) comment that:

> We continue to assert that rapid-naming tasks measure an important dimension of phonological processing skill because ... these tasks show a consistent pattern of significant correlations with other measures of phonological skill (p. 223).

Although the current study suggests that there are significant correlations between ISI speed and phonological awareness, the results also suggest that some children with phonological awareness below the mean have serial naming speed above the mean, indicating that the skills can have considerable independence.

11.5 Summary

- The results suggest a significant association between ISI rate and reading ability in children age 5.0 to 5.5. This finding extends previous knowledge by suggesting that previously reported associations between serial naming speed and reading ability (for example, Scarborough, 1998) can be attributed to ISI time. It seems unlikely that this result is attributable to the children's previous reading experience as all of the children were inexperienced readers.

- The results provide no evidence of an association between articulation time and reading ability, as suggested by McDougall and her colleagues (McDougall et al., 1994). However, it is hypothesised that articulation speed that is measured as an element of the serial naming test may be qualitatively different from articulation speed measured in other ways.

- The results suggest that, in children aged 4.0 to 5.5 years, there is wide variability in ISI rate but comparatively little variability in articulation rate. Gradual reductions in overall serial naming over the period of the study appear to be predominately attributable to decreases in ISI time.

- The results provide some support for the hypothesis of Wolf and Bowers (1999) that children who are slow in serial naming and poor in phonological awareness find learning to read particularly difficult.

Chapter 12

The Development of Verbal Short-Term Memory and the Relationship with Reading Ability

Introduction and chapter overview

In the current study, verbal short-term memory was measured at three time points using the BAS Digit Span Test (Elliott et al., 1983). This chapter presents results and discussion relating to the following research questions that were identified in Chapter 4:

- Is there a relationship between verbal short-term memory and reading ability?
- Is there a relationship between articulation rate or ISI rate (measured as elements of the rapid serial naming test) and verbal short-term memory?

The chapter is organized under the following headings:

- summary of rationale
- summary of methodology
- results
- discussion

12.1 Rationale

Previous research, discussed in Chapter 3, section 3.1, suggests that poor readers frequently have poor short-term verbal memories (Gathercole & Baddeley, 1993; Jorm, 1983; Passenger et al., 2000; Vellutino et al., 1997; Wagner et al., 1994, 1997). McDougall and Hulme (1994) hypothesize that there may be two possible reasons for variability in children's performances on short-term memory tasks: articulation rate and verbal long-term memory. The relationship between articulation rate and verbal short-term memory is hypothesized to occur because subvocal rehearsal is used as an aid to remembering auditory stimuli over a short period of time (Baddeley, Lewis & Vallar, 1984; Baddeley, 1986). The relationship between long-term verbal memory and short-term verbal memory is hypothesised to occur because phonological codes in long-term memory can be called upon to refresh decaying traces of words in short-term memory, thus improving performance on short-term memory tasks. Research with older participants suggests that this process is independent of speech rate (Hulme et al., 1997).

Gathercole and Adams (1994) suggest that verbal short-term memory (measured by digit span) is significantly related to articulation rate in children aged five ($r = .35$, $p \leq .05$), but not in children aged four. On the basis of this finding the authors suggest that subvocal rehearsal strategies might develop between the ages of four and five years.

Wagner and his colleagues (Wagner et al., 1993, 1994,1997) use rapid serial naming tests as a measure of the speed with which children can retrieve phonological codes from long-term memory. This is clearly stated when these authors discuss possible causes of the relationship between serial naming speed and reading ability:

> The efficiency with which children are able to retrieve phonological codes associated with individual phonemes, word segments or entire words should influence the degree to which phonological information is useful in decoding (Wagner et al., 1993, p. 84).

In the current study, the ISI element of the rapid serial naming task is hypothesised to be a more pure measure of children's ability to retrieve phonological codes from long-term memory, because the articulation element of the rapid serial naming test has been extracted. A relationship between ISI rate and verbal short-term memory would support the hypothesis of Hulme and his colleagues (Hulme et al., 1997) that verbal long-term memory influences performance on short-term memory tests.

12.2 Methodology

The current study investigates the relationships between:

- articulation rate (measured as an element of the rapid serial naming test)
- ISI rate (measured as an element of the rapid serial naming test)
- verbal short-term memory (measured by digit span).

The methodology for testing articulation rate and ISI rate has previously been discussed in Chapter 5, section 5.6.5. The methodology for testing verbal short-term memory was discussed in Chapter 5, section 5.6.3.

12.3 Results

Descriptive statistics for the tests of reading and rapid serial naming have been presented previously. This section presents descriptive statistics for the verbal short-term memory tests at each time of testing, followed by results associated with the specific research questions that were identified at the beginning of the chapter.

Descriptive statistics for the verbal short-term memory tests at Time 1 and Time 3 are contained in Table 32.

Table 32: Descriptive statistics for verbal short-term memory

	M	SD	Min	Max
Time 1	7.9	3.5	0	14
Time 2	10.2	3.4	0	16
Time 3	12.5	3.1	5	19

All tests were normally distributed with no outlying scores. The results suggest a steady improvement in performance over the time period investigated.

12.3.1 Investigating the relationship between verbal short-term memory and reading ability?

The relationship between verbal short-term memory and reading ability was investigated with correlational analysis. The results are presented in Table 33.

Table 33: Correlations between verbal short-term memory and reading ability at each time of testing.

Independent variable	Correlation with reading ability
VSTM Time 1	.48**
VSTM Time 2	.59**
VSTM Time 3	.58**

** $p < .01$ VSTM = verbal short-term memory

The results suggest a significant and stable association between verbal short-term memory and reading ability. The significant correlation between verbal short-term memory at Time 1 and subsequent reading ability suggests that the relationship is longitudinally, as well as concurrently, predictive.

12.3.2 Investigating the relationship between articulation rate, ISI rate and verbal short-term memory?

Correlational analyses were used to investigate the relationship of articulation rate and ISI rate with verbal short-term memory. The results are presented in Table 34.

Table 34: Correlations between articulation rate, ISI rate and verbal short-term memory

	Correlations at each time of testing		
Variables	Time 1	Time 2	Time 3
ISI rate and VSTM	.15	.23	.42**
Articulation rate and VSTM	.05	.09	.04

** $p < .05$ VSTM = verbal short-term memory

A noteworthy result is the significant correlation between ISI rate and verbal short-term memory in children aged 5.0 to 5.5.

12.4 Discussion

The results are discussed under the following headings:

- The relationship between verbal short-term memory and reading ability
- The relationship between verbal short-term memory, ISI rate and articulation rate.

12.4.1 The relationship between verbal short-term memory and reading ability

The finding of a significant and stable association between verbal short-term memory and reading ability converges with a substantial amount of previous research. Torgesen and Burgess (1998) comment that:

> Difficulty in remembering exact sequences of verbal information over brief periods of time is one of the most frequently reported cognitive characteristics of children with severe reading disabilities (p. 164).

A consequence of high levels of stability and significant correlations with reading ability would be that children who exhibit poor verbal short-term memory at an early age would be likely to need considerable extra support in establishing early reading skills.

12.4.2 The relationship between verbal short-term memory, ISI rate and articulation rate

The results of the correlational analysis investigating the relationship between verbal short-term memory and ISI rate indicate that the relationship strengthened and became significant over the period of the study. This finding provides support for the hypothesis that speed of retrieving phonological codes from long-term memory influences performance on short-term memory tasks (Hulme et al., 1997). The hypothesis is that participants who can quickly retrieve phonological codes from memory are able to use the retrieval process to refresh decaying traces of words during short-term memory tests.

There is converging evidence for an association between articulation rate and verbal short-term memory (Avons & Hannah, 1995; Baddeley, 1986; Hulme & Roodenrys, 1995; McDougall et al., 1994). In a longitudinal study, Gathercole and Adams (1994) found that the association was statistically non-significant in children aged four years, but became significant as the children progressed through their fifth year. However, the current study found no evidence of a relationship between verbal short-term memory and articulation rate at any time of testing. It remains possible, however, that any such relationship is time sensitive and develops gradually over the early school years. It is also possible, as discussed previously, that articulation rate measured as an element of the serial naming test is a qualitatively different measure to articulation rate measured using other methods.

12.5 Summary

- The results of the current study converge with previous research, suggesting a stable and significant, predictive association between verbal short-term memory and reading ability (for example, Wagner et al., 1994, 1997).

- The relationship between verbal short-term memory and inter-stimulus interval (ISI) rate was significant in children aged 5.0 to 5.5 years, providing support for the hypothesis that speed of retrieving phonological codes from long-term memory influences performance on short-term memory tasks (Hulme et al., 1995, 1997).

- The results of the current study converge with the findings of Gathercole and Adams (1994) that there is no significant association between articulation rate and verbal short-term memory in children aged four years. Gathercole and Adams (1994) found that the relationship between these two skills became significant during the child's fifth year, but the current study found no evidence of this developing relationship. It could be argued that articulation rate measured as an element of the serial naming test is a qualitatively different measure to articulation rate measured using other methods.

Chapter 13

The Relationship Between Letter Knowledge Speed of Learning Verbal/Visual Symbol Associations and Reading Ability

Introduction and chapter overview

In the current study, children' s letter knowledge was measured at three time points and their ability to learn novel verbal/visual symbol associations was measured at Time 1 and Time 3. This chapter presents results and discussion relating to the following research question that was identified in Chapter 4:

- What is the relationship between the ability to learn verbal/ visual symbol associations quickly, letter knowledge and reading ability in children aged 4.0 to 5.5 years?

The chapter is organised under the following headings:

- summary of rationale
- summary of methodology
- results
- discussion

13.1 Summary of rationale

Most models of reading development (for example, Frith, 1985; Ehri, 1995) include a stage or phase at which children use knowledge of letter sounds to help them to recognise or decode words (Ehri & Wilce, 1985; Laing & Hulme, 1999). Letter knowledge has frequently been found to be a reliable predictor of reading ability (Badian, 1998; Chall, 1967). Gallagher and her colleagues (Gallagher et al., 2000) report that the letter knowledge of children aged 45 months is a significant predictor of reading ability at age six. These authors suggest that some children might have a specific difficulty in learning associations that involve a verbal component, due to weaknesses in their ability to store clear phonological representations in lexical memory.

The results of a study by Mauer and Kamhi (1996) support this hypothesis. These authors compared the number of trials needed by poor and average readers to learn novel phoneme/grapheme associations. Analysis of between-group differences suggests that poor readers need a significantly greater number of trials to learn associations than average readers ($p \leq .05$).

Letter knowledge is a taught skill. Therefore, the results of letter knowledge tests do not necessarily measure the speed at which children are able to learn verbal/visual symbol associations. It is always likely that some children will have had more opportunity to gain letter knowledge than other children. The current study therefore aimed to differentiate letter knowledge from the ability to quickly learn verbal/visual symbol associations and to compare each test with subsequent and concurrent reading ability. In order to measure children's speed of learning verbal/visual symbol associations the current study used an experimental computer-based test (see Chapter 5, section 5.6.4). It was hypothesised that children's ability to learn the associations quickly would correlate more strongly with subsequent reading ability than their letter knowledge.

13.2 Summary of methodology

The methodology for measuring letter knowledge was discussed in Chapter 5, section 5.6.2. In summary, children were tested on their ability to recognise 14 letters when told the sounds (letter sound identification) and on their ability to say the same 14 letter sounds after being shown the letters (letter sound production). The 14 letters in the tests comprised seven that previous research suggested were early-learned letters and seven that have been suggested to be later-learned letters (Coleman, 1970; Stuart, 1987; Huxford, 1993).

The design of the test for measuring children's ability to learn verbal/visual symbol associations was discussed in Chapter 5, section 5.6.4. In summary, a computer program presented three consonant-vowel-consonant nonwords and three associated letter-like forms to the children twelve times. After each presentation, children were asked to match one of the words to one of the pictures. One point was scored for each correct response. The maximum score was twelve.

13.3 Results

In this section, descriptive statistics are followed by results relating to the research question identified at the beginning of this chapter.

13.3.1 Descriptive statistics

Scores from the letter sound identification test and the letter sound production were found to be significantly and strongly correlated. The correlations are shown in Table 35.

Table 35: **Correlations between letter sound identification and letter sound production at each time of testing**

	Time 1	Time 2	Time 3
Correlation between letter sound identification and letter sound production	.79	.85	.83

All correlations significant at the $p \leq .01$ level

It was therefore decided to create a derived variable of 'letter knowledge', calculated by taking the mean score of the two tests (letter sound identification and letter sound production) at each time of testing. Descriptive statistics for the letter knowledge variable are shown in Table 36 and descriptive statistics for the test of speed of learning verbal/visual symbol associations are shown in Table 37. Following the descriptive statistics, further results relating to the research question identified at the beginning of the chapter are presented.

Table 36: **Descriptive statistics for the tests of letter knowledge**

Variable	M	SD	Min	Max
Time 1 letter knowledge	3.8	4.2	0	14
Time 2 letter knowledge	8.3	4.0	0	14
Time 3 letter knowledge	11.3	3.6	0	14

Letter knowledge at Time 1 was affected by floor effects, but a square root transformation was successful in creating a normal distribution.

Table 37: Descriptive statistics for speed of learning verbal/visual symbol associations

Variable	M	SD	Min	Max
Time 1: Speed of learning associations	6.5	2.3	2	12
Time 3: Speed of learning associations	8.9	2.2	3	12

Scores on the speed of learning verbal/visual symbol associations test were normally distributed.

13.3.2 The relationship between letter knowledge and reading ability

The relationship between letter knowledge and reading ability was investigated through correlational analysis. The results are presented in Table 38.

Table 38: Correlations between letter knowledge reading ability

Independent variable	Correlation with reading ability (Time 3)
Time 1 letter knowledge	.66**
Time 2 letter knowledge	.69**
Time 3 letter knowledge	.72**

**$p \leq .01$

The results suggest that there is a significant, predictive association between the letter knowledge of non-readers aged 4.0 to 4.5 and subsequent reading ability, which strengthens as children start to learn to read.

13.3.3 The relationship between speed of learning verbal/visual symbol associations and reading ability

Table 39 shows the results of correlations between speed of learning associations and reading ability.

Table 39: Correlations between speed of learning associations and reading ability

Independent variable	Correlation with reading ability (Time 3)
Time 1 rate of learning verbal/visual symbol associations	.36**
Time 3 rate of learning verbal/visual symbol associations	.31*

* $p \leq .05$ **$p \leq 01$

The results suggest that the ability of non-readers aged 4.0 to 4.5 to learn verbal/visual symbol associations is significantly associated with subsequent reading ability ($p \leq .01$). However, the correlation between speed of learning associations and reading ability is weaker than the correlation between letter knowledge and reading ability, suggesting that the ability to learn associations had less influence on reading ability than letter knowledge.

13.4 Discussion

The results of the current study converge with previous research to suggest that children's letter knowledge is significantly associated with reading ability (for example, Byrne, 1998; Ehri, 1995; Gallagher et al., 2000). However, the results do not support the hypothesis that speed of learning verbal/visual symbol associations has more influence on subsequent reading ability than letter knowledge itself. The finding that letter knowledge per se is more closely associated with word-level reading than the ability to learn verbal/visual symbol associations quickly suggests that the more influential factor may be the quality and quantity of children's letter learning experiences.

The results of an investigation by Gallagher and her colleagues (Gallagher et al., 2000) are contrary to this theory. These authors measured the relationship between the letter knowledge of a group of three-year-old non-readers and subsequent reading ability at age six. They suggested that the poor letter knowledge of the children who went on to become poor readers was not due to a lack of opportunity to learn. Their study involved the cooperation of parents who were asked to record the amount of time spent with children focusing on letter learning activities. The poor reader group were reported to have spent more time on letter learning activities than the children who went on to become average readers. The Gallagher et al. (2000) results therefore seem to be contradictory to the results of the current study. It is hypothesised that the conflicting results are due to the differences in the study sample. In the Gallagher et al. (2000) study, most of the children who comprised the poor readers group at age six had been selected for participation in the study because they were considered to be genetically 'at risk' of dyslexia. The sample of children under consideration was therefore substantially different from the sample in the current study that was selected to be representative of a normal population.

13.5 Summary

- The current study reports a significant relationship between the letter knowledge of non-reading children aged 4.0 to 4.5 and subsequent word-level reading ability at age 5.0 to 5.5. These results converge with much previous research (for example, Byrne, 1998; Ehri, 1995, Gallagher et al., 2000).

- The results suggest that speed of learning verbal/visual symbol associations is significantly associated with subsequent reading ability but appears to be less influential than letter knowledge per se This finding suggests that, for most children, the quality and quantity of early letter-learning experiences has a more significant influence on subsequent reading ability than a natural aptitude to learn verbal/visual symbol associations quickly.

Chapter 14

Predicting Variance in Word-Level Reading Ability Using Multiple Regression Analyses

Introduction and chapter outline

Previous chapters have investigated relationships between the word-level reading ability of children aged 5.0 to 5.5 and the following skills:

- phonological awareness
- serial naming speed and the component elements of articulation rate and ISI rate
- verbal short-term memory
- letter knowledge
- speed of learning verbal/visual symbol associations.

The current chapter discusses how these skills combine to predict variance in reading ability and therefore addresses the following research question that was identified in Chapter 4.

- How much variance in word-level reading at age 5.0 to 5.5 years can be accounted for by phonological awareness, verbal short-term memory, letter knowledge, speed of learning verbal/visual symbol associations and the component elements of rapid serial naming?

The predictive relationships between the independent variables (at three time points) and reading ability (measured at the end of the study when children were aged 5.0 to 5.5) are investigated.

The chapter is organised under the following headings:

- rationale
- methodology
- results
- discussion.

14.1 Rationale

Bivariate analyses, such as those presented in previous chapters, provide useful and interesting insights into the inter-relationships between the developing skills that are, or might be, associated with reading ability. However, from the practitioners viewpoint there comes a point at which it is useful to know which reading-related skills, alone or in combination, will provide the most accurate information about a child's potential reading ability and/or important skill deficits. As discussed in Chapter 7, section 7.5.3, multiple regression is a useful statistical technique that is frequently used in the research literature to investigate the relative impact of independent variables on the dependent variable. Tabachnick and Fidell (1996) advise that:

> Whether or not an IV [independent variable] appears particularly important in a solution depends on the other IV's in the set. If the IV of interest is the only one that assesses some important facet of the DV, the IV will appear important; if the IV of interest is only one of several that assess the same important facet of the DV, it will appear less important. An optimal set of IV's is the smallest, reliable uncorrelated set that 'covers the waterfront' with respect to the DV (p. 132).

14.2 Methodology

The test of reading ability used in the current study was described in Chapter 6. The testing methodology associated with each of the independent variables was described in Chapter 5.

The phonological awareness variable used in these analyses was a composite score, calculated by adding together the scores from the individual phonological awareness tests. Careful consideration was given to the calculation of the composite phonological awareness score, with two possible strategies considered. The first possibility was to include scores from only those tasks that had been found to correlate significantly with reading ability. The second possibility was to include scores from all phonological awareness tasks. The first option would have removed scores of different tasks from the composite score for each time of testing. For the sake of 'completeness', and with regard to the argument previously presented that phonological awareness is a unitary construct, it was decided to include scores from all tasks.

Although there were some floor effects in the composite score at Time 1, a square root transformation created a suitably normal distribution. The component elements of rapid serial naming (articulation rate and ISI rate) were used in preference to the composite measure of rapid serial naming because previous analysis suggested that ISI rate was the element of serial naming that was more strongly associated with reading ability.

There are several different types of multiple regression. They differ in their treatment of overlapping variance and in terms of the order of entry of the independent variables into the regression equation (Coakes & Steed, 1999). In the current analyses, the aim was to investigate shared variance and to establish the amount of independent variance in reading ability that was contributed by each independent variable. It was decided to use the principle of forward selection multiple regression to achieve this objective.

Forward selection multiple regression is explained by Vogt (1999). The steps of the procedure are summarised below.

1. The computer program calculates simple regressions for each of the independent variables.
2. The independent variable that accounts for the largest percentage of variance (R^2) in the dependent variable is selected and entered into the multiple regression analysis.
3. The selected variable is then tried in combination with the other independent variables in order to find the pair of independent variables that will account for most variance in the dependent variable.
4. The computer program continues to search for the independent variable that, when added to the regression equation, will give the greatest increase in the percentage of variance accounted for.
5. The process continues until a stage is reached at which the addition of another predictor variable does not increase the percentage of variance accounted for.
6. The cumulative amount of variance accounted for as the regression analysis continues is labelled 'cumulative R^2'.

Goswami and Bryant (1990) discuss the importance of controlling for intelligence when carrying out multiple regressions investigating variance in reading ability. Commenting on the multiple regression analysis carried out by Stanovich and his colleagues (1984), which investigated predictive relationships between phoneme awareness and reading, Goswami and Bryant point out that:

> You can only be sure that such scores predict reading in a multiple regression if you put I.Q. into the regression first and then the phonological scores (p. 104).

To take account of this advice, a second stage of multiple regression analysis was carried out. The second stage was hierarchical multiple regression in which ' the independent variables enter the equation in an order specified by the researcher' (Tabachnick & Fidell, 1996). In the second stage of multiple regression, results from the BPVS test of receptive vocabulary (Dunn et al., 1997) and results from the BAS similarities test (Elliott et al., 1983) were entered sequentially into the regression equation before the independent variables that had been identified in the previous forwards regression analysis to have the strongest predictive relationships with reading ability. As discussed in Chapter 5, section 5.6.6, the BPVS test of receptive language (Dunn et al., 1997) and the BAS Similarities test (Elliott et al., 1983) are both considered to be appropriate tests of general verbal ability for children aged 4.0 to 5.5 years.

14.3 Results

The results are presented under the following headings:

- the longitudinal prediction of reading ability from Time 1 independent variables
- the longitudinal prediction of reading ability from Time 2 independent variables
- the concurrent prediction of reading ability from Time 3 independent variables.

14.3.1 The longitudinal prediction of reading ability from Time 1 independent variables

The following independent variables were entered into the first stage of regression analysis (forward regression analysis):

- phonological awareness (composite score)
- letter knowledge
- verbal short-term memory

- articulation rate
- inter-stimulus interval rate.

The results of the first stage of the regression analysis are contained in Table 40.

Table 40: Results of the forward regression analysis using Time 1 data

Variable	β	Cumulative adjusted R^2	Significance
Phonological awareness	.44	29%	.001
Letter knowledge	.30	35%	.008
Articulation rate	-.22	39%	.034

The results suggest that the most influential predictor of later reading ability in children aged 4.0 to 4.5 years is phonological awareness, which accounts for 35% of the variance in subsequent reading ability. Letter knowledge accounts for a further 6% of independent variance and articulation rate accounts for a further 4% of variance. The contribution of articulation rate to variance in reading ability was in reverse of the expected direction, suggesting that slow articulation was indicative of successful reading in children aged 4.0 to 4.5. The total amount of variance explained by these three independent variables was 39%. Verbal short-term memory, ISI rate and speed of learning verbal/visual symbol associations were not statistically significant in the equation and were therefore excluded. Full details of the SPSS (1993) regression analysis using Time 1 data, including an analysis of residuals, are contained in Appendix J.

The results of the second stage of the regression analysis are shown in Table 41. Independently, the Similarities Test (Elliott et al., 1983) at Time 1 accounted for 21% of the variance in reading ability and the BPVS

(Dunn et al., 1997) test of receptive vocabulary accounted for 18% of the variance. Therefore, the similarities test was entered before the test of receptive vocabulary, as it made a greater independent contribution.

Table 41: **Results of the hierarchical regression analysis using Time 1 data**

Variable	β	Cumulative adjusted R^2	Significance
Similarities	.34	21%	.006
BPVS	-.02	25%	.869
Phonological awareness	.24	38%	.037
Letter knowledge	.30	42%	.007
Articulation rate	-.31	47%	.003

The results suggest that phonological awareness, letter knowledge and articulation rate account for significant amounts of variance in reading ability even when verbal intelligence is controlled in the equation. With the inclusion of the two tests of verbal ability, the total amount of variance in reading ability accounted for increases to 47%.

14.3.2 The longitudinal prediction of reading ability from Time 2 independent variables

Following the procedure described above, the following independent variables from the Time 2 data were entered into the first stage of regression analysis (forward regression analysis):

- phonological awareness (composite score)
- letter knowledge
- speed of learning verbal visual/symbol associations;
- verbal short-term memory
- articulation rate
- inter-stimulus interval rate.

The results of the first stage of the regression analysis are contained in Table 42.

Table 42: Results of the forward regression analysis using Time 2 data

Variable	β	Cumulative adjusted R^2	Significance
Phonological awareness	.47	55%	.000
Letter knowledge	.42	65%	.000

The results suggest that the most influential predictor of later reading ability in children aged 4.5 to 5.0 years is still phonological awareness, which accounts for 55% of the variance in subsequent reading ability. Letter knowledge accounts for a further 10% of independent variance. Verbal short-term memory, articulation rate, ISI rate and speed of learning verbal/visual symbol associations were again not statistically significant in the equation and were therefore excluded. Full details of the SPSS (1993) regression analysis using Time 2 data are contained in Appendix K.

The results of the second stage of the regression analysis are shown in Table 43.

Table 43: Results of the hierarchical regression analysis using Time 2 data

Variable	β	Cumulative adjusted R^2	Significance
Similarities	.34	21%	.006
BPVS	-.02	25%	.869
Phonological awareness	.43	58%	.000
Letter knowledge	.39	65%	.000

These results again suggest that phonological awareness and letter knowledge account for significant amounts of variance in reading ability even when verbal intelligence is controlled in the equation. With the inclusion of the two tests of verbal ability, the total amount of variance in reading ability accounted for remained at 65%.

14.3.3 The longitudinal prediction of reading ability from Time 3 independent variables

Again following the procedure described above, the independent variables from the Time 3 data were entered into the first stage of regression analysis (forward regression analysis). The results of the first stage of the regression analysis are contained in Table 44.

Table 44: Results of the forward regression analysis using Time 3 data

Variable	β	Cumulative adjusted R^2	Significance
Phonological awareness	.52	64%	.000
Letter knowledge	.42	71%	.000

The results again suggest that the most influential predictor of concurrent reading ability in children aged 5.0 to 5.5 years is phonological awareness, which accounts for 64% of the variance in reading ability. Letter knowledge accounts for a further 7% of independent variance. Verbal short-term memory, articulation rate ISI rate and speed of learning verbal/visual symbol associations were again not statistically significant in the equation and were therefore excluded. Full details of the SPSS (1993) regression analysis using Time 3 data are contained in Appendix L.

The results of the second stage of the regression analysis are shown in Table 45.

Table 45: Results of the hierarchical regression analysis using Time 3 data

Variable	β	Cumulative adjusted R^2	Significance
Similarities	.34	28%	.006
BPVS	-.02	29%	.869
Phonological awareness	.43	64%	.000
Letter knowledge	.39	71%	.000

The results suggest that phonological awareness and letter knowledge account for significant amounts of variance in reading ability even when verbal intelligence is controlled in the equation. With the inclusion of the two tests of verbal ability, the total amount of variance in reading ability accounted for remained at 71%.

14.4 Discussion

Results of the current study suggest that variance in reading ability is accounted for by phonological awareness and letter knowledge even when verbal intelligence is accounted for.

Results of the regression analysis using Time 1 data suggest that, at age 4.5 to 5.0 years, 35% of the variance in children's later reading ability can be accounted for by phonological awareness and letter knowledge. This converges with much previous research (for example, Byrne, 1998; Wagner et al., 1997; Gallagher et al., 2000). It is noteworthy that verbal short-term memory, which was significantly associated with reading ability in correlational analysis ($r = .48$, $p \leq .01$) becomes redundant in the regression equation. This finding suggests that verbal short-term memory shares considerable variance with phonological awareness and letter knowledge.

The finding that articulation rate at Time 1(measured as an element of the rapid serial naming test) contributes unique variance to subsequent reading ability merits further investigation. It was noted during the analysis of the serial naming sound files that children who articulated words more clearly took marginally longer to articulate each word. It could be argued that the ability and the tendency to articulate words clearly might indicate distinct phonological representations of words in memory, which is suggested by Snowling (2000) to be a causal factor underpinning phonological awareness and reading ability. On the basis of the Time 1 data it was hypothesised that children who had slower articulation rates would subsequently be found to have higher scores on phoneme awareness. However no evidence was found to support this hypothesis. The correlations between articulation rate and phoneme awareness did not achieve significance.

The results of the regression analysis using Time 2 data indicate that in children aged 5.0 to 5.5 years, phonological awareness and letter knowledge were again the most significant predictors of word level reading. It is noteworthy that the amount of variance in reading ability accounted for by the independent variables increased from 47% at Time 1 to 65% at Time 2. Three possible reasons for this are considered.

1. At Time 2 of testing, the children were all experiencing their first term at school. It is possible that there was a sudden intensification of teaching of letter sounds and phonological awareness at this time.
2. At Time 2 of testing, it is possible that those who already had good phonological awareness and letter knowledge were better able to learn to understand the alphabetic principle that Byrne (1998) hypothesises to be a necessary prerequisite to successful reading.

3. The tester became aware that, at the second time of testing, children were more relaxed about the testing procedures than they had been six months previously. It is hypothesised that the 'strangeness factors' at Time 1 may have marginally affected the reliability of measurements. At Time 1, children were introduced to new and unfamiliar procedures with a tester that they had met only once before. It was often also the case that they were working in rooms in which they did not usually work, as the provision of a 'quiet room' had been a criterion for settings to be involved in the project.

By Time 3 of testing the amount of variance in reading ability accounted for by phonological awareness and letter knowledge had increased again and reached 71%. The developing strength of the relationship between phonological awareness and reading ability over the period of the study supports the theory that the relationship is reciprocal (Share & Stanovich, 1995). The strength of the association also supports the hypothesis that good readers use 'pictured spelling' to perform phonological awareness tasks (Stuart, 1990). It could be argued that, as children's literacy skills develop, they are likely to reach a point of literacy proficiency at which reading tests and phonological awareness tests measure the same skills.

14.5 Summary

- In children aged 4.0 to 4.5, phonological awareness and letter knowledge accounted for 35% of variance in subsequent reading ability. The finding that pre-literate phonological awareness and letter knowledge were significant predictors of later reading was an unsurprising result that converges with much previous research (for example, Byrne, 1998; Gallagher et al., 2000; Muter et al., 1997).

- In children aged 4.5 to 5.0 years, sixty-five percent of the variance in subsequent reading ability was accounted for by phonological awareness and letter knowledge. It is hypothesised that the increase in variance in reading ability predicted from Time 2 data (compared to Time 1 data) could be due to a sudden increase in focused teaching. It could be argued that children with good phonological awareness at Time 1 would be likely to derive particular benefit from the structured teaching of phonological awareness and letter knowledge that they experienced during their first term at school.

- The developing strength of the relationship between phonological awareness and reading ability over the 12 month period of the study, as children emerged from a pre-literate stage into the early stages of reading, provides support for the hypothesis that the relationship between phonological awareness and reading ability is reciprocal (Share & Stanovich, 1995). It could be argued that, as children's literacy skills develop, it is increasingly likely that they use their reading and spelling skills as an aid to performing phonological awareness tasks (Scholes, 1998; Stuart, 1990). If this is the case, it is likely that there comes a point at which reading tests and phonological awareness tests are measuring the same skills.

Chapter 15

Summary of Main Findings and Conclusions

Introduction and chapter outline

The research literature, reviewed in Chapter 2 and Chapter 3, identifies a great deal of interest and some confusion concerning the skills that are associated with successful reading. This study has investigated the very early stages of reading. Between the ages of 4.0 and 5.5 most children make a seamless transition from being unable to read to being able to recognise and decode words. For children who possess the necessary skills, the transition happens quickly. However, for a few children the transition can be slow and difficult, causing bewilderment and frustration.

In order to understand why some children find the transition difficult, it is necessary to know more about the developmental pathways towards successful word-level reading. For this reason, this longitudinal study has focused not only on measurement of the skills that might correlate with successful reading, but also on the development of these skills over the twelve-month period during which children in England enter school and start to learn to read.

This chapter summarises the main findings arising from the research questions that were identified in Chapter 4 and considers implications for early years education and future research.

15.1 The main findings and conclusions arising from the research questions

This section summarises the main findings and conclusions under the following headings:

- Phonological awareness
- Rapid serial naming
- Verbal short-term memory
- Letter knowledge.

15.1.1 Phonological awareness

The current study argues that phonological awareness is a developmental, unitary construct (see also Schatschneider et al., 1999) comprising awareness of rhymes, syllables, onset-rimes and phonemes. The results of the current study suggest that the development of phonological awareness skills follows a generally consistent pattern in children aged 4.0 to 5.5 years, although there appears to be considerable variability in the speed and timing of development. In the sample of children followed in this study, which was considered to be representative of a normal population, slower developing children were found to be approximately 12 months behind their faster developing peers by the age of 5.5 years.

In convergence with much previous research, the current study suggests that phonological awareness is significantly predictive of reading ability. However, it seems that the phonological awareness skills that predict reading change as children progress from being non-readers to being able to recognise and decode words. In non-readers aged 4.0 to 4.5 years, awareness of the onsets and rimes in words appears to be the linguistic level that is most predictive of subsequent reading ability. This finding provides some support for Goswami and Bryant (1990) who suggest that non-readers' awareness of rhyme and their ability to manipulate onsets and rimes are predictive of subsequent reading ability. However, the current study also provides support for the suggestion by Cardoso-Martins (1994) that global rhyme awareness and onset-rime awareness requiring manipulation of the sound elements of words are different skills. The results of this study suggest that, at age 4.0 to 4.5, onset-rime manipulation is more predictive of subsequent reading ability than simple rhyme awareness.

There is debate in the research literature concerning the extent to which non-readers can demonstrate awareness of phonemes in words. The current study suggests that most non-readers do not show a secure and explicit awareness of phonemes, demonstrated by the ability to blend, segment and delete individual phonemes in words. Some studies that have claimed that non-readers can discriminate phonemes in words have tested a simple level of phoneme awareness that could be reclassified as a global awareness of sounds in words or awareness of onsets in words (for example, Muter et al., 1997).

The results of the current study support a commonly voiced theory that, as children start to learn to read, awareness of phonemes in words becomes more predictive of their reading ability than awareness of other linguistic levels of phonological awareness (for example, Wagner et al., 1994, 1997). However, as children become more proficient in reading and spelling, it could be argued that they use their reading and spelling skills to perform phoneme awareness tasks to such an extent that it becomes difficult to differentiate between tests of phoneme awareness and tests of reading and 'pictured spelling' (Stuart, 1990).

15.1.2 Rapid serial naming

The current study measured two component elements of the rapid serial naming test (Nicolson & Fawcett, 1996): articulation time and inter-stimulus interval time (ISI). Previous research has reported wide variability in the time taken by children to complete serial naming tests (Scarborough, 1998, McBride-Chang & Manis, 1998). The current study also reports wide variability in the time taken to complete the task. However, the results suggest that the variability in overall serial naming time is predominately attributable to variability in ISI time. There was comparatively little variation in articulation time.

Previous research has suggested that slow serial naming is associated with reading disability (Wolf, 1997). The current study argues that it is ISI time, rather than overall serial naming time, that correlates with reading ability. The results of the present study provide some support for Obregon (1994) who suggests that ISI time differentiates normal from dyslexic readers.

The findings of the current study provide some support for the 'double deficit hypothesis' (Wolf & Bowers, 1999), which suggests that children who have slow serial naming speed in combination with poor phonological awareness are frequently severely impaired readers. In the current study, it was noted that eleven of the subgroup of poorest readers (n = 17) all had scores in both serial naming and phonological awareness that were below the mean.

15.1.3 Verbal short-term memory

In line with much previous research (for example, Passenger, 1997; Wagner et al., 1994, 1997), the current study reports a stable and significant association between verbal short-term memory and both subsequent and concurrent reading ability. It is also noteworthy that verbal short-term memory correlates significantly with phonological awareness, letter knowledge and ISI time, providing support for the theory put forward by Elbro et al., 1998 and Snowling, 2000 that all of these skills may rely to some extent on an underlying skill, such as a child's ability to store clear and distinct phonological forms of sounds and words in memory.

Hulme and his colleagues (Hulme et al., 1995, 1997) suggest that children's performance on verbal short-term memory tasks that involve real words may be influenced by the ability to use phonological codes stored in long-term lexical memory to refresh phonological codes that are gradually being lost from short-term memory. The significant correlation between verbal short-term memory and the ISI element of the serial naming test reported in the current study provides support for this hypothesis, as ISI time can be viewed as a measure of the time taken to retrieve phonological codes from long-term lexical memory.

Gathercole and Adams (1994) report a significant correlation between articulation rate and verbal short-term memory (as measured by a digit span test) in children aged five years. They suggest that this association develops between the age of four and five years. The current study found no support for this hypothesis, as no evidence was found of an association between verbal short-term memory and articulation rate at any time. However, it is possible that articulation rate measured as an element of the serial naming test is a qualitatively different measure from articulation rate measured by repeating words out of context.

15.1.4 Letter knowledge

In line with previous research, the current study reports a significant association between the letter knowledge of pre-readers and subsequent reading ability (for example, Gallagher et al., 2000). Letter knowledge and phonological awareness were the two most significant skills to predict reading ability at each time of testing. This finding provides support for Byrne (1998) who suggests that children who can combine letter knowledge with phonological awareness skills are well placed to understand the alphabetic principle that he suggests is necessary for successful reading of an alphabetic script.

15.2 Educational implications

The results of the current study have considerable educational implications, which are discussed under the following headings:

- teaching phonological awareness and letter knowledge
- monitoring progress in the development of phonological awareness
- measuring and improving the quality of phonological representations in memory.

15.2.1 Teaching phonological awareness and letter knowledge

The results suggest that, at all time points from age 4.0 to 5.5 years, phonological awareness and letter knowledge are the most significant predictors of reading ability.

From an educational perspective, Blachman (1997) poses the question 'What are the most appropriate tasks for our early intervention efforts?' (p. 412). The argument put forward in this thesis, that phonological awareness is a developmental, unitary construct, has implications for the choice of activities that are used with young children to encourage the development of the construct. The results of this study suggest that it is not necessary to concentrate specifically on phoneme awareness during the early years even though phoneme awareness might be the longer-term goal. It could be argued that activities that promote awareness of the sound structure of words at lower linguistic levels, such as syllable and onset and rime, can be equally beneficial if they are provided at the appropriate stage of the child's phonological awareness development. An important element of a teaching programme would therefore be for the teacher to be aware of the stage of phonological awareness development that particular children or groups of children have reached, so that the teaching programme moves them forward from this point. In most other aspects of teaching young children this would be accepted as good pedagogy, yet in developing children's awareness of phonological awareness there is sometimes a tendency to believe that only phonemic awareness can influence future reading success.

Byrne (1998) suggests that children need to be taught letter knowledge and phoneme awareness simultaneously in order to understand the alphabetic principle that he considers to underpin successful reading. Recent research involving 51 pre-school, non-reading children has suggested that phoneme awareness generally develops after, and possibly as a consequence of, letter knowledge (Johnston et al., 1996). It could be argued, therefore, that awareness of lower linguistic levels of phonological awareness should be taught together with letter knowledge. The results of the current study suggest that the linguistic level of onset and rime is an ideal vehicle for such linked phonological awareness and letter sound learning.

15.2.2 Monitoring progress in the development of phonological awareness

The results of the current study suggest that normal populations of children follow similar patterns of phonological awareness development, regardless of the speed and timing of that development. It is important, therefore, that teachers are aware that this developmental pattern exists so that they can:

- identify where children are on the continuum
- identify any child who appears not to be following this normal developmental pattern (i.e. developmental deficit rather than developmental lag (Francis et al., 1996).

Tests of word-level reading and nonword reading that are suitable for monitoring children's progress in reading and decoding are now frequently used as part of the assessment procedures in primary schools. However, such tests tend to be more suitable for children who have passed the initial stages of learning to read. There is less emphasis on assessment of the skills of pre-readers and emergent readers. The phonological awareness tests designed for use in the current study could be adapted for use by classroom teachers to be used as either diagnostic assessment instruments or teaching activities.

15.2.3 Measuring and improving the quality of phonological representations

It has been suggested that the ability to store clear phonological representations of words and sounds in memory may be an underlying cause of several deficits that appear to be associated with reading disability (Elbro et al., 1998; Swan & Goswami, 1997). Snowling and Hulme (1994) hypothesise that children who come to the task of learning to read with well-specified phonological representations are better able to establish links between phonemes and graphemes and written words and spoken words. Snowling (2000) discusses a range of tasks that might be considered to be measures of the quality of phonological representations, such as phoneme awareness, verbal short-term memory (measured by digit span or nonword repetition) and serial naming speed. However, there is comparatively little discussion in the research literature about the causes of poorly specified phonological representations or about possible remediation strategies. It would be of value to investigate whether such deficits are genetic, non-genetically biological or experiential and, whatever their cause, it would be educationally valuable to screen for them at a young age, so that compensatory teaching strategies can be considered.

15.3 Research implications

The results of the current study suggest two specific areas for future research. The first of these has already been mentioned in this chapter: the need to gain greater understanding of the phonological representations hypothesis (Elbro et al., 1998; Snowling, 2000; Swan & Goswami, 1997). This thesis has been careful not to confuse prediction with causality (see Chapter 2, section 2.4.2). Although phonological awareness and letter knowledge have been suggested to predict reading ability (both longitudinally and concurrently), a range of evidence from this study and other research suggests that the direct cause of skill deficits lie more deeply in the child's genetic, biological and/or experiential history. In particular, it has been noted in recent research, including the current study, that there are a range of inter-related skills that predict reading difficulty. For example, the current study identifies several phonological deficits that correlate significantly with reading ability: phonological awareness at four linguistic levels, letter knowledge, verbal short-term memory measured by digit span, the ISI element of serial naming and the ability to quickly learn verbal/visual symbol associations. Other research has also included speech rate (Hulme & Roodenrys, 1995) as a possible phonological correlate with reading ability. However, there appears to have been little research to date that investigates the phonological representations of younger children and the possible causes of imperfectly acquired and stored phonological codes.

The second area for future research suggested by the current study is a continued investigation of the ISI element of rapid serial naming. The current study investigated only the serial naming of pictured objects, as this was the most appropriate stimulus for the age range concerned. It would be interesting to compare the ISI time of a cohort of children at different stages of their development using different stimulus items. Results over the period of this study, and noted in previous research (for example, Scarborough, 1998), suggest that ISI time is a relatively stable construct over time. It would therefore be interesting to measure ISI time both before and after reading instruction, in children of different ages, using different stimulus items.

15.4 Limitations of the study

Rudestam and Newton (1992) comment on the importance of recognising the limitations of a study. There are three limitations that are particularly worthy of mention. They are concerned with:

- The size of the sample
- The length of the investigation
- The skills measured during the course of the study.

15.4.1 The size of the sample

At the start of the study, 78 children were involved. However, 10 children were lost through attrition. It had been hoped that the attrition rate would be lower. As the parents of all of the children had given written permission for their children to be involved, it was assumed that if they knew that they were leaving the area they would have mentioned this fact, or declined the invitation to take part. The research methodology literature was to some extent ambiguous about the minimum number of children who should be involved in a study that planned to use multiple regression analysis. Practical considerations also had to be taken into account, as it was a single-researcher study. In retrospect, however, it may have improved the credibility of the study and the overall reliability of results if more children had been included.

15.4.2 The length of the investigation

The length of the reported investigation was also constrained by practical considerations. The investigation focused on the important period of time as children emerged from being non-readers into the early stages of being able to read. However, it would have been interesting to lengthen the study by continuing to investigate progress over time, particularly for the slower developing children so that any possible developmental deficit, in addition to developmental lag, could have been investigated (Francis et al., 1996).

15.4.3 The skills measured during the course of the study

During the pilot study, two measures of verbal short-term memory were used. It was decided not to use the Non-Word Repetition Test (Gathercole et al., 1994) during the main study for reasons discussed in Chapter 6, section 6.2.3. In retrospect however, it would have been valuable to have left this test in the test battery, as it is hypothesised in the research literature (for example, Snowling, 2000) that nonword repetition is an alternative measure of the quality of a child's phonological representations.

15.5 Conclusion

This study has measured a range of reading related skills and investigated associations with subsequent and concurrent reading ability. Phonological awareness and letter knowledge are suggested to be the most significant predictors of reading ability in normal populations of children aged from 4.0 to 5.5 years. It is argued that phonological awareness is a developmental, unitary construct and that the phonological awareness tasks that most significantly predict reading ability change over time. Children who exhibit developmental lag in phonological awareness can be detected from as young as four years of age.

The children who were most delayed in acquiring word-level reading ability at age 5.0 to 5.5 years appeared to perform below average on a range of skills, including phonological awareness, letter knowledge, verbal short-term memory and inter-stimulus interval (ISI) time, measured as a component element of rapid serial naming. Deficits in phonological awareness, letter knowledge and verbal short-term memory can be detected in children as young as four years of age, but the relationship between ISI time and reading ability appears to develop later, between the ages of 5.0 and 5.5 years.

The results of the study suggest that children's abilities in important reading-related skills can be monitored from age four years and that sensitive monitoring can identify children at risk of subsequent reading difficulty. Such identification can be valuable if intervention programmes can provide extra support for children as they begin to make the transition from being non-readers to readers. It could be argued that it is no longer necessary or acceptable to wait for children to fail at reading before intervention programmes are implemented.

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Appendix A

Order of presentation for blending, segmenting and elision test items during the longitudinal study.

Syllable Awareness

Blending	Segmenting	Elision (part of word in brackets to be deleted)
breakfast	bedroom	bed(room)
sister	spider	(rain)bow
carpet	rainbow	(spi)der
Monday	pencil	(ta)ble
baby	tiger	ti(ger)
monkey	table	pen(cil)

Onset-Rime Awareness

Blending	Segmenting	Elision (part of word in brackets to be deleted)
bird	cold	g(ame)
girl	game	w(all)
jam	to	f(oot)
rain	wall	(t)o
car	queen	(qu)een
farm	foot	(c)old

Phoneme Awareness

Blending	Segmenting	Elision (part of word in brackets to be deleted)
tap	bag	(p)in
cat	pin	(p)eg
bed	mud	(m)ud
leg	ten	ba(g)
fox	peg	te(n)
sun	box	bo(x)

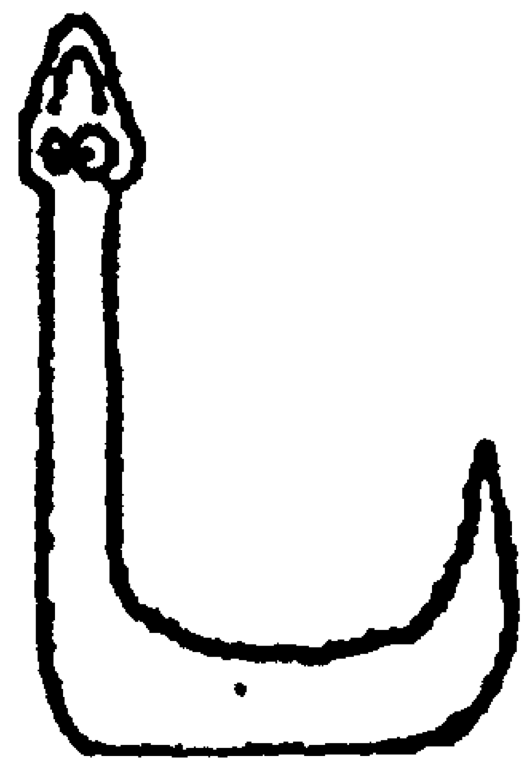
Appendix B

Order of presentation for rhyme awareness test items during longitudinal study.

Word pairs	
blink,	think
peg,	leg
cup,	pen
dig,	bag
skip,	flip
bad,	bag
cap,	tap
pen,	peg

Appendix C

The stimuli used for the rate of learning sound/visual symbol associations test



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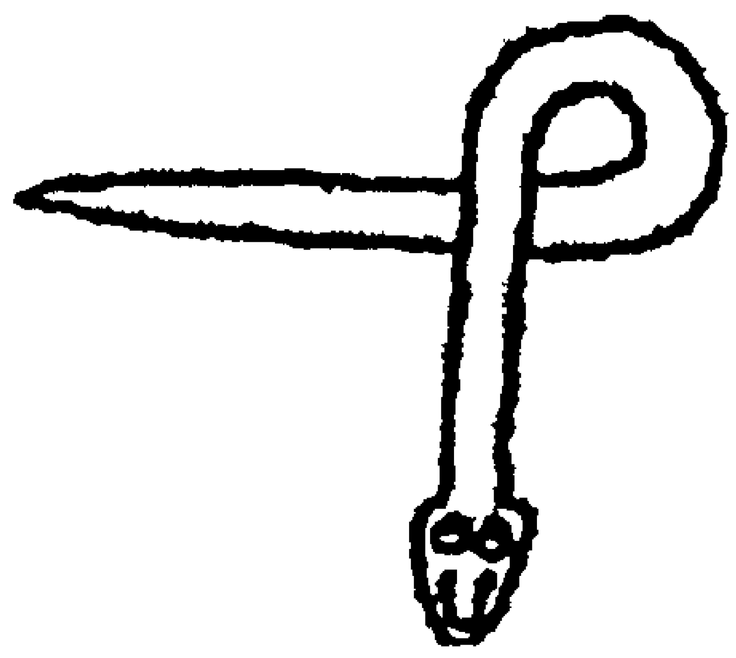

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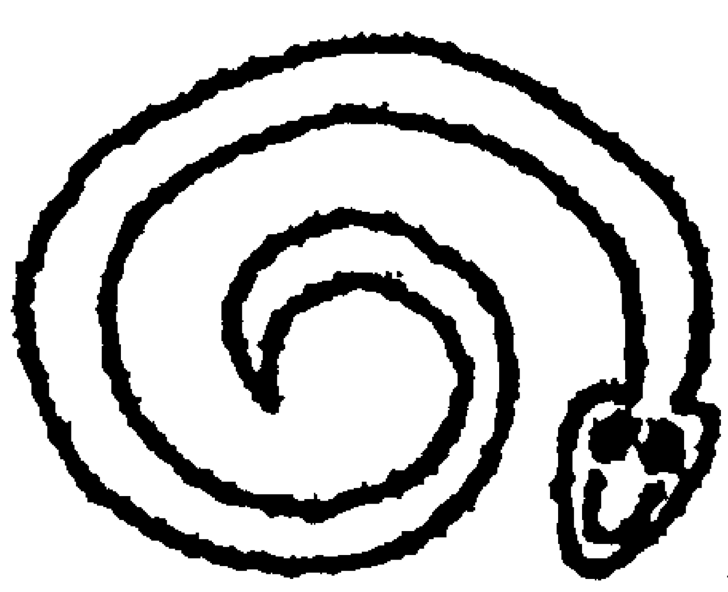

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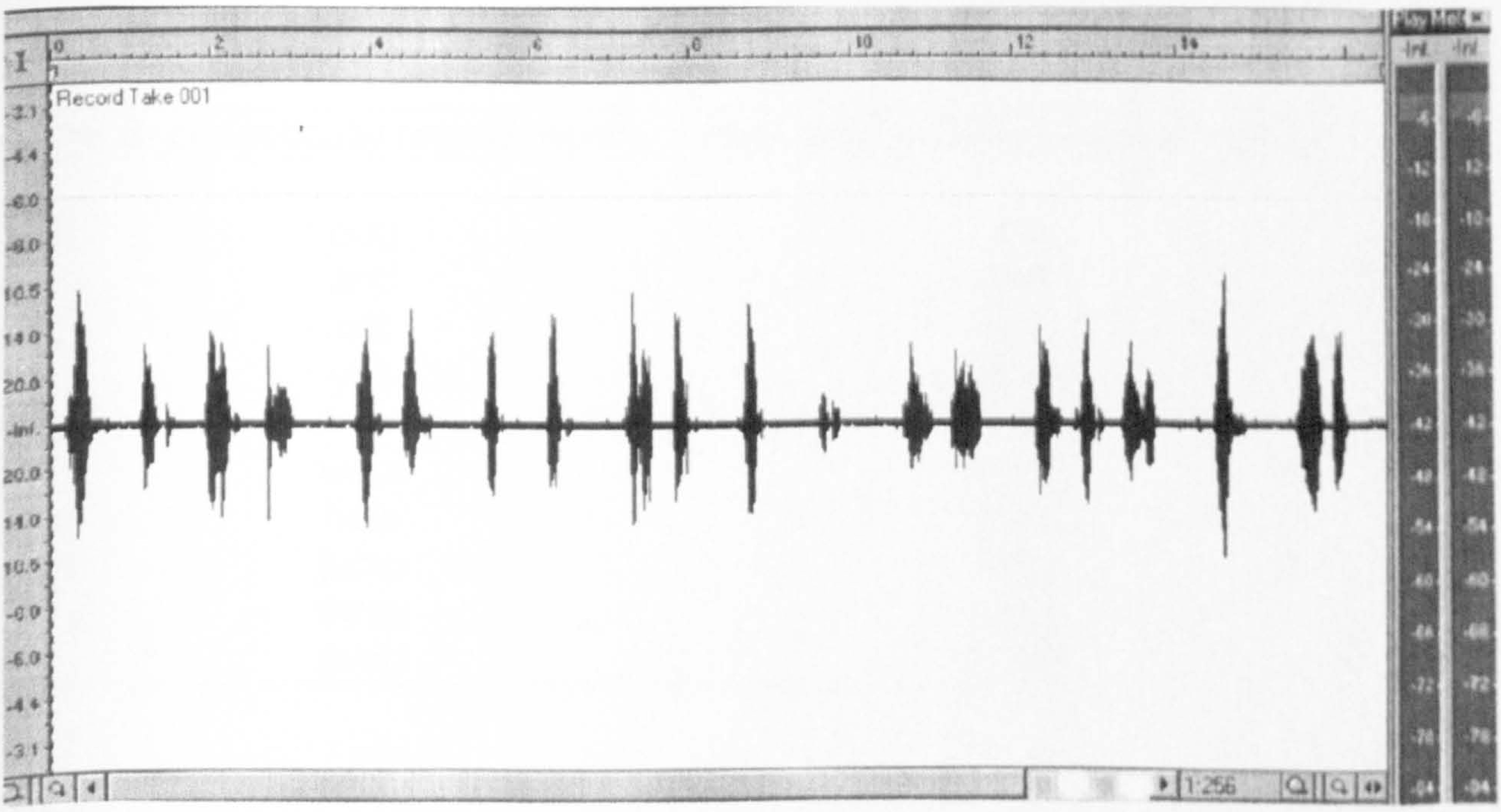
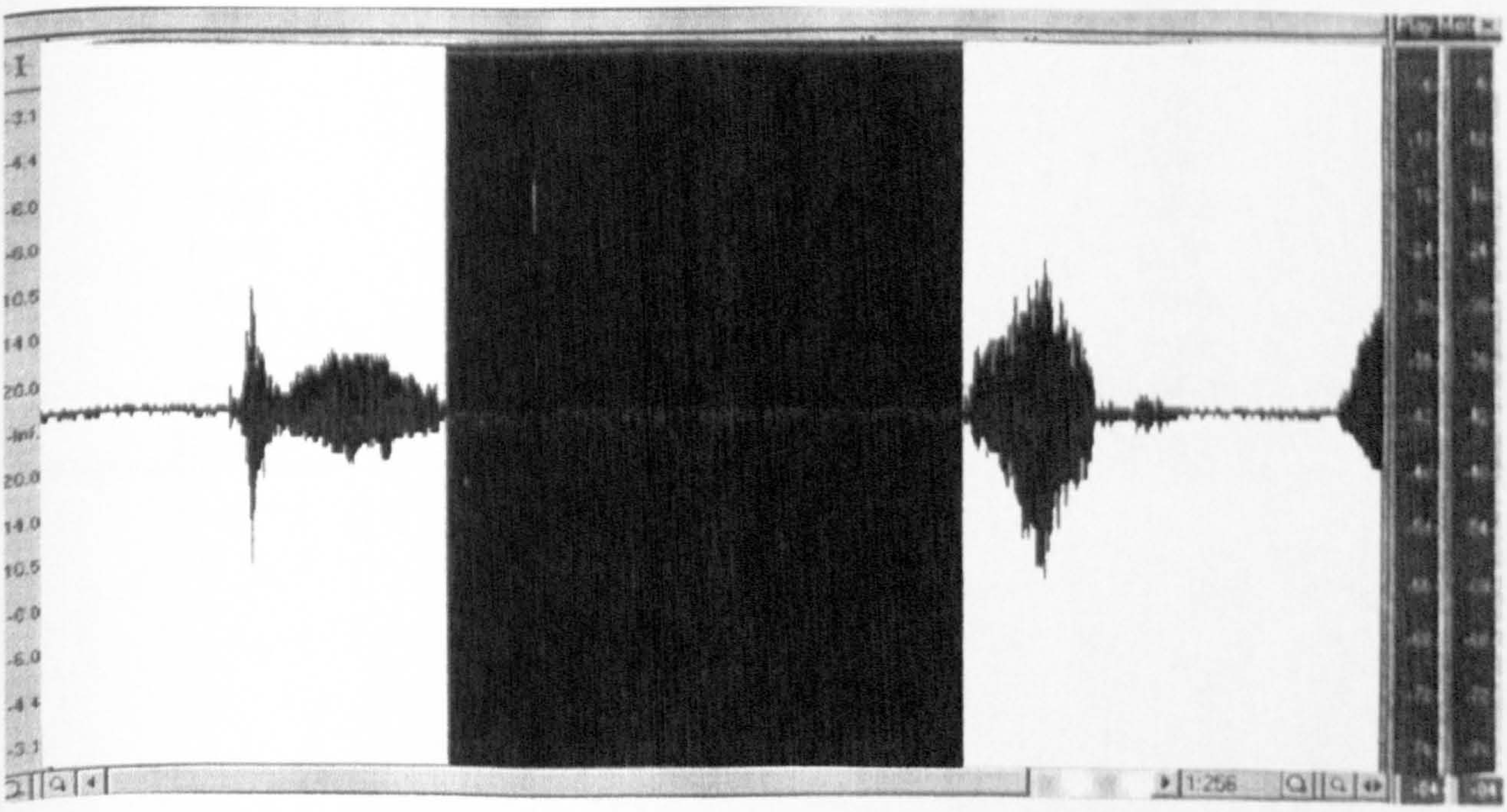
Appendix D

The sound waveforms for the 20 words of the serial naming test



The sound waveforms of two words from the serial naming test with the inter-stimulus time highlighted



Appendix E

The Reading Test Word List
NLS = National Literacy Strategy

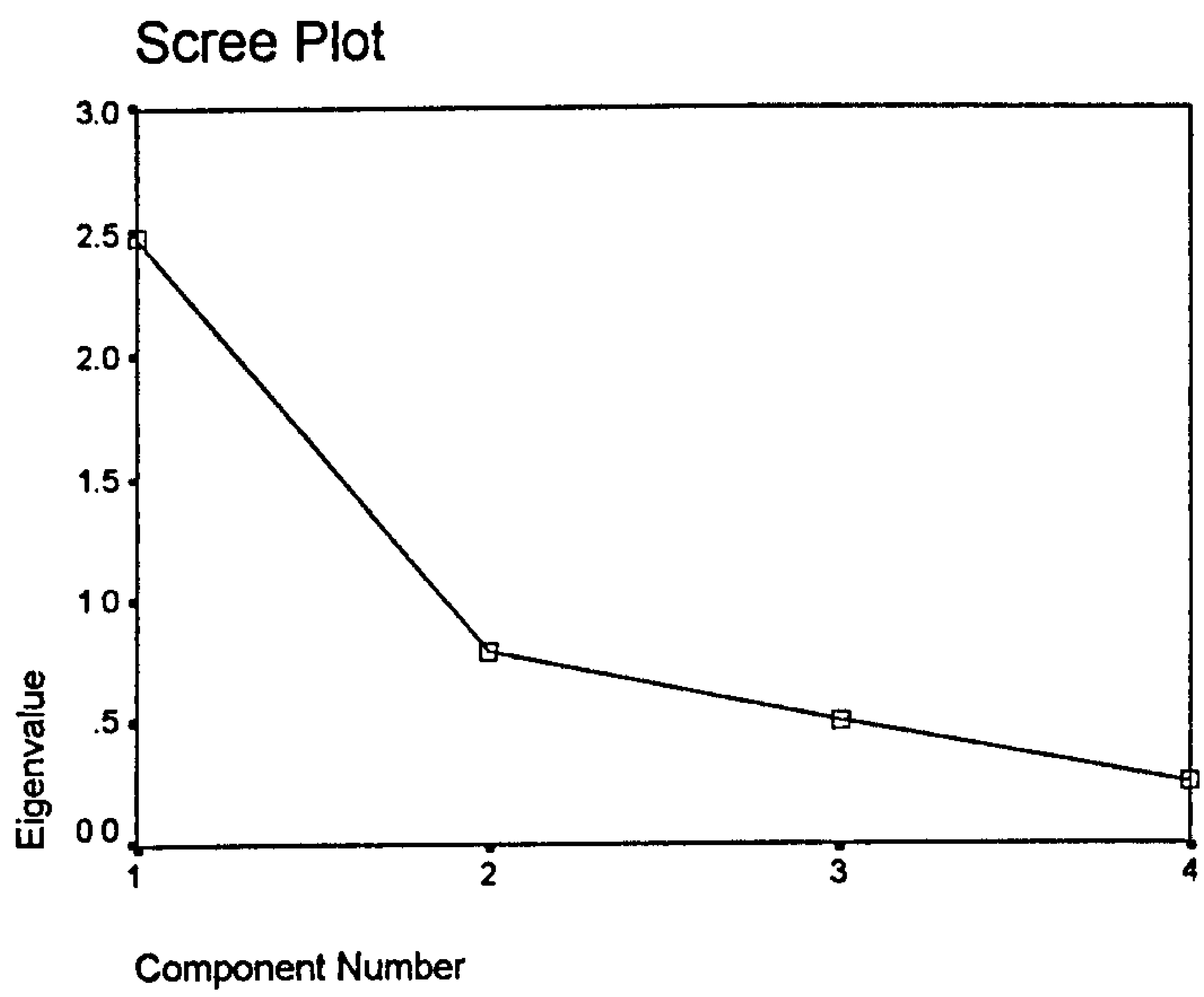
NLS: phonetically regular words	NLS: phonetically irregular words
dog	the
and	was
cat	you
yes	she
from	girl
went	come
help	said
jump	they
three	night
lived	laugh

Non-NLS: phonetically regular words	Non-NLS: phonetically irregular words	Phonetically regular nonwords
fat	cow	mot
bus	toy	hin
pig	fly	feg
hop	Mrs.	kib
frog	bird	mosp
hand	shoe	hast
swim	work	prab
skip	talk	sted
think	table	gromp
stamp	write	drant

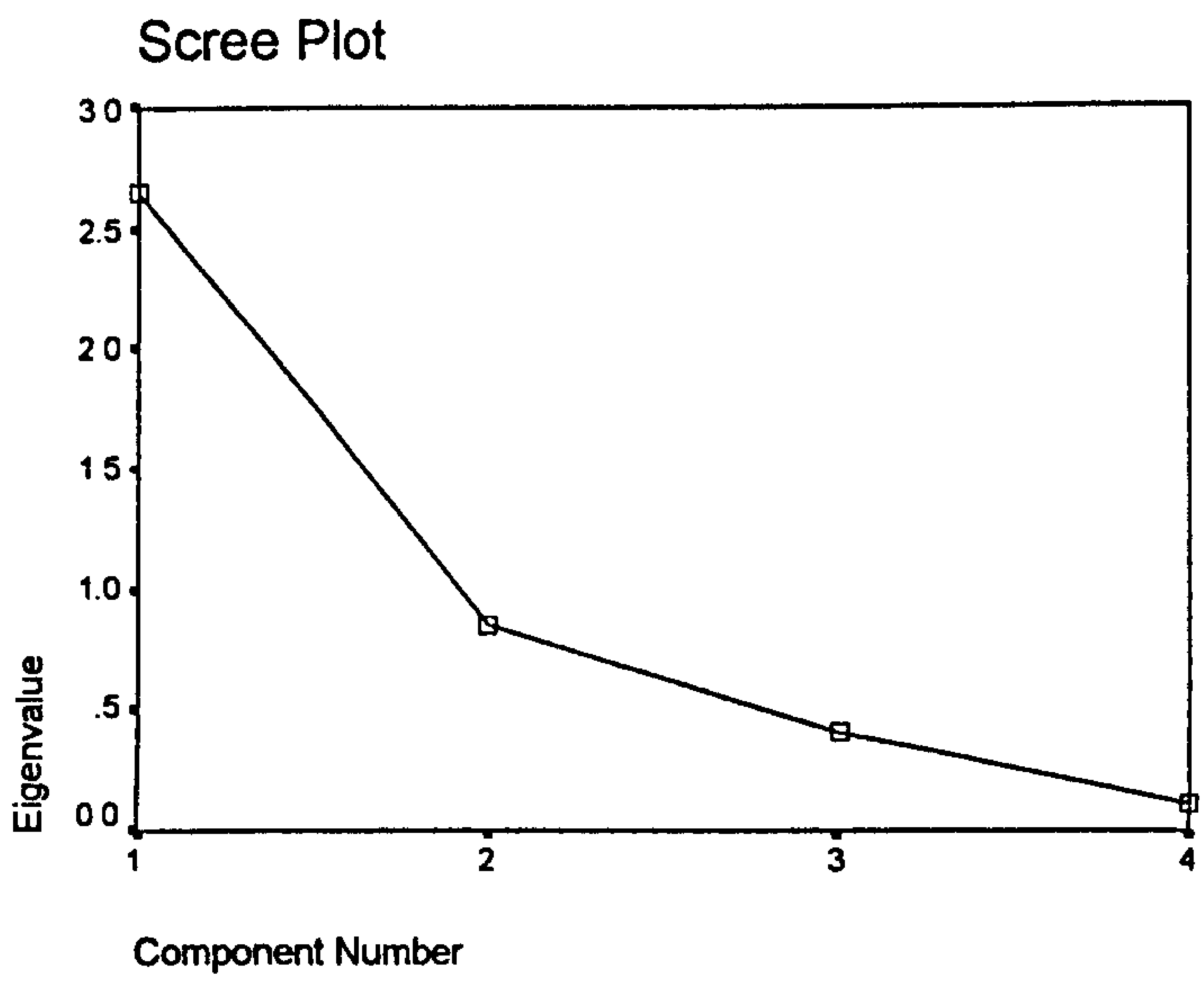
Appendix F

Scree plots (Cattell, 1966) resulting from factor analyses investigating structure of phonological awareness construct.

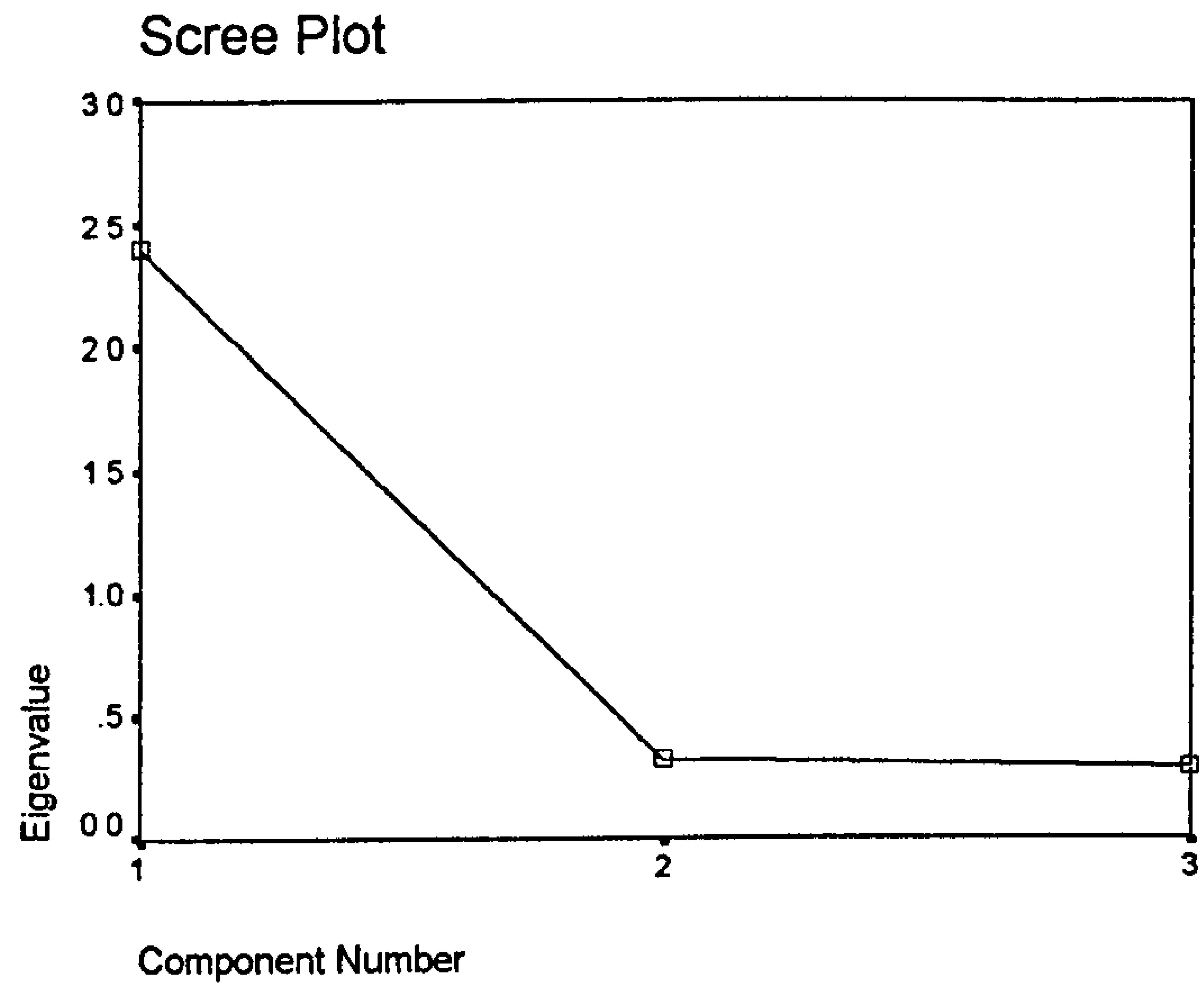
Factor analysis 1:
Scree plot resulting from factor analysis of tasks at different linguistic levels (rhymes, syllables, onset-rimes and phonemes) at Time 1.



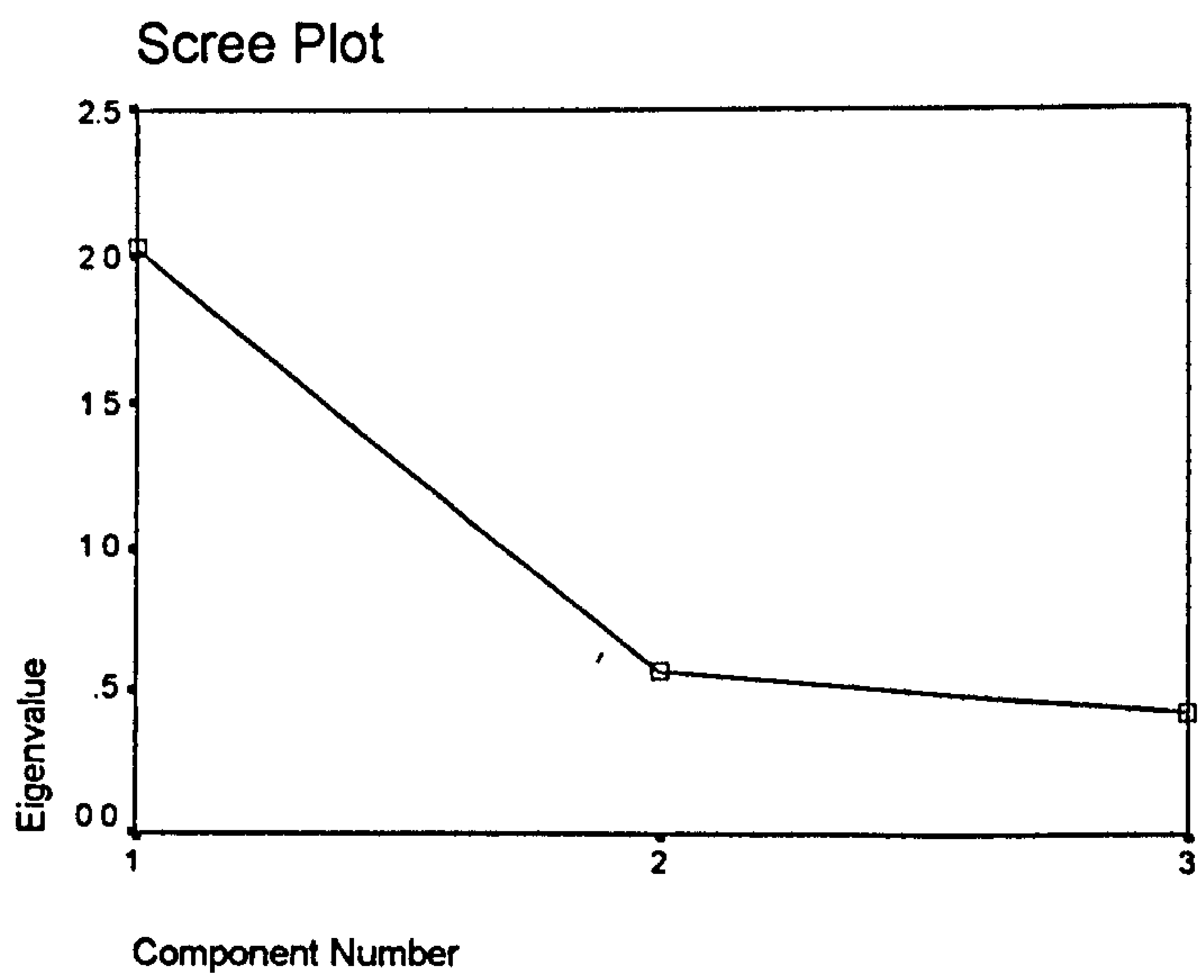
Factor analysis 2:
Scree plot resulting from factor analysis of tasks at different linguistic levels (rhymes, syllables, onset-rimes and phonemes) at Time 3.



Factor analysis 3:
Scree plot resulting from factor analysis of different task types (blending, segmenting and elision) at Time 1.



Factor analysis 4:
Scree plot resulting from factor analysis of different task types (blending, segmenting and elision) at Time 3.



Appendix G
Multiple Regression on reading ability from Time 1 independent variables

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	PA1	.	Forward (Criterion: Probability -of-F-to-enter <= .050)
2	LKN1	.	Forward (Criterion: Probability -of-F-to-enter <= .050)
3	ARTRAT1	.	Forward (Criterion: Probability -of-F-to-enter <= .050)

a. Dependent Variable: READNORM

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.544[a]	.296	.285	1.5338
2	.609[b]	.371	.350	1.4623
3	.646[c]	.417	.388	1.4191

a. Predictors: (Constant), PA1

b. Predictors: (Constant), PA1, LKN1

c. Predictors: (Constant), PA1, LKN1, ARTRAT1

d. Dependent Variable: READNORM

continued...

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1.923	.386		4.979	.000
	PA1	.107	.021	.544	5.066	.000
2	(Constant)	1.762	.373		4.721	.000
	PA1	8.101E-02	.023	.410	3.596	.001
	LKN1	.416	.156	.304	2.667	.010
3	(Constant)	6.801	2.350		2.895	.005
	PA1	8.049E-02	.022	.408	3.682	.001
	LKN1	.414	.151	.303	2.738	.008
	ARTRAT1	-3.948	1.819	-.216	-2.171	.034

a. Dependent Variable: READNORM

Excluded Variables[d]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	LKN1	.304[a]	2.667	.010	.326	.806
	RIME1	.178[a]	1.439	.155	.183	.740
	VSTM1	.249[a]	1.733	.088	.218	.541
	ISIRAT1	-.017[a]	-.152	.879	-.020	.983
	ARTRAT1	-.217[a]	-2.075	.042	-.259	1.000
2	RIME1	.082[b]	.644	.522	.084	.659
	VSTM1	.174[b]	1.225	.226	.157	.513
	ISIRAT1	.002[b]	.018	.986	.002	.979
	ARTRAT1	-.216[b]	-2.171	.034	-.272	1.000
3	RIME1	.133[c]	1.068	.290	.139	.638
	VSTM1	.157[c]	1.136	.261	.148	.511
	ISIRAT1	.036[c]	.349	.728	.046	.956

a. Predictors in the Model: (Constant), PA1

b. Predictors in the Model: (Constant), PA1, LKN1

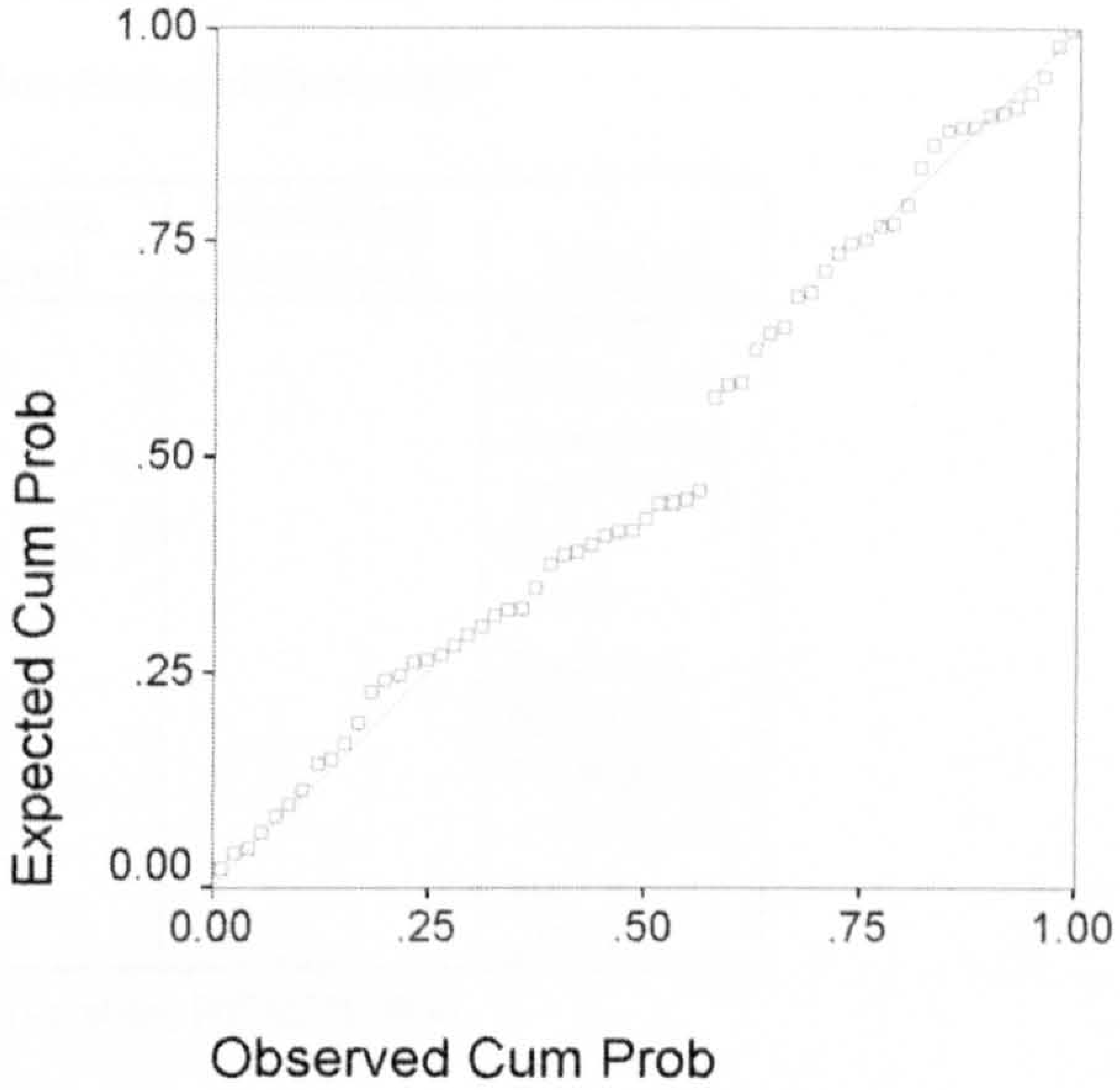
c. Predictors in the Model: (Constant), PA1, LKN1, ARTRAT1

d. Dependent Variable: READNORM

continued...

Analysis of residuals

Dependent Variable: READING



Appendix H
Multiple Regression on reading ability from Time 2 independent variables

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	PA2	.	Forward (Criterion: Probability -of-F-to-en ter <= .050)
2	LKN2	.	Forward (Criterion: Probability -of-F-to-en ter <= .050)

a. Dependent Variable: READNORM

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.739[a]	.546	.539	1.2221
2	.801[b]	.641	.630	1.0957

Model Summary[c]

Model	Change Statistics				
	R Square Change	F Change	df1	df2	Sig. F Change
1	.546	77.112	1	64	.000
2	.095	16.613	1	63	.000

a. Predictors: (Constant), PA2

b. Predictors: (Constant), PA2, LKN2

c. Dependent Variable: READNORM

continued....

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.533	.375		1.421	.160
	PA2	.110	.013	.739	8.781	.000
2	(Constant)	3.396	.779		4.361	.000
	PA2	6.857E-02	.015	.460	4.506	.000
	LKN2	-.725	.178	-.416	-4.076	.000

a. Dependent Variable: READNORM

Excluded Variables[c]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	LKN2	-.416[a]	-4.076	.000	-.457	.548
	RIME2	-.151[a]	-1.624	.109	-.200	.798
	VSTM2	.091[a]	.697	.488	.087	.415
	ROL3	.121[a]	1.354	.180	.168	.872
	ISIRAT2	-.049[a]	-.579	.564	-.073	1.000
	ARTRAT2	-.078[a]	-.920	.361	-.115	.999
2	RIME2	-.151[b]	-1.825	.073	-.226	.798
	VSTM2	.006[b]	.046	.963	.006	.401
	ROL3	.104[b]	1.290	.202	.162	.870
	ISIRAT2	-.058[b]	-.770	.444	-.097	.999
	ARTRAT2	-.101[b]	-1.339	.185	-.168	.994

a. Predictors in the Model: (Constant), PA2

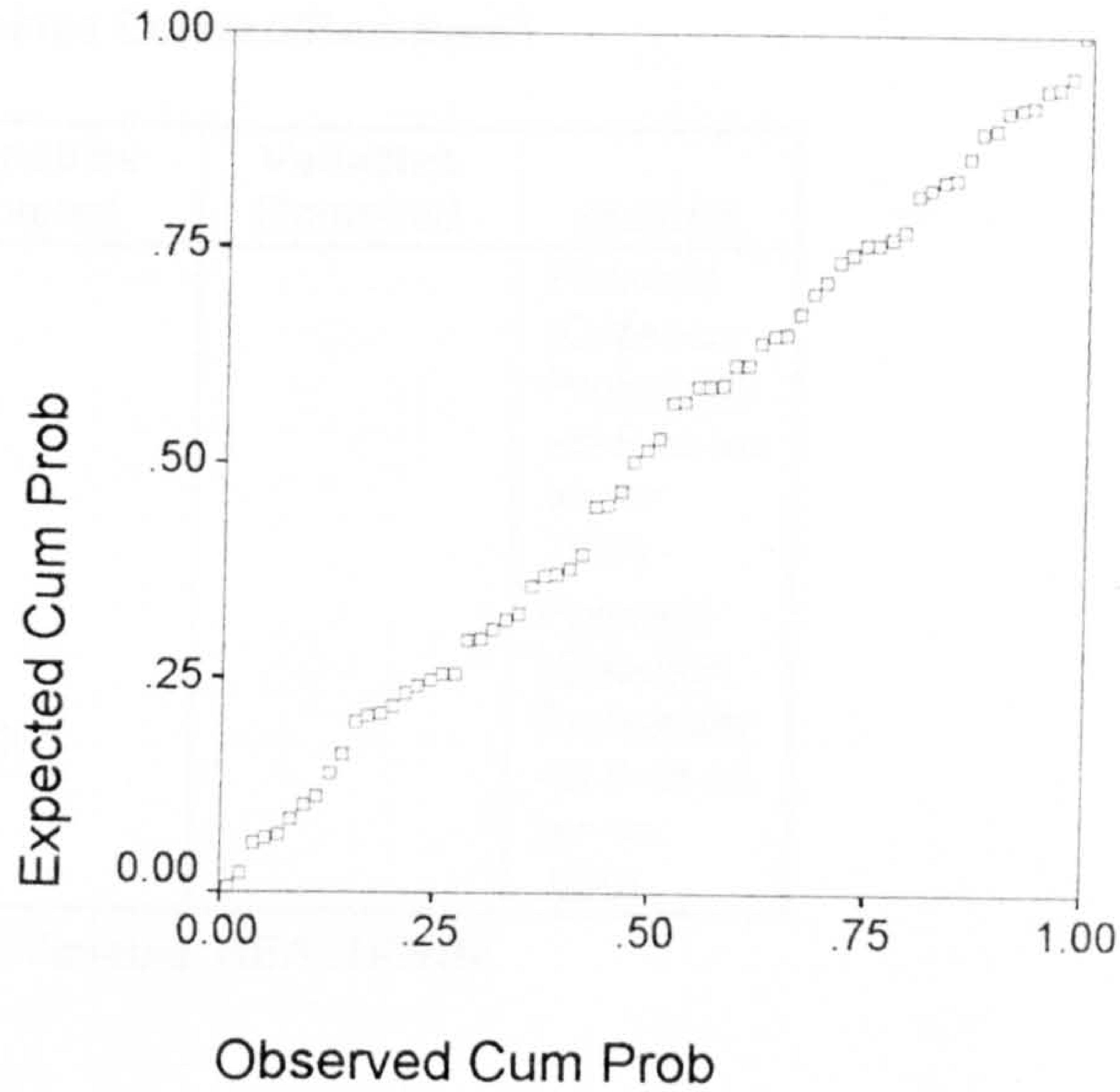
b. Predictors in the Model: (Constant), PA2, LKN2

c. Dependent Variable: READNORM

continued....

Analysis of residuals

Dependent Variable: READING



Appendix J
Multiple regression on reading ability from Time 3 independent variables

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	PA3	.	Forward (Criterion: Probability-of-F-to-enter <= .050)
2	LKN3	.	Forward (Criterion: Probability-of-F-to-enter <= .050)

a. Dependent Variable: READNORM

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.803[a]	.644	.639	1.0905
2	.845[b]	.714	.704	.9865

Model Summary[c]

Model	Change Statistics				
	R Square Change	F Change	df1	df2	Sig. F Change
1	.644	114.200	1	63	.000
2	.069	14.984	1	62	.000

a. Predictors: (Constant), PA3

b. Predictors: (Constant), PA3, LKN3

c. Dependent Variable: READNORM

continued....

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.031	.450		-2.291	.025
	PA3	.112	.010	.803	10.686	.000
2	(Constant)	.815	.627		1.301	.198
	PA3	8.328E-02	.012	.596	6.895	.000
	LKN3	-1.668	.431	-.335	-3.871	.000

a. Dependent Variable: READNORM

Excluded Variables[c]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	RIME3	.052[a]	.653	.516	.083	.899
	VSTM3	-.038[a]	-.365	.716	-.046	.536
	ROL3	.080[a]	.984	.329	.124	.855
	ISIRAT3	.024[a]	.304	.762	.039	.919
	ARTRAT3	.049[a]	.647	.520	.082	1.000
	LKN3	-.335[a]	-3.871	.000	-.441	.618
2	RIME3	.015[b]	.212	.833	.027	.883
	VSTM3	-.161[b]	-1.672	.100	-.209	.487
	ROL3	.022[b]	.287	.775	.037	.818
	ISIRAT3	-.056[b]	-.751	.455	-.096	.850
	ARTRAT3	.068[b]	.993	.325	.126	.995

a. Predictors in the Model: (Constant), PA3

b. Predictors in the Model: (Constant), PA3, LKN3

c. Dependent Variable: READNORM

continued....

Analysis of residuals

Dependent Variable: READING