A PHONEME DELETION TASK WITH NO VERBAL PRODUCTION COMPONENT

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by

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Abstract

The abilities of good and poor readers were investigated in a phoneme awareness task in which the first phoneme of a word was deleted. Instead of having to produce the answer, like traditional phoneme awareness experiments, the participants had to recognize the correct target of phoneme deletion by comparing word pairs. For example, participants had to determine that the word pair 'Blake-bake', which was presented aurally, was an incorrect answer, because the second phoneme had been removed from the second word of the word pair. The results show that there was a significant effect of group, with poor readers' performance being intermediate between that of younger and older groups of good readers. An effect of condition was also found, with all groups having difficulty distinguishing between word pairs in which the first sound has been removed ('Blake-lake') and word pairs in which the whole cluster had been removed ('Blake-ache'). Other results suggest that phoneme awareness develops incrementally. In conclusion, even with the production component removed, this modified phoneme awareness task is still a reliable measure of reading ability, since it distinguishes between good and poor readers.

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1 Introduction

Dyslexics have been viewed as individuals with deficits in reading and spelling, with an impaired ability to use an alphabetic writing system (see § 5 for more). However, dyslexia is more than just a reading/spelling deficit; it is a type of Specific Language Impairment (Snowling, 2000: 213). As such, dyslexia sheds light on the normal linguistic system, specifically its relationship to reading and spelling ability, and is of theoretical interest to linguists. One way of examining the linguistic system is by testing knowledge such as phoneme awareness, a type of metalinguistic knowledge involving the awareness that words are composed of individual sounds (Ball, 1993: 142) (see § 3 for more). The interesting question about phoneme awareness is whether this analytical metaphonological knowledge arises independently of knowledge of an alphabetic writing system. By testing both good and poor readers, a normal and disordered system can be compared to determine what is a typical and an atypical linguistic system, and thus how abilities such as phoneme awareness reading/spelling ability are related.

This thesis reexamines dyslexics' phoneme awareness abilities. Traditional phoneme awareness tasks (such as those described in § 3.2) require participants to *produce* the result of whatever sort of operation they are completing. For example, when asked what the word 'trip' is without the '/t/' sound, the participant must produce the target answer, 'rip'. However, this study examines what would happen if the participants no longer had to *produce* the answer, but instead merely had to decide whether or not the answer was correct by recognizing the correct target of phoneme deletion. A survey of the literature reveals that no other experiment employs a similar methodology, in which the experimenters have eliminated production from the task in such a fashion.

Furthermore, this experiment will also reduce orthographic priming as a factor influencing the results of phoneme awareness tasks. Orthographic knowledge can both hinder and enhance performance on phoneme awareness tasks and is often used as a compensatory strategy by dyslexics (as discussed in § 7.1.3). Therefore, it is important that this factor also be eliminated, or at the very least reduced, from any task involving phoneme awareness.

The first several sections will provide introductory and background information on several general areas crucial to this thesis, such as specific language impairment (§ 2), phoneme awareness (§ 3), perception/production and memory types (§ 4), and dyslexia (§ 5). This will be followed by discussions of the hypotheses (§ 6), the methodology of this experiment and the associated methodological underpinnings (§ 7), the presentation of the results (§ 8) and an interpretation of the results which indicate that production does not influence the performance of good and poor readers on this phoneme awareness task (§ 9).

2 Dyslexia and Specific Language Impairment

This section will introduce and define dyslexia and specific language impairment, in order to introduce the purpose of this study and the abilities and deficits of some of its participants. Dyslexia will be discussed in more detail in § 5.

While dyslexia has been traditionally viewed as a reading disability, in reality there is more to this disorder than reading problems alone. Dyslexia is a mild form of specific language impairment. Specific language impairment (SLI) is "the diagnostic category for children who fail to develop age-appropriate language despite being normal in other respects" (Joanisse and Seidenberg, 1998: 240). SLI is characterized by problems or deficits which are limited to language development. People with SLI show no intellectual, emotional, or hearing impairment and their development in other areas is normal (James, 1999: 223).

Like people with other forms of specific language impairment, dyslexics may experience delays in phonological development (Joanisse and Seidenberg, 1998: 244; James, 1999: 223; Snowling, 2000: 88). Furthermore, there is also evidence that people with SLI, including dyslexics, have impairments in speech perception (see § 5.4), and that these speech-processing impairments result in the development of poor phonological representations (Joanisse and Seidenberg, 1998: 241).

Many children with SLI/dyslexia also display abnormal phonological production. This can be seen in their "poor repetition of nonsense words, misarticulating or deleting phonemes from words, difficulty in identifying words with similar phonemes [...] and poor 'phonological awareness' as measured by tasks requiring them to analyze a word into its constituent segments" (Joanisse and Seidenberg, 1998: 243) (see § 5.2 for details). Finally, people with SLI/dyslexia exhibit reduced verbal short-term working memory spans for both speech and non-speech strings (Joanisse and Seidenberg, 1998: 242; Snowling, 2000: 35) (see § 5.3 for details).

In summary, deficits associated with dyslexia do not just include difficulties with reading, spelling, and associated metaphonological tasks; they also include phonological deficits and associated verbal short-term memory deficits. Meanwhile, as will be discussed in § 7.1, phoneme awareness tasks often tax short-term memory heavily.

Before discussing dyslexic deficits in detail (§ 5), it is first necessary to describe the normal system with which the dyslexics are being compared. Section § 3.1 defines phoneme awareness (a metaphonological/metalinguistic skill that develops synchronically with reading ability); section § 3.2 discusses different types of phoneme awareness tasks; section § 3.3 overviews the normal development of phoneme awareness; section § 3.4 discusses the relationship between reading/spelling ability and phoneme awareness; and section § 4 overviews verbal short-term memory and speech processing in the normal system.

3 Phoneme awareness

3.1 What is phoneme awareness?

Phoneme awareness is a term used to describe the "conscious access to the phonemic level of the speech stream and some ability to cognitively manipulate representations at this level" (Stanovich 1986b: 362 in Ball, 1993: 141). Phoneme awareness is an instance of the ability to treat an aspect of language as an object of study or introspection. As such, phoneme awareness is quite different from the unconscious ability to use language for its primary purpose - communication. Phoneme awareness can thus be considered as a subcategory of a more general ability, metalinguistic awareness. Both terms refer "to the ability of the language user to reflect on and to manipulate the form (*structural* features) of spoken language" (Ball, 1993: 142).

As a subcategory, phoneme awareness is the area of metalinguistic awareness involved with the comprehension that spoken words are composed of individual sound units or phonemes (Ball, 1993: 142). Phoneme awareness is the ability to segment words into their constituent phonemes. It is considered necessary to master reading in an alphabetic system (Brady and Shankweiler, 1991: 1) and correlates with both reading and spelling abilities (Bruck and Treiman, 1990: 159).

There are many different types of phoneme awareness. These different types will be overviewed in the next section.

3.2 *Types of phoneme awareness tasks*

Typically, phoneme awareness tasks "involve counting, adding, deleting, or identifying the position of phonemes in familiar words and nonwords" (Joanisse, Manis, Keating and Seidenberg, 1998: 136). There are numerous different types of metalinguistic awareness and thus different types of phoneme awareness tasks, which will be briefly outlined, with examples, in this section. These different types of phoneme awareness are from Elbro (1996: 456).

1) One type of phoneme awareness looks at rhyme related tasks including providing, categorizing and judging rhymes; for example, deciding whether sets of words rhyme when they have different spelling patterns, such as though/low and wait/late.
2) Another involves finding words that contain certain sounds, such as providing alliterations or categorizing words by single sounds or strings of sounds; for example, identifying words beginning with /t/ or /tr/.
3) Phoneme awareness may also involve combining sounds into words through tasks involving phoneme synthesis or blending; for example, combining the phonemes /k/, /œ/ and /t/, to get the word 'cat'.
4) Another type of phoneme awareness involves segmentation of sounds using blocks, clapping, or counting sounds; for example, 'cat' (/k/ + /œ/ + /t/) could be segmented using three blocks, three claps, or by counting three sounds.
5) Omitting sounds from words is a type of phoneme awareness task where phonemes are deleted. Phoneme awareness includes the ability to remove consonants from a word and pronounce the result, a task known in the literature as a 'Rosner' task. A

typical 'Rosner' task, for example, would be to remove the first sound of the word 'trip' and pronounce the result, 'rip' (Rosner and Simon, 1971).

6) One final type of phoneme awareness task involves phoneme substitution, phoneme reversal, or phoneme games such as 'pig latin' where the first sound of a word is moved to the end and 'ay' is added to it. (For example, cat becomes 'at-cay' and trip becomes 'rip-tay').

This thesis concerns only with one particular type of phoneme awareness, the so-called 'Rosner' task. As discussed above, a typical 'Rosner' task would be to remove the first sound of the word 'trip' and pronounce the result, 'rip'. The next section will discuss the normal development of phoneme awareness.

3.3 Normal development of phoneme awareness

Phoneme awareness occurs on a continuum (Treiman and Zukowski, 1991: 67) and its development follows an incremental pattern (Ball, 1993: 142). Children first become aware that a string of speech can be divided into smaller units of meaning, or words. This is followed by the awareness that words can be segmented into syllables, syllables into onsets and rhymes, and onsets and rhymes into phonemes (Ball, 1993: 142). Before children are able to segment clusters into singleton segments or phonemes they treat clusters as a single unit (Barton, Miller and Macken, 1980: 105). Support for the incremental development pattern comes from various studies, such as Treiman and Zukowski (1991: 74) who found that the level of the metaphonological task distinguishes between preschool, kindergarten and first grade children. The preschool children could only perform well on tasks involving the knowledge of words and syllables. However, the kindergarten children were able to complete tasks requiring knowledge of onsets and rhymes, and the first grade children performed well on tasks requiring knowledge of phonemes. Studies such as Treiman and Zukowski (1991) have led to the conclusion that there is a sequence of stages in the development of phoneme awareness.

There is a relationship between phoneme awareness and the ability to read and spell whereby these abilities require the use of an alphabetic and a phonetic code (Ball, 1993: 143). Therefore, when learning to read children need to realize that words are composed of phonemes or sounds and that these phonemes, in turn, are represented by graphemes or letters (Ball, 1993: 143). Unfortunately, "in some children, the relation between phonological and orthographic representation does not develop readily, even with instruction" (Post, Foorman and Hiscock, 1997: 4). These children, i.e. dyslexics, will not yet have developed an awareness of the grapheme-phoneme correspondences which are needed to be able to read. The relationship between phoneme awareness and reading/spelling will be discussed further in the following section.

3.4 Relationship between reading/spelling and metaphonological awareness

Numerous studies show that a strong correlation exists between reading and spelling performance and the ability to perform phoneme awareness tasks (for example, Ehri and Wilce, 1980). It is difficult to tell whether phoneme awareness is a consequence of, or a prerequisite to reading ability (Ehri and Wilce, 1980: 371). However, orthographic knowledge has been shown to affect the results of phoneme awareness experiments. For example, Ehri and Wilce (1980) showed that normally developing children with orthographic knowledge detect an extra segment in words with an extra letter. Thus in matched pairs such as 'new-do' and 'catch-much', the children in this study determined, in a segmentation task, that there were more segments in 'new' and 'catch' which are spelled with an extra silent segment, than there were in 'do' and 'much', when in fact they have the same number of segments or phonemes underlyingly. Therefore, this study shows that orthographic knowledge influences metaphonological analysis.

Traditional phoneme awareness tasks have confirmed the finding that as readers become more and more skilled their performance on phoneme awareness tasks increasingly improves (Landerl, Frith and Wimmer, 1996: 1). Furthermore, in skilled readers, "phonological and orthographic information in words are closely connected, so that these two types of representation are automatically coactivated" (Landerl, et al., 1996: 2). For example, as discussed above, Ehri and Wilce (1980) showed that young (skilled) readers base phonological judgments on orthographic factors.

In summary, in order to develop knowledge of sound-spelling correspondences some conscious knowledge of the units of speech is required. However, whether knowledge of sound-spelling correspondences is prerequisite to phonological awareness, or vice versa, is a matter of debate. The literature discussed above indicates that the reality lies somewhere in between: both abilities are reciprocal and are learned in tandem. To follow this discussion of the normal development of phoneme awareness I will now overview the normal system of language development in § 4. Later, in § 5, I will overview the disordered system of language development, focusing on dyslexia.

4 Verbal short-term memory and speech processing

This section will discuss perception and production, verbal short-term memory and other memory types, and will provide some associated models. The purpose of this section is to provide a model of a normal system of language processing in contrast to the disordered system, which will be discussed in § 5.

A model of speech processing will now be introduced as an explanatory tool. This model can be seen in Figure 1.

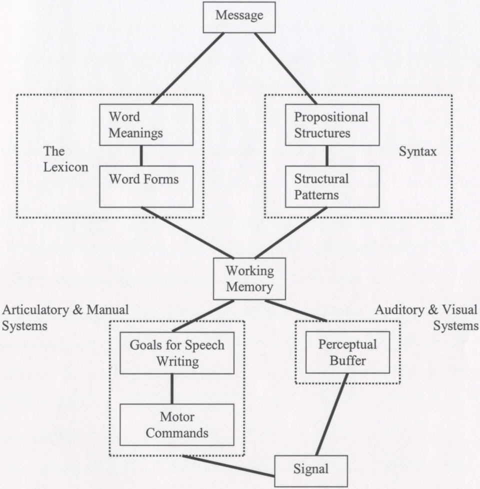

Figure 1: "The components of language processing" (from Garman, 1990: 182).

Two routes of information flow are shown in Figure 1. The first route passes through the lexicon, carrying "the information flow for that part of the utterance meaning and form which is represented in terms of constituent words" (Garman, 1990: 181). The lexicon is composed of word meanings and word forms. The second route passes through syntax carrying the information flow "for the constituent relations between words in utterances" (Garman, 1990: 181). Syntax is composed of propositional structures (i.e. semantics or meaning) and structural patterns (i.e. linear syntactic rules). Both of these routes (the lexicon and syntax) can derive and contribute information to working memory. Working memory will be described in more detail later in this section. Below the level of working memory are the perception and production systems which are mediators between the signal and the other components of the system (Garman, 1990: 181). The perception system in this figure is composed of the perceptual buffer, while the production system is composed of goals for speech writing and motor commands both of which involve planning the steps required for speech and writing.

The figure above can be thought of as an information flow diagram, and will be used to overview perception and production. I will begin by breaking the diagram down into separate perception and production systems, which I will briefly overview. Then I will follow this with a more specific explanation of the components of the language processing system and their function in language processing, especially perception.

Production goes from the message to the signal, as can be seen in Figure 2:

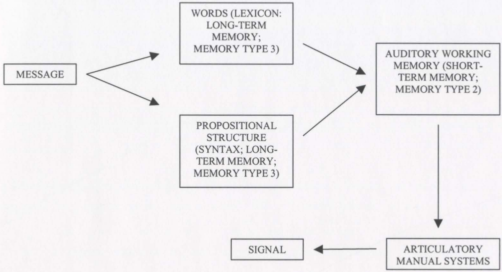

Figure 2: A Model of Production

As can be seen in the above diagram, production begins with a message (a proposition formed in the 'concept' centre). The words necessary to convey the message are retrieved from the lexicon which is part of long-term memory (memory type 3; memory types will be discussed further below). The propositional structure or meaning of the message is encoded syntactically. The words appropriate to the propositional structure are then retrieved from long-term memory and inserted into the appropriate places in the syntactic structure. The information from the message then flows to auditory working memory. This is part of short-term memory (memory type 2) where language operations take place. Next, the information flows to the articulatory/manual system where motor commands are formed. The result of this process is the signal, which is produced in the form of speech.

Perception, on the other hand, goes from the signal to the message:

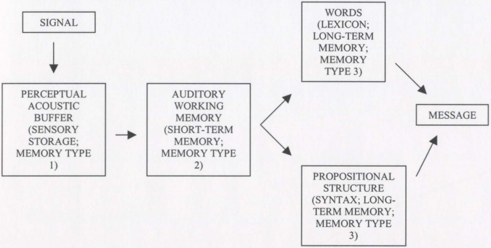

Figure 3: A Model of Perception

Perception is "the mental operation involved in analysing what the signal contains. The term 'perception' is applied to lower-level processes, where the language user is decoding information that is physically there" (Field, 2003: 18). As can be seen in Figure 3, perception begins with a signal, which could be visual or aural, which flows to the perceptual acoustic buffer and then to auditory working memory. Then the information from the signal is matched with information stored in long-term memory and the message is interpreted. Perception involves pattern recognition, whereby word forms are matched to previously stored representations. I will now look in detail at the types of memory involved in pattern recognition, and other language operations and processes.

There are three types of memory or storage: sensory storage (type 1), short-term memory (type 2) and long-term memory (type 3) (Field, 2003: 18). These can be seen in

Figure 4. The sensory storage (type 1) and short-term memory components (type 2) of language processing are problematic for dyslexics and will be discussed further in § 5.3.

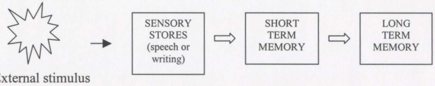

Figure 4: A Three Store Model of Human Memory (from Field, 2003: 19).

The first type of memory shown in Figure 4 is sensory storage, which contains a trace of the stimulus as it is matched to a pattern. The sensory store can also be called the *perceptual* or *acoustic buffer*, a type of memory for sensory storage. The acoustic or perceptual buffer is a temporary storage place for acoustic information (Garman, 1990: 183). Sensory storage for auditory information is called 'echoic memory'. The echoic memory trace is composed of two phases, both of which are short in duration. The first phase of an echoic trace lasts for about 0.25 seconds and is used for pattern recognition. The second phase is maintained for at least 3 seconds and is a back-up which is used to double check stimulus interpretation (Field, 2002: 18). The main function of the second phase is to hold the stimuli long enough for the information to undergo language operations.

The second type of memory is *short-term memory*, also known as *working memory*. Working memory is a type of *auditory memory*, containing the processed contents of the acoustic buffer (Garman, 1990: 183). *Working memory* is the preferred terminology, since this reflects the fact that in addition to temporarily storing current information, working memory also performs language operations such pattern recognition (Field, 2003: 19). Pattern recognition involves:

1. "breaking the input into different characteristics"
2. "matching the whole to a representation which is based upon previous experiences and is stored permanently in Long Term Memory"
3. "allocating an identity or category to the sensation" (Field, 2003: 18).

Information in working memory can come from the environment (through the perceptual buffer), or from long-term memory, but is usually a combination of both. Working memory has a limited information capacity, with a maximum capacity of about seven (± 2) pieces of information (for example, numbers or words) (Field, 2003: 113). To identify a word, working memory must perform a lexical search, and extract lexical information from long-term memory. The mechanism of lexical recall will be discussed further below with reference to the cohort model of word recognition. But first, further definitions of working and long-term memory will be presented.

An influential model of working memory is the Baddeley model of working memory, which can be seen in Figure 5 (from Field, 2003: 111). The Baddeley model refers to the information flow between memory types 1 (the perceptual buffer) and 2 (working memory). This model contains a *phonological loop* consisting of the *perceptual buffer* and a *rehearsal mechanism* (i.e. working memory, which performs the language operations). In this model the signal, spoken language, is able to directly access the phonological short-term store. However, like all working memory, this store has a limited capacity and the trace of spoken words decays rapidly, lasting only a few seconds. Therefore to retain information, it is rehearsed to prevent the trace from fading (Field, 2003: 111).

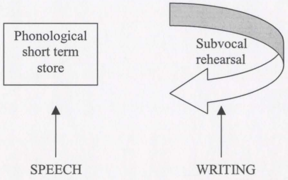

Figure 5: The Baddeley Model of Working Memory (from Field, 2003: 111).

Long term-memory (memory type 3), is the store for information that has been processed and acquired (Field, 2003: 19). Long-term memory holds information that is retained for a long period of time, or even permanently (Field, 2003: 109). The two components of long-term memory are the lexicon and syntax. A lexical item is also made up of two components: word meanings and word forms (Garman, 1990: 243). This is where representations are stored and where working memory matches the current stimuli with previously stored stimuli when performing pattern recognition. One model of doing this is the cohort model which will now be discussed.

The cohort model is a model of perception or word recognition and serves as a good example of one component of perceptual processing - getting from working memory to the message (for the original works please refer to Marslen-Wilson and

Welsh, 1978). In this model a cohort or group of words stored in long-term memory is activated by the initial phonetic input from the stimulus (Altmann, 1990: 142). The stimulus initially activates a large group of words, but these are reduced in working memory through two sources: "continued phonetic input and top-down contextual information" (Altmann, 1990: 142). As more and more information becomes available, words are eliminated from the cohort of potential words (Cutler, 1995: 101). For example, the initial segment /s/ would activate a large cohort of words beginning with /s/, including *sad, several, spelling, psychology*. Then, if the next segment was /p/ the cohort would be further reduced, including words like *spinach, spirit, spill* (Cutler, 1995: 101). The process would continue until enough segments have been recognized to eliminate all but one word from the cohort (Cutler, 1995: 101). A word is recognized when it is the last word left in the activated cohort (Altmann, 1990: 142).

This section has discussed the normal system of language processing. The following section will discuss dyslexia, and the associated deficits of a disordered language system in comparison to the normal system just described.

5 Dyslexia: What is known about dyslexics

5.1 Reading and spelling abilities

This section will introduce the deficits of dyslexia, focusing on reading and spelling problems. Dyslexics are "children who, after a few years at school, are consistently seen to fail at the tasks of reading, writing, and spelling, despite normal intelligence, instruction, and opportunity to learn" (Crystal, 1997: 275). While dyslexia is primarily diagnosed based on reading difficulty, when compared to normally developing children of the same age, dyslexics also exhibit severe spelling deficits (Bruck and Treiman, 1990: 159). The spelling deficits of dyslexics are due, in part, to their inability to link sound-spelling (phoneme-grapheme) information in order to accurately spell words (Bruck and Treiman, 1990: 159).

Due to these deficits, dyslexics have difficulty with phoneme awareness tasks since they have trouble accessing phonemes in tasks such as those requiring them to delete sounds from words (Bruck and Treiman, 1990: 159). In fact, there is "a compelling body of evidence that supports the existence of a robust association between developmental dyslexics' phonological awareness deficits and their reading disability" (Swan and Goswami, 1997: 18). In accordance with this fact, previous research has shown that impairment in phoneme awareness is the best indicator of dyslexia. The reading and spelling abilities of dyslexics are important here, as they will be compared to other abilities in this study, such as phoneme awareness.

5.2 Metaphonological awareness ("phoneme awareness")

It is a well-known fact that dyslexics experience deficits in terms of phoneme awareness. In fact, "by contrast to the rather subtle impairments observed in speech perception and production amongst dyslexics readers, the difficulties that dyslexic children experience on phonological awareness tasks are highly significant" (Snowling, 2000: 54).

One study which exemplifies poor ability to use phoneme awareness and knowledge of spelling comes from Landerl, Frith and Wimmer (1996) who investigated the effect of orthographic knowledge on phoneme awareness tasks in dyslexics. Their experiment used high frequency real words so that the participants would have a good chance of knowing the spelling of the words, and words were matched in rhyming pairs that differed orthographically, whereby one member of the set of words had a silent letter, for example, *sword* vs. *lord*. They found that "in phonological awareness tasks, normal readers are heavily distracted by the knowledge of word spellings, while, for dyslexics, the distraction is less strong" (Landerl, Frith and Wimmer, 1996: 10). These results are thought to be linked to the fact that the connection between orthographic representations and phonological representations is not as strong in the dyslexics' mental lexicon as it is in that of normal readers (Landerl, Frith and Wimmer, 1996: 12).

In general, normal readers use orthographic knowledge to perform phoneme awareness tasks to a greater degree than dyslexics. However, once dyslexics *have* mastered an orthography, they tend to use this knowledge to supplement their weak perceptual skills; for example, they use spelling to help them learn or remember how to pronounce words with certain sounds that they may have difficulty distinguishing, such as 'th' and 'f' (Campbell and Butterworth, 1985 in Post et al.,1997: 6). As well, "while dyslexic readers fail some phonological awareness tasks because of deficits in phonological processing, they may sometimes succeed on others where they can bring to bear cognitive strategies, such as the use of orthographic cues, to compensate for their difficulties" (Snowling, 2000: 56). A study by Perin (1983, in Snowling, 2000: 56) serves as an example of the use of this sort of compensational strategy. This study investigated dyslexics' spoonerisms and found that 'Phil Collins' was often spoonerized as 'Chil [tS] Follins [f]' instead of 'Cil [k] Phollins [f]', where the initial letters of the words were switched instead of the initial sounds.

Finally, as discussed in an earlier section (§ 3.3), the development of phoneme awareness follows an incremental pattern. Normally developing children will, for a period of time, be able to analyze words into onsets and rhymes but have trouble further analyzing onsets and rhymes into phonemes (Treiman and Zukowski, 1991: 80). However, older dyslexics tend to perform similar to younger normally developing readers (for example, Bruck and Treiman, 1990: 175).

In summary, phoneme awareness and reading/spelling abilities correlate highly. Dyslexics perform poorly on phoneme awareness tasks. A question that has not been addressed is whether dyslexics' poor performance on phoneme awareness tasks is a reflection of their reading disability alone, or a reflection of their other disabilities, such as short-term memory deficits. Verbal short-term memory deficits will be discussed next

5.3 Verbal short-term memory deficits

Deficits in short-term memory and verbal working memory lead to difficulties in repetition and even naming familiar symbols like letters and numbers, amongst other things (Snowling, 2000: 35, 44). Dyslexics have been shown to have verbal short-term memory deficits, and as such experience these types of difficulties. One study found that for a normally-developing individual, spoken material could only be held for about 4 seconds while being produced in a recall task, and "the duration for which items can be held by poor readers is even shorter and this can lead to problems, for example when trying to follow a list of instructions" (Hulme, Newton, Cowan, Stuart and Brown, 1999, in Snowling, 2000: 35). Memory deficits such as this have methodological implications as well, as they could explain why dyslexics have trouble with complex methodologies requiring numerous steps.

The results of a study by Brady, Shankweiler and Mann (1983) are typical of memory and perception tasks applied to dyslexics. Their study found that the poor readers recalled fewer items than the good readers on a word string repetition task. As well, they found that the poor readers were less affected than good readers by phonetic similarity within a list; therefore they were less able to organize and retrieve words based on their phonological properties. This can adversely impact performance on verbal short-term memory tasks.

Dyslexics also experience nonword repetition deficits, a consequence of short-term memory deficits. For example, Snowling (1981: 231) found that dyslexics had difficulty in a repetition task, and this difficulty was more marked both when nonwords were used, and when the number of syllables was increased. Furthermore, studies which have used a rapid automatized naming (RAN) task, where participants must name familiar objects such as letters, numbers or colours under fast conditions, have consistently shown that dyslexics take considerably longer to complete the task (Snowling, 2000: 43). One longitudinal study, for example, which investigated naming deficits in dyslexia using a rapid, alternating stimulus (RAS, which follows the same principles as RAN), found that RAS could consistently differentiate average readers from dyslexic readers (Wolf, 1986: 373-374). Other studies, which do not use the serial task (i.e. without the fast naming), but instead use discrete trials, have found similar results (for example, Bowers and Swanson, 1991, in Snowling, 2000: 44).

In summary, the results of numerous studies have shown that dyslexics have verbal short-term memory deficits, and this can impact on their ability to perform on phoneme awareness tasks. I will now discuss another area of dyslexic deficits, that of speech-specific perceptual deficits.

5.4 Perceptual deficits (speech-specific)

Recent research has investigated whether perceptual deficits underlie the dyslexic deficits discussed elsewhere. Such research has shown that poor readers do indeed have perceptual deficits. Some (e.g. Tallal, Stark and Mellitis, 1985, in Tallal, 1990) believe that the perceptual deficits are non-speech specific; others think they are specific to speech. For example, Joanisse et al. (1998: 136) maintain that "phonological deficits are thought to interfere with learning the correspondences between spelling and sound, an important step in reading acquisition". This controversy will not be addressed here because the purpose of this thesis is to investigate a different question; however both hypotheses will be briefly overviewed.

One study found that the speech perception skills of poor readers were less efficient than that of good readers, but only when perceiving degraded or weak stimuli. Brady, Shankweiler and Mann (1983) found that in the single word repetition task, both groups (good and poor readers) performed well in the session without background noise, but when noise was added, the poor readers performed significantly worse than the good readers. When environmental sound stimuli were used, both groups performed well and the poor readers actually performed better than the good readers on this task. The combined results indicate that poor readers have perceptual difficulties which are limited to speech.

On the other side of the controversy, Tallal maintains that the perceptual impairment is related to the processing of rapidly changing, sequential information (Joanisse and Seidenberg, 1998: 242). Perception of spoken language involves the interpretation of a complex auditory signal. This signal is both rapidly changing and also fades rather quickly. An inability to perceive aspects of this signal would result in impaired language learning and development (Joanisse and Seidenberg, 1998: 242). This theory would predict impairments in the perception of short, transient acoustic cues (shorter than 50 ms), but not in longer acoustic cues (longer than 100 ms). These longer cues would include vowels and fricatives. Most important in relation to this theory is that

"Tallal's studies have also identified impairments in perceiving rapid stimuli in the visual and tactile modalities in these children, suggesting that the deficit is not speech-specific" (Joanisse and Seidenberg, 1998: 242). For example, one study (Tallal, Stark and Mellitis, 1985, in Tallal, 1990: 616) found that there was a set of variables which could be used to classify normal and language impaired children in terms of basic perceptual and motor abilities. These variables were: "rapid speech production", "a finger identification subtest", "the discrimination of the computer-synthesized syllables /ba/ versus /da/", "the ability to integrate nonverbal stimuli presented cross-modally at rapid rates", and "the ability of subjects to locate two touches presented simultaneously to the cheeks and/or hands on either side of the body" (Tallal, Stark and Mellitis, 1985, in Tallal, 1990: 616-617).

In summary, dyslexics have weak perceptual skills. The consequences of this inability will be discussed in the following section.

5.5 Summary of dyslexic deficits

In summary, dyslexics have been shown to have deficits in terms of both reading and spelling abilities, as well as in phoneme awareness. They also experience verbal short-term memory deficits as is reflected in their inability to accurately perform, for example, word string repetition tasks, other repetition tasks, and rapid automized naming tasks. These short-term memory deficits likely have an adverse impact on dyslexics' ability to learn sound-spelling correspondences because their ability to recall letters and sounds is impaired. Furthermore, dyslexics have perceptual deficits which may or may not be speech-specific. These deficits likely have an adverse impact on dyslexics' ability to learn sound-spelling correspondences.

6 Background and rationale for methodology

From the literature review discussed thus far, several logically separable dimensions to phoneme awareness tasks have been identified, including speech perception (short-term memory, lexical access and retrieval/long term memory), as well as speech production and orthographic knowledge. This section will demonstrate that all of these components are present in a typical 'Rosner' task, where not only must a participant perceive a stimulus (either visually or aurally), but they must also produce a target word after the relevant segment has been removed. Given that all of these components are present, several questions become obvious. To begin with, are all of these components necessary in the 'Rosner' task or can some be removed? Secondly, is the poor performance of dyslexics' on 'Rosner' tasks due to task effects, due to, for example, dyslexics' short-term memory deficits? After demonstrating (in § 6.1) that 'Rosner' tasks typically contain perception, production, and orthographic components, the questions presented above will be discussed more concretely.

6.1 The 'Rosner' task

This section will begin with a discussion of the 'Rosner' task (first introduced in § 3.2) in more detail in order to motivate removing orthographic and production components from the experimental methodology. It will start with discussions of two experiments, Bruck and Treiman (1990) and Brady, Shankweiler and Mann (1983). Both of these experiments will be used to overview different phoneme awareness tasks and this will be followed by a discussion on the effects of orthography in tasks. Once the rationale behind each experiment has been outlined, I will critically reexamine the necessity for tasks involving production.

6.1.1 Bruck and Treiman (1990): A phoneme awareness experiment

A wide range of tasks have been used in phoneme awareness experiments. The experiments reported in Bruck and Treiman (1990) present a good cross-section of such tasks. This article will be discussed in order to overview several different phoneme awareness tasks, including their methodology, purpose, advantages, and shortcomings. Bruck and Treiman (1990) looked at spelling and phonological awareness in both normally-developing children and dyslexics, using five experimental tasks.

Task 1, an auditory recognition task, was designed to test the participants' ability to determine whether or not a prespecified sound was contained within a word they heard. Before this task began, there was a pre-task involving production, whereby the participants were required to repeat words. This was done to ensure that they could accurately reproduce what they heard and accurately produce all of the phonemes of the word in question. After they had completed the pre-task, the actual task began. In Block 1 of the actual task participants were presented with CCV (note: C refers to a consonant and V refers to a vowel) and CVC nonwords, and were required to indicate ('yes' or 'no') whether the initial phoneme corresponded to a prespecified target. For example, if the target was /f/ they had to indicate whether or not the word they were presented with began with /f/. In Block 2 participants were presented with CCV and VCV nonwords and were required to indicate whether the second phoneme corresponded to a prespecified target. For example, if the target was /f/ they had to indicate whether or not the second sound in the word was /f/. For both blocks the child had to repeat the nonword and were corrected if they pronounced it incorrectly.

One advantage of this task was that the participants did not have to produce a manipulated word as an answer in the task, they simply had to answer 'yes' or 'no'. The only production they did was in the pre-task. The results show that dyslexics performed worse than the normal readers on some tasks; therefore these tasks can separate dyslexics from normal readers. While Task 1 tested phoneme recognition, it did not test segmentation ability. (Types of phoneme awareness tasks are discussed in § 3.2). The results from Task 1 showed that the participants failed to recognize the initial consonant of a complex onset more often than a singleton onset; however the participants performed well overall. The dyslexics performed worse than the normal readers on CCV items only and participants made more errors on CCV stimuli in Block 2 than in Block 1.

Task 2 was an auditory phoneme deletion task, which tested the participants' ability to segment monosyllabic words, by removing one of the phonemes. In Block 1, participants had to delete the first sound of a CCV or CVC nonword and say the resulting nonword. In Block 2, they had to delete the second sound of a CCV or VCV nonword and say the resulting nonword. In Block 3, the experimenter pronounced the sound or sounds that the participants had to remove from a CCVC or CVC nonword. For both types of words, the participants were required to remove the onset and pronounce the resulting nonword. For example, if the word was /prov/ the answer would be /ov/ and if the word was /pov/ the answer would also be /ov/.

This task is designed to show whether or not the participants are able to segment words into phonemes. This is a classical "Rosner" task (described below), and the results on such tasks are strong indicators of reading ability. While this task did test phoneme deletion abilities, the participants also had to produce (i.e. pronounce) the resulting nonword, thus adding an extra production task, and potentially increasing the level of difficulty of the task.

Task 3 was a visual deletion task designed to test whether the participants could perform segmentation visually and not just aurally. In this task, the experimenter said a nonword and subsequently placed a different colored block in front of the participant. Each of these colored blocks represented a different sound of the nonword. In Block 1 the experimenter removed the first colored block, in Block 2 the second colored block, and in Block 3 either the first or the first and second colored blocks. In all three test blocks the participant was required to say the resulting nonword when the colored block representing a phoneme was removed from the original nonword.

The experimental design of this task adds an extra visual factor, which, combined with the production requirement already incorporated into the task, makes for a relatively difficult task. The participants are required to associated sounds with colored blocks, then take away one of the blocks, figure out what they have left, and pronounce the resulting nonword. This is highly similar to a task which uses orthography, since each block is associated with a sound, similar to the way letters are associated with sounds. However this task is likely more difficult than using orthography alone, because the participants are required to learn and apply a new system. Each part of this task appears to be difficult and it is unclear what this task tests.

The results from Tasks 2 and 3 were combined and according to the authors, showed that dyslexics performed worse than normal readers in both Block 1 and Block 2. Participants were able to delete the entire onsets, but did worse on CCVC than CVC syllables.

Tasks 4 and 5 were spelling tasks, designed to show the relationship between phoneme awareness and spelling ability. One task used real words and the other used nonwords. All words in both tasks were monosyllabic CCV (for example, blow and /bli/) and CVC (for example, leap and /bul/) words, constructed so that pairs contained the same phonemes and, in many cases, the same letters. For the nonword spelling task, VCV (for example, /∂mi/) words were also included, for comparison with other tasks. Participants were required to repeat the word after the experimenter and then spell it. For the real word stimuli the word was said on its own twice and in a sentence once before the child repeated and spelled it. For the nonwords, each was repeated three times before the child repeated and spelled it. Unfortunately, these tasks build in two factors that exacerbate dyslexics' performance – orthography and non-words. The results showed that for task 4 (real word spelling) and task 5 (nonword spelling) the dyslexics produced more illegal spellings than the controls. Tasks such as these are typically effective in distinguishing dyslexics from normal readers.

The range of methodologies employed by Bruck and Treiman (1990) illustrates that phoneme awareness experiments often include a *production* task. There are various reasons why production tasks are often used: to ensure that the participant has heard the word correctly, to ensure that the participant is able to produce all of the phonemes in the word, or to test the participant's ability to pronounce phonemes. While all of these reasons are valid for the necessity of production, they do not explain why production is included in the design of all the tasks, consequently raising their level of difficulty. Perhaps a simpler way of including production in the experiment without making the true target task more difficult is to design a separate task testing production. This 'pre-test' would be completed before the actual task in which production was to be incorporated in the first place. The pre-test would then be followed by the real test which would not involve production. Since both tasks, or tests, are separate, neither would make the other more difficult, yet production could still be included in the experiment.

6.1.2 Brady, Shankweiler and Mann (1983): A memory and phoneme awareness experiment

As discussed above, experiments designed to test phoneme awareness ability rely on production. Similarly, experiments designed to examine dyslexic short-term memory deficits also rely heavily on production tasks, as the following example shows.

Brady, Shankweiler and Mann (1983), investigated the possibility that poor readers' memory deficits originate in perception and with the encoding of stimuli. Their study was divided into three experiments. Experiment 1 of their study was a short-term memory task which used rhyming and non-rhyming word strings in a repetition task.

Each participant heard a prerecorded set of 10 five-item word strings and was told to repeat the word list in the order given. The purpose of this task was "to confirm previous evidence that poor readers make less effective use of phonetic coding in short-term memory than do good readers" (Brady, Shankweiler and Mann, 1983: 349). This purpose was confirmed by the results of Experiment 1 which showed that poor readers recall less items than good readers and were less affected by phonetic similarity in a word list (Brady, Shankweiler and Mann, 1983: 353).

Experiment 2 of their study looked at speech perception abilities in good and poor readers to see if the language deficits of the poor reader manifest in phonetic perception. There were two sessions in this task: in Session 1 the participants listened to the words in a noise-masked condition and in Session 2 the participants listened to words in an unmasked condition. The participants were required to repeat the recorded word immediately after hearing it. These tasks, like the tasks discussed earlier in Bruck and Treiman (1990), add an extra degree of difficulty to the experiment, by having the participants repeat (i.e. produce) the word. It should be noted however that in this case repetition was essential to the design since Brady et al. (1983) were looking at verbal short-term memory, heavily involved in perception tasks.

Experiment 3 involved the perception of environmental sounds. During a single session, participants were presented with noise-masked and unmasked stimuli and asked to identify the source of a sound immediately after hearing it. The purpose of this experiment was to determine whether or not the perceptual difficulties of dyslexics are limited to speech, or if they extend to all sounds. The results of this study show that poor readers have perceptual difficulties which are limited to speech, and which are affected by degraded stimuli (i.e. noise masking). While this task is not necessarily relevant to the present discussion, the results are. They indicate the necessity of clear stimuli recordings, since degraded stimuli have been shown to affect poor readers perceptual abilities.

In summary, Bruck and Treiman (1990) and Brady, Shankweiler and Mann (1983) employ methodologies that use production. The use of production is sometimes necessary, such as when testing production or memory abilities, but is it really necessary for all Rosner-type tasks? On its own, auditory perception involves perception/verbal short-term memory, and the phonological analysis of what is perceived into syllables, onsets/rhymes, and phonemes (see § 4, Figure 3). When production is added, further abilities are involved, such as motor planning and execution of a phonological representation, which was acquired, for example, through auditory perception (see § 4, Figure 2). By including production as a component of consonant-removal tasks, the experimenters have added an unnecessary extra task with the potential to adversely impact the performance of the poor readers since they experience verbal short-term memory deficits. To examine the extent of the potential task effect of production, my experiment will eliminate production as an unnecessary methodological factor, and thus will rely solely upon perception.

6.1.3 Phoneme awareness and the effects of orthography

Phoneme awareness tasks often rely heavily on orthography, another factor that will be eliminated from the proposed experimental design. The removal of orthography in the proposed experiment is inspired by Bruck and Treiman's (1990) non-orthographic Rosner tasks.

The presence of orthography and orthographic knowledge can both hinder and enhance performance on phoneme awareness tasks, such as phoneme removal (see § 3 for more examples of phoneme awareness tasks). For example, if a child is presented with a series of isolated words written down on pieces of paper, and told to remove the first sound from each of the words that s/he is going to be shown. If one of the words s/he is shown is a word such as 'trip' which has a one-to-one correspondence between phonemes and graphemes, s/he only needs to remove the first letter to get the correct response, 'rip'. The one-to-one correspondence means that the first sound is equal to the first letter, and therefore no matter which strategy s/he is using to complete the task (i.e. remove the first letter or remove the first sound), s/he will get the correct response in this instance. This therefore shows how orthography has the potential to enhance performance on phoneme awareness tasks. However, if s/he is then shown a word like 'chip' which does not have a one-to-one correspondence between graphemes and phonemes, and s/he removes the first letter, s/he will get an incorrect response, 'hip'. In this case, removing the first sound is the only way to get the correct response, 'ip', and this shows how orthography can hinder performance phoneme awareness tasks, as participants may rely on the written letters to perform a task, rather than their phonemic knowledge.

This analysis holds mainly for normal readers or remediated dyslexics. As discussed earlier (§ 3.4), in skilled readers phonological and orthographic information are closely linked. Therefore orthographic knowledge tends to influence their answers on phoneme awareness tasks such as consonant removal tasks. Non-remediated dyslexics, however, will rely on orthography to compensate for their poor phonological skills. Orthography should be eliminated from dyslexic tasks because it would hinder their performance equally whether the stimuli contained a silent letter or not.

6.1.4 Summary: Components of a perceptually-based Rosner task

Production and orthographic tasks are logically separate from the perception component of metaphonological awareness tasks. A typical 'Rosner' task activates/involves all the components presented in Figure 6 below. It should be noted however that this figure does not completely illustrate the information flow in metaphonological processing. More complete figures were presented in § 4. Figure 6 does show however, a simplified version of the flow of information involved in speech perception and production, including storage (long-term and short term memory), and perception (signal) and production (articulatory and manual systems).

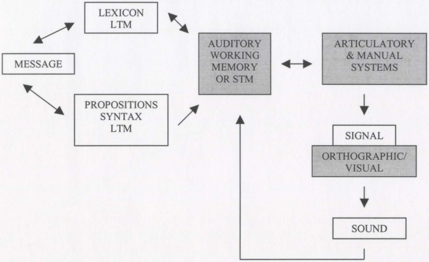

Figure 6: Speech Perception and Production in a Typical Rosner Task

Depending on the task, the components in the shaded boxes of Figure 6 can be eliminated, or in the case of short-term memory, the task load can be reduced. Production (articulatory and manual systems) can be removed since it is not necessary to physically utter an answer in a phoneme awareness task. Instead a participant could indicate whether or not an answer that has been provided to them is correct. As well, orthography (orthographic signal) is not necessary since stimuli can be presented aurally instead of visually. Thus, neither production nor orthography are required in a perception based phoneme awareness task.

This experiment (described in § 7) eliminates production and orthography from part of its design, while also including them in separate tasks. To the extent that the results of my task differ from those of more typical phoneme awareness tasks, differing results could indicate a task effect involving production and/or orthography. The following section will discuss the hypotheses of this experiment with reference to the expected affects of removing production and orthography from a phoneme awareness task.

6.2 Hypotheses

The realization that there are separable dimensions to phoneme awareness tasks (as discussed in § 6.1) has enabled some unique research questions, which this experiment is designed to answer. These research questions will be discussed in this section.

Given that dyslexics have (1) a poor knowledge of sound/spelling correspondences (§ 5.2), (2) poor short-term memories (§ 5.3), and (3) speech production (and perception) deficits (§ 5.4), and given that all three of these components are present in a typical 'Rosner' task, is dyslexics' typically poor performance a task effect? In other words, would their performance on a phoneme awareness 'Rosner' task be more comparable to controls' performance if these three components were eliminated, or reduced as much as possible. Furthermore, what is the relationship between reading/spelling ability and phoneme awareness? Can phoneme awareness arise in the absence of reading/spelling knowledge? The proposed experiment is designed to address these questions.

This experiment removes the speech production and visual orthographic components and reduces the short-term memory load. This experiment will also verify that performance on a novel phoneme awareness task correlates well with spelling ability, as other, more traditional, phoneme awareness tasks do.

It is hypothesized that reading ability will still correlate with the ability to perform on phoneme awareness tasks: the poor readers will still perform more poorly than controls on the modified 'Rosner' task because they have perceptual/memory deficits. (Perception and short-term memory cannot be eliminated from the task, although the methodology used in this experiment reduces the short-term memory load). If correct, a possible interpretation is that production does not have an effect on phoneme awareness abilities; therefore, its inclusion does not affect performance. If incorrect, a possible interpretation is that phoneme awareness abilities are negatively influenced by production such that when it is removed from the task performance improves.

It is also hypothesized that spelling ability will correlate with performance on the modified 'Rosner' task. If correct, then a possible interpretation is that even with production removed, this phoneme awareness task is still a good predictor of spelling ability. If incorrect, then a possible interpretation is the modified 'Rosner' task bears no reflection on spelling ability.

The next section will discuss the experimental design used to test these hypotheses.

7 Methodology

7.1 Experimental design

Based on the literature review presented in § 6.1, an experiment was designed that eliminates orthography and production and reduces the verbal short-term memory load. To address the hypothesis presented in § 6.2, an independent groups design was employed. Both will be described below.

7.1.1 Participants

This experiment uses an independent groups design. The experimental group was composed of poor readers enrolled in Grade 8 at the time of testing (N = 10; average age = 13 years 7 months; range = 13 years 3 months – 15 years 0 months). Their classification as poor readers was based on their referral from their teachers; they were recognized as having weak reading abilities. There were two control groups: older normal readers (N = 11; average age = 13 years 6 months; range = 13 years 5 months – 14 years 2 months) and younger normal readers (N = 16; average age = 7 years 7 months; range = 7 years 3 months – 8 years 5 months). The older normal readers were students enrolled in Grade 8 at the time of testing who were recognized by their teachers as having strong reading skills. The younger normal readers were students enrolled in grades 2-3 at the time of testing. They were selected based on teacher input and were recognized as being the strongest readers in comparison with their peers. All participants were from schools in the Avalon East School District in St. John's, NL. The independent groups design was used to enable a comparison between good and poor readers on each task.

7.1.2 Procedure and materials

This experimental design employed three tasks: a forced-choice auditory cue task which requires recognition of correct targets of phoneme deletion plus a production pre-task and a spelling task for comparison purposes. A training session was also used to ensure that the participants understood what a 'sound' is. The reasons for the training session will be explained in § 7.3 All tasks (with the exception of the training session) used the same stimuli. This accounts for the ordering of the tasks. In the first task, the participants were required to produce the words. Then, in the second task the words were produced for the participants and they had to manipulate or segment the cluster. Finally, the participants were asked to spell the words. The ordering ensured minimal task effects from task to task. All testing was completed in the participants' school in a quiet room, during class time with the permission of their parent(s)/guardian(s) and their classroom teachers. Ethical documentation can be found in Appendix 1.

7.1.2.1 Stimuli

The stimuli for this experiment consisted of 80 monosyllabic CCVC real words that remain real words when any combination of consonants from the consonant cluster are removed. Non-word results were not used as these are problematic for all types of participants, in particular poor readers, and cause unnecessary stress on verbal short-term memory. Examples of the stimuli used include:

Original Word	C1 Deletion	C2 Deletion	CC Deletion
crate	rate	Kate	ate
bleach	leech	beach	each
twin	win	tin	in

In addition to these stimuli, foils were also included. The purpose of these foils was to ensure that the participants were unable to determine the purpose of the experiment. Since the foils contain non-word answers, their use also ensured that the participants could not develop a strategy of looking for real-word answers. There was a total of 24 foils, which consisted of monosyllabic CCVC real words that become nonwords when any combination of the consonants is removed. Examples of foils include:

Original Word	C1 Deletion	C2 Deletion	CC Deletion
crisp	'risp'	'kisp'	'isp'
scarf	'carf'	'sarf'	'arf'
prove	'roove'	'poove'	'oove'

A clear adult male voice was used to record the stimuli. Stimuli were recorded in a soundproof room using a Sony ECM-MS907 Microphone and a Sony NetMD MZ-N707 MiniDisc Recorder. Once all of the stimuli were recorded they were transferred to a desktop computer using the recording software Amadeus II. The sound recording format was a 16 bit sample size recorded at a rate of 44100 Hz. The data files were then transferred to a laptop computer to be used in the sound editing software program

Macromedia SoundEdit 16. SoundEdit was used to label the stimuli and extract them from the carrier sentences they had been recorded in to form media files containing individual stimuli words.

7.1.2.2 Task 1: Production task (pre-task)

This task solely required the *production* of the words used for the phoneme deletion task described in § 7.2.2.3. Its purpose was to ensure that the participants could correctly pronounce (and hence perceive) the target clusters. (If they were unable to perceive the cluster then they would be unable to accurately perform the phoneme deletion task.) The words were played one at a time using a computer and headphones and the participants were asked to repeat the words as they were presented. For example, participants were asked to repeat words such as *crate, bleach,* and *twin.* If the participant inaccurately repeated a word that word was played again after the remainder of the words had been completed, up to a maximum of three times. None of the subjects exhibited production deficits, thus all were able to complete this task and none were eliminated from the study.

7.1.2.3 Task 2: Forced-choice auditory cue task (signature task)

The signature task of this experiment was a forced-choice auditory cue task, which involved phoneme removal but without a production or orthographic component.

The participants were required to mentally remove the first phoneme of a consonant cluster in a word such as 'Blake' and to decide whether or not the next word presented had the first phoneme removed as they had mentally calculated (correct answer: 'lake'; incorrect answers: 'bake', 'ache', and 'Blake'). This task required participants to recognize the correct target of phoneme deletion.

In all trials participants were asked to respond to the basic question "Is the first sound gone?" and were presented with word pairs. The first member of the pair was the original word containing a consonant cluster (such as 'Blake') while the second member of the pair could have had the first phoneme of the cluster removed (e.g., 'Blake' – 'lake'), the second phoneme of the cluster removed (e.g., 'Blake' – 'bake'), both phonemes of the cluster removed (e.g., 'Blake' – 'ache', or no phonemes removed (e.g., 'Blake' – 'Blake'). After hearing a pair of words, the participant was then required to press a button on a keypad indicating whether or not the second word was the correct answer to the proposed question. Colored stickers on the keypad buttons were used to represent the 'yes' and 'no' buttons, with green being 'yes' and red being 'no. In addition, to prevent confusion a 'Y' and 'N' were printed on the stickers to ensure that having to remember what the colors stood for did not affect performance by overtaxing the participants' memory. It was made very clear to the participants that they were only to answer 'yes' if the first sound had been removed, and only the first sound. All of the participants understood that if there was more than one sound missing they were to answer 'no'.

To ensure that the participants' attention remained focused on the task at hand, immediately before each pair of words was presented the participants heard a beeping tone and a line of dots flashed on the computer screen. Thus the order of presentation of the components of each trial of the experiment was as follows: the tone and dots were presented 500ms after the start of the trial for a duration of 500ms. Word 1 was presented 500ms after the tone and dots and word 2 was presented 200ms after word 1. The reaction time was calculated from the end of the presentation of word 2 to the instant the participant pressed a button on the keypad indicating a 'yes' or 'no' answer.

This task took place during two separate sessions (A and B), each consisting of four blocks of 62 trials (word pairs) with a break between each block. Participants were required to complete both sessions (A and B) for a total of 496 trials each (360 stimuli + 136 foils). Each block contained 10 trials where the second word has the first phoneme of the cluster deleted, 10 with the second phoneme deleted, 10 with both phonemes deleted, 10 where nothing had been deleted, plus 12 foils. The presentation of all stimuli (including foils) within a block was random, and the participants were always asked to answer the same simple question. Furthermore, a particular set of words only occurred once throughout the entire task; there was no repetition of word pairs. For example, if 'Blake' – 'lake' appeared in block 1 of session A, it did not appear anywhere else in sessions A and B. Furthermore, there was not another pair using the word 'Blake' in that block. The words were separated such that while each original word forms four word pairs (for example: 'Blake' – 'lake', 'Blake' – 'bake', 'Blake' – 'ache', and 'Blake' – 'Blake'), any given block did not contain two pairs with the same first word. This was done in an effort to ensure that the blocks are all relatively equal, as well as to avoid the benefits of practicing by ensuring that the participants did not become overly familiar with performing operations on any given word.

This task was designed and administered using the experiment program PsyScope, version 1.2.5 on an Apple iBook computer. All stimuli were presented aurally using Sony MDR-V300 headphones to minimize interference from the testing environment.

7.1.2.4 Task 3: Spelling Task (post-test)

This task solely required the participants to *spell* the words used for the phoneme deletion task described in § 7.2.2.3. The words were presented one at a time using a computer and headphones. The participants were asked to spell the word immediately after hearing it. Each word was played once and the participant had the option to ask to have it repeated up to a maximum of three times. This task had to go last because it involved orthography and used the same stimuli as the previous tasks. Since it was very important that there was no influence of orthography on the results of the earlier pre-test and signature task, the spelling task had to be completed last. This comparison task provided a score which could be correlated with the score from the forced-choice auditory cue task. Combined with the production task, this task could provide a measure of how securely phonemic and orthographic representations are linked.

7.2 Piloting

The forced-choice auditory cue task (task 2) was initially piloted on three participants (average age = 22.67 years, age range = 15-29). The purpose of this piloting was to ensure that any problems with the newly developed task would be rectified before testing began on the experimental participants. During this piloting the error rate (the number of incorrect answers divided by the total number of trials) was very high – near chance levels. Through an investigation of the results and in-depth conversations with two of the three pilot participants, it was discovered that the problem was not with the recognition task itself, but rather a problem with the terminology used in the question for the forced-choice auditory cue task. The investigation revealed that the participants did not know what a 'sound' was and were therefore unable to accurately answer the question "Is the first <u>sound</u> gone?".

To remedy this problem it was decided that a training session was needed to teach the participants what a sound was through examples. An investigation into what makes a good training session for teaching what a sound was revealed several important characteristics which were included in this training session:

- Lengthening the sounds of the words and then asking the participant to segment the sounds (Barton et al., 1980: 111)
- Demonstrating through examples and providing corrective feedback (Morais, Bertelson and Alegria, 1986: 51)
- Using colored wooden blocks where each block represents a different sound (Troia, Roth and Yeni-Komshian, 1996: 39).

Adopting these three concepts in the training session, participants were asked to use blocks to represent individual sounds in words beginning with either one, two or three consonants (for example: rap, trap, strap or rain, train, strain). The participants were shown an example and then asked to sound out the words slowly and to use colored blocks to represent each sound they heard in the word. The participants were told to say out loud what each block represented. By doing this, the investigator was able to provide corrective feedback, if the participant provided an incorrect answer, as to exactly where the participant was having difficulty. By providing this feedback participants were able to determine what was meant by the term 'sound' and knew what was a single sound and what was more than a sound.

The training session, once fully developed, was piloted along with the forced-choice task (§ 7.2.2.3) on six pilot participants (average age = 14.67, age range = 6-24). Five of these six participants had not completed the task previous to this time, whereas one of them was used as a pilot participant both with and without the training session. Compared with the error rate resulting from piloting without the training session, the error rates with the training session dropped substantially. Whereas the earlier average error rate had been near chance level, the new average error rate fell to less than 10%. This indicates that teaching the participants what a sound is using this method was effective.

At the end of the training session the participants talked with the experimenter about taking sounds off words in preparation for the forced-choice task. None of the stimuli from the forced-choice task were used in the training session. In addition, the type of questions asked in the training session did not involve word pair comparison as in the forced-choice auditory cue task. Instead, the participants were asked to remove, for example, the first sound, to ensure that they knew what was meant by 'the first sound'. All of the participants were able to answer questions about sound removal which were considered necessary before they would be able to complete the forced-choice task. In the training session the participants learned now to perform the task, i.e. removal of the first phoneme in an word initial two phoneme cluster, but without doing the signature task itself.

8 Results

8.1 Introduction

This section will present the statistical results of this study and is divided into several subsections. The first six subsections discuss the results of the forced-choice auditory cue task in terms of the effects of group, condition and cluster type on performance, as well as in terms of the performance of the participants as a whole and as three separate groups. The last part of this section presents the results from the spelling task and its relationship to phoneme awareness.

In this section the terms *percent acceptances* and *reaction time* will be used frequently. The term *percent acceptances* is used to refer to the number of 'yes' responses on the forced-choice auditory cue task divided by the total number of trials. For the C1 deletion process a 'yes' response is the correct response; however for the C2 deletion, CC deletion or NO deletion processes a 'yes' response is the incorrect response to the task's question 'is the first sound gone?'. The term *reaction time* refers to the length of time, in milliseconds, between the instant the second word of the pair is finished until the participant presses a button for a 'yes' or 'no' response. *Reaction time* was calculated by averaging the *reaction time* for each condition and cluster type (a total of 24 average reaction times). There are two *reaction time* measures used. The first measure represents the *reaction time* for both correct and incorrect answers (i.e. for all trials), and this will be referred to as the *reaction time combined* measure. The second measure represents only the *reaction time* for the correct answers and will be referred to as the *reaction time correct* measure. These correct answers are 'yes' responses for C1 deletion word pairs and 'no' responses for C2 deletion, CC deletion, and NO deletion word pairs.

8.2 Forced-choice auditory cue task

8.2.1 Groups

Group (older normal readers, poor readers, or younger normal readers) was found to have a significant effect on the *percent acceptances* measure. An ANOVA for all subjects for the *percent acceptances* measure revealed a significant CONDITION X GROUP interaction ($F (6, 99) = 8.818$; $MSe = 1985.101$; $p < 0.05$). This effect indicates that the participants in each group performed differently on the task depending on the condition or process exhibited by the word pair (i.e. C1 deletion, C2 deletion, CC deletion, or NO deletion). Table 1 presents the means which show a substantial difference between the groups for each condition, which resulted in the significant effect. The average of these means can also be seen in Figure 7. This result means that each group accepted a significantly different percentage of the trials for each condition.

Table 1 A-D: Condition by Group Table (All Subjects Combined)

Table 1A - Mean Percent Acceptances

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Older Normal Readers (Group 1)	95.38%	1.57%	23.66%	0.92%
Poor Readers (Group 2)	74.18%	20.42%	37.13%	4.31%
Younger Normal Readers (Group 3)	66.59%	38.27%	50.00%	10.02%
All Participants Combined	77.20%	22.54%	38.69%	5.77%

Table 1B - Standard Deviation

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Older Normal Readers (Group 1)	4.45%	4.78%	36.84%	1.52%
Poor Readers (Group 2)	20.10%	21.73%	26.72%	5.14%
Younger Normal Readers (Group 3)	21.19%	28.71%	30.90%	14.01%
All Participants Combined	21.15%	26.71%	32.86%	10.24%

Table 1C – Maximum

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Older Normal Readers (Group 1)	100.00%	15.93%	99.63%	4.07%
Poor Readers (Group 2)	99.26%	59.86%	82.75%	12.09%
Younger Normal Readers (Group 3)	99.02%	85.77%	98.65%	53.53%
All Participants Combined	100.00%	85.77%	99.63%	53.53%

Table 1D – Minimum

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Older Normal Readers (Group 1)	89.52%	0.00%	0.00%	0.00%
Poor Readers (Group 2)	31.65%	2.38%	7.14%	0.00%
Younger Normal Readers (Group 3)	26.12%	7.28%	6.43%	0.00%
All Participants Combined	26.12%	0.00%	0.00%	0.00%

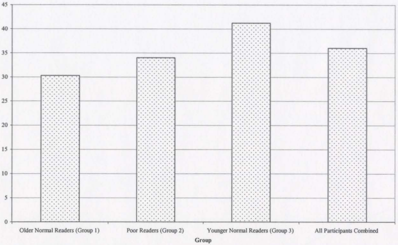

Figure 7: Average Percent Acceptances by Group (Forced-Choice Auditory Cue Task)

In contrast, the groups did not exhibit significantly different overall reaction times in comparison with each other. An ANOVA for all participants on the *reaction time combined* measure did not show a significant CONDITION X GROUP interaction ($F(6, 102) = 1.823$; $MSe = 6969222.262$; $p > 0.05$). An ANOVA for all participants on the *reaction time correct* measure also did not show a significant CONDITION X GROUP interaction ($F(6, 51) = 11.521$, $MSe = 9497425.514$; $p < 0.05$). This indicates that the task's level of processing difficulty was approximately equivalent for all groups and across all conditions.

The effects of condition and cluster type will be presented in detail in § 8.2.2 - § 8.2.3. The performance of each group on all measures will be presented in more detail in § 8.2.4 - § 8.2.6.

8.2.2 Conditions

This section will discuss the effect of condition on the overall performance of all of the participants. Condition, that is which process the word pair represented, was significant for all three of the measures, *percent acceptances*, *reaction time combined* and *reaction time correct*. The four conditions or processes were C1 deletion (ex. *Blake-lake*), C2 deletion (ex. *Blake-bake*), CC deletion (ex. *Blake-ache*) and NO deletion (ex. *Blake-Blake*). The results for all participants combined will be presented in this section and the results for the individual groups (older normal readers, poor readers, and younger normal readers) will be presented in § 8.2.4 - § 8.2.6.

An ANOVA for all participants for the *percent acceptances* measure revealed a significant effect of condition ($F(3, 99) = 105.773$; $MSe = 1985.101$; $p < 0.05$). This significant effect indicates that the participants' performance was indeed affected by the condition (i.e. which process was exhibited by the word pair). Table 2 shows the average *percent acceptances* for each condition which are considerably far apart and which demonstrate this significant effect. For all of the participants combined, the highest acceptance rate was for the C1 deletion word pairs, followed by CC deletion and then C2 deletion, as shown in Figure 8.

Table 2: Percent Acceptances by Condition (All Subjects Combined)

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Mean	77.20%	22.54%	38.69%	5.77%
Standard Deviation	21.15%	26.71%	32.86%	10.24%
Minimum	26.12%	0.00%	0.00%	0.00%
Maximum	100.00%	85.77%	99.63%	53.53%

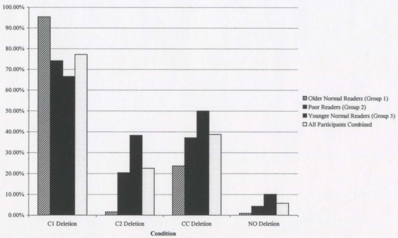

Figure 8: Percent Acceptances For Each Group by Condition (Forced-Choice Auditory Cue Task)

In support of the results from the *percent acceptances* measure, ANOVAs for all participants revealed significant effects of condition for the *reaction time combined* measure ($F(3, 102) = 13.157$; $MSe = 6969222.262$; $p < 0.05$), and the *reaction time correct* measure ($F(3, 51) = 11.521$; $MSe = 9497425.514$; $p < 0.05$). These results show that reaction time performance was significantly influenced by whether the second word had the first phoneme deleted, the second phoneme deleted, the first two phonemes deleted, or was exactly the same as the first word presented. Table 3 shows the means which demonstrate a significant effect of condition for the *reaction time combined* measure and Table 4 shows the means for the *reaction time correct* measure.

Table 3: Reaction Time (ms) Combined By Condition (All Subjects Combined)

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Mean	2935.27	3003.15	3476.10	1816.82
Standard Deviation	1633.71	2216.27	2231.20	621.55
Minimum	1012.15	1198.56	1142.92	979.02
Maximum	8594.17	13563.30	10267.73	4310.60

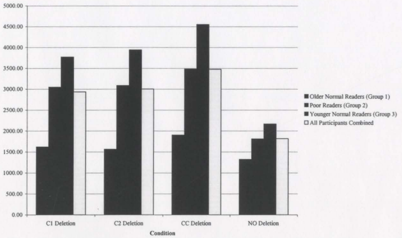

Figure 9: Reaction Time Combined For Each Group by Condition (Forced-Choice Auditory Cue Task)

Table 4: Reaction Time (ms) Correct By Condition (All Subjects Combined)

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Mean	3065.70	3141.67	3623.80	1768.42
Standard Deviation	1701.81	2383.35	2469.04	591.23
Minimum	1046.79	1204.05	694.00	986.75
Maximum	8079.57	14371.63	11723.56	3969.48

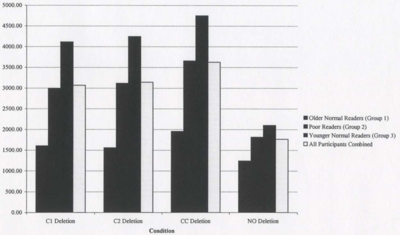

Figure 10: Reaction Time Correct For Each Group By Condition (Forced-Choice Auditory Cue Task)

The shortest reaction times for both reaction time measures were for the NO deletion word pairs. The C1 deletion and C2 deletion reaction times were very similar in range. The longest reaction time was for the CC deletion word pairs, indicating the difficulty the participants had in analyzing clusters into phonemes (further discussion in § 9.2.1). These means can be seen in Figures 9 (*reaction time combined*) and 10 (*reaction time correct*). The next section (§ 8.2.3) will discuss the effect of cluster type on the overall performance of all of the subjects.

8.2.3 Cluster type

This section will discuss the effect of *cluster type* on the overall performance of all of the participants in terms of three measures: *percent acceptances*, *reaction time* *combined*, and *reaction time correct*. The six cluster types referred to in this section are *s + obstruent* (cluster type 1), *obstruent + liquid* (cluster type 2), *obstruent + glide* (cluster type 3), *s + liquid* (cluster type 4), *s + glide* (cluster type 5), and *s + nasal* (cluster type 6).

An ANOVA for the *percent acceptances* measure revealed that the effect of cluster type was not significant ($F(5, 165) = 2.211$; $MSe = 181.674$; $p < 0.05$). Therefore cluster type did not influence the participants' performance. As well, the CLUSTER TYPE X GROUP interaction ($F(10, 165) = 1.178$; $MSe = 181.674$; $p > 0.05$) and the CLUSTER TYPE X CONDITION interaction ($F(15, 495) = 1.032$; $MSe = 228.694$; $p > 0.05$) were not significant. This suggests that the participants' overall performance did not vary across these factors. The means can be seen in Figure 11.

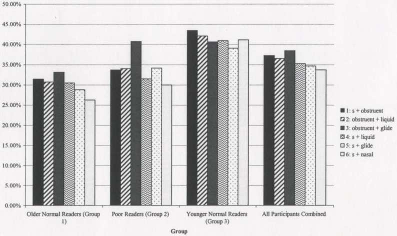

Figure 11: Percent Acceptances For Each Group by Cluster Type (Forced-Choice Auditory Cue Task)

In contrast, while cluster type did not have a significant effect for the *percent acceptances* measure, it was significant for both of the *reaction time* measures. An ANOVA on the *combined reaction time* measure ($F (5, 170) = 2.495$; $MSe = 2752076.534$; $p < 0.05$) revealed a significant effect of cluster type. This effect indicates that cluster type influenced the length of the reaction time overall. Furthermore, an ANOVA for the *reaction time correct* measure also showed that cluster type had a significant effect ($F (5, 85) = 4.924$; $MSe = 3284232.277$; $p < 0.05$). Thus all of the participants combined were affected by cluster type in terms of the time it took them to analyze the cluster and provide a response for the trials where they provided the correct answer.

Table 5 presents the means which show a significant effect of cluster type for the *reaction time combined* measure. While the means are close in range, the difference is still enough to produce a moderate effect of cluster type. The shortest reaction times were for cluster types 1 (*s* + *obstruent*), 2 (*obstruent* + *liquid*), 4 (*s* + *liquid*), and 5 (*s* + *glide*), which were all very close in range. The longest reaction times were for cluster types 3 (*obstruent* + *glide*) and 6 (*s* + *nasal*). These means can be seen in Figure 12. While these are still relatively close in range to the other reaction times, they are nonetheless the longest reaction times out of the six cluster types.

Table 6 shows a significant effect of cluster type for the *reaction time correct* measure. Like the means for the *combined reaction time* measure, the means for the *reaction time correct* measure are also close in range. The longest reaction time was once again for cluster type 3 (*obstruent* + *glide*), and for the *reaction time correct* measure cluster type 3 (*obstruent + glide*) had an average reaction time that was considerably longer than for the other five cluster types. These means can be seen in Figure 13. Combined with the results from the other measures this indicates that cluster type 3 (*obstruent + glide*) may be difficult for the participants to analyze.

Table 5: Reaction Time (ms) Combined By Cluster Type (All Subjects Combined)

	1: s + obstruent	2: obstruent + liquid	3: obstruent + glide	4: s + liquid	5: s + glide	6: s + na
Mean	2654.76	2691.65	3145.29	2856.89	2695.34	3042.2
Standard Deviation	1211.48	1302.49	1900.55	1633.27	2092.64	2031.3
Minimum	1032.99	1091.38	1189.60	1069.84	1019.63	1081.8
Maximum	5440.73	6767.86	8842.95	9143.88	13133.69	10882.5

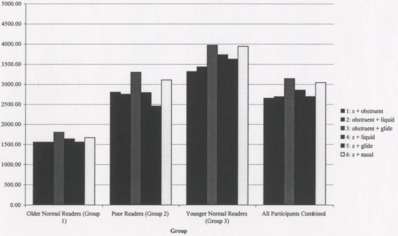

Figure 12: Reaction Time Combined For Each Group by Cluster Type (Forced-Choice Auditory Cue Task)

Table 6: Reaction Time (ms) Correct By Cluster Type (All Subjects Combined)

	1: s + obstruent	2: obstruent + liquid	3: obstruent + glide	4: s + liquid	5: s + glide	6: s + nasa
Mean	2647.98	2787.81	3543.83	2537.22	2745.11	3001.91
Standard Deviation	1227.37	1340.01	2885.01	1262.56	1878.62	2255.21
Minimum	1021.39	1202.26	1207.50	1057.25	1058.58	1068.54
Maximum	5399.02	6453.74	16283.88	6334.80	11139.38	12668.13

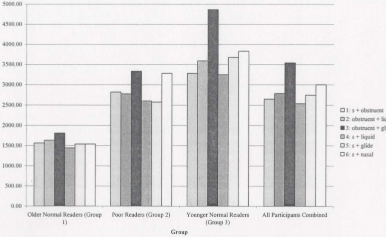

Figure 13: Reaction Time Correct For Each Group By Cluster Type (Forced-Choice Auditory Cue Task)

For the *reaction time combined* measure the CLUSTER TYPE X GROUP interaction ($F(10, 170) = 0.393$; $MSe = 2752076.534$; $p > 0.05$) and the CLUSTER TYPE X CONDITION interaction ($F(15, 510) = 1.210$; $MSe = 2861890.491$; $p > 0.05$) were not significant. This means that the participants' overall performance did not vary across these factors on this measure. For the *reaction time correct measure*, the interaction between cluster type and group was not significant ($F(10, 85) = 1.947$; $MSe= 3284232.277$; $p > 0.05$, however the CLUSTER TYPE X CONDITION interaction was ($F(15, 255) = 1.851$; $MSe = 3179597.648$; $p < 0.05$). This indicates that performance varied amongst cluster types and conditions but not amongst cluster types and groups on this measure.

The presentation of the results for the individual groups below will detail for which groups cluster type had a significant effect.

8.2.4 Group 1's (older normal readers) performance on tasks

This section will discuss the performance of the older normal readers (Group 1) in terms of the three measures used earlier to discuss the participants as a whole: *percent acceptances, reaction time combined,* and *reaction time correct.*

The performance of this group was affected by condition, as is indicated by significant results for ANOVAs on all three measures. An ANOVA on the *percent acceptances* measure revealed a significant effect of condition ($F(3, 27) = 84.523$; $MSe = 1479.666$; $p < 0.05$). This means that the process that the word pair had undergone (i.e. C1 deletion, C2 deletion, CC deletion, or NO deletion) had a significant effect on the performance of the older normal readers. This effect is expected since the participants should react differently to the different processes in the forced-choice auditory cue task. Table 7 shows the means demonstrating a significant effect of condition for the *percent acceptances* measure. The older normal readers (Group 1) accepted a high percentage of the C1 deletion word pairs (correct answers) and a very low percentage of the C2 deletion and NO deletion word pairs (incorrect answers). While their acceptances of the CC deletion word pairs (incorrect answers) were still relatively low, they were nevertheless high enough to indicate that this deletion process was more difficult for even skilled readers to analyze. The means for the percent acceptances are shown in Figure 8.

Table 7: Percent Acceptances For Group 1 – Effect of Condition

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Mean	95.38%	1.57%	23.66%	0.92%
Standard Deviation	4.45%	4.78%	36.84%	1.52%
Minimum	89.52%	0.00%	0.00%	0.00%
Maximum	100.00%	15.93%	99.63%	4.07%

An ANOVA on the *reaction time combined* measure also revealed a significant effect of condition ($F (3, 30) = 5.851$; $MSe = 646103.643$; $p < 0.05$). This means that the process the word pair had undergone significantly influenced the average overall reaction time of this group (correct and incorrect answers combined). Table 8 shows the means that demonstrate the significant effect of condition for the *reaction time combined* measure. Further support for the significant effect of condition is provided by an ANOVA on the *reaction time correct* measure which revealed another significant effect of condition ($F (3, 24) = 14.488$; $MSe = 356581.547$; $p < 0.05$). This indicates that once again the participants' performance differed depending on the condition presented by the word pair. Table 9 shows a significant effect of condition for the *reaction time correct* measure, consistent with the results from the other measures presented earlier.

Table 8: Reaction Time (ms) Combined For Group 1 – Effect of Condition

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Mean	1616.88	1561.31	1902.71	1319.96
Standard Deviation	273.50	266.96	529.58	292.42
Minimum	1012.15	1198.56	1142.92	979.02
Maximum	1937.68	2181.78	2874.63	2085.10

Table 9: Reaction Time (ms) Correct For Group 1 – Effect of Condition

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Mean	1603.88	1557.94	1956.99	1241.80
Standard Deviation	228.24	273.84	715.19	140.22
Minimum	1046.79	1204.05	694.00	986.75
Maximum	1878.09	2283.21	3194.50	1415.20

The participants took varying amounts of time to analyze the cluster depending on the condition. The longest reaction time was for the CC deletion word pairs; the shortest for the NO deletion word pairs, and the C1 and C2 deletion word pairs reaction times were intermediate between the others and very close together. The average reaction times for the *reaction time combined* measure can be seen in Figure 9 and for the *reaction time correct* in Figure 10. Consistent with results presented earlier, this indicates a higher level of difficulty in processing the onset deletion task, even for skilled readers, such as this group of older normal readers.

The performance of this group was also affected by cluster type, however not for all three of the measures. The results presented below will show that the older normal readers' performance was affected by cluster type only in terms of reaction time, and not in terms of the percentage of word pairs they accepted as being correct (i.e. 'yes' answers).

An ANOVA revealed that for the *percent acceptances* measure the effect of cluster type was not significant ($F(5, 45) = 1.592$; $MSe = 49.759$; $p > 0.05$) nor was the CONDITION X CLUSTER TYPE interaction ($F(15, 135) = 1.300$; $MSe = 68.505$; $p > 0.05$). This suggests that not only was performance unaffected by cluster type, but also that this lack of an effect was consistent across all conditions. The means can be seen in Figure 11.

However, an ANOVA for the *reaction time combined* measure revealed a significant effect of cluster type ($F(5, 50) = 2.912$; $MSe = 211481.838$; $p < 0.05$). This significant effect indicates that reaction time performance differed depending on the cluster type of the word pair. In contrast, the CONDITION X CLUSTER TYPE interaction was not significant ($F(15, 150) = 1.582$; $MSe = 233289.565$; $p > 0.05$), indicating that the participants' performance was consistent across the four conditions. Table 10 shows the means which demonstrate a significant effect of cluster type for the *reaction time combined* measure. The longest reaction times were for cluster type 3 (*obstruent* + *glide*) and cluster type 6 (*s* + *nasal*) indicating that these cluster types were more difficult for the participants to analyze. These means can be seen in Figure 12.

Table 10: Reaction Time (ms) Combined For Group 1 – Effect of Cluster Type

	1: s + obstruent	2: obstruent + liquid	3: obstruent + glide	4: s + liquid	5: s + glide	6: s + nasal
Mean	1556.39	1555.47	1800.97	1636.32	1558.38	1668.77
Standard Deviation	251.95	228.23	350.60	290.38	266.25	455.37
Minimum	1032.99	1091.38	1189.60	1069.84	1019.63	1087.13
Maximum	1916.64	1877.19	2266.24	2105.57	1918.50	2674.56

An ANOVA on the *reaction time correct* measure supported the *reaction time combined* results by revealing a significant effect of cluster type ($F(5, 40) = 4.515$; $MSe = 125785.806$; $p < 0.05$). In contrast to the *reaction time combined* results, however, the ANOVA also revealed a significant CONDITION X CLUSTER TYPE interaction ($F(15, 120) = 1.867$; $MSe = 134927.622$; $p < 0.05$). These significant results mean that the participants in Group 1 (older normal readers) were affected both by the process and by the cluster type exhibited by the word pair, and that the effect of cluster type on their performance varied depending on the condition, but only for those trials where they provided the correct response. Table 11 shows the means which demonstrate a significant effect of cluster type on the *reaction time correct* measure. The participants had the longest reaction time on this measure for cluster type 3 (*obstruent + glide)* while the remainder of the cluster types were in close range in terms of reaction time. These means can be seen in Figure 13.

Table 11: Reaction Time (ms) Correct For Group 1 – Effect of Cluster Type

	1: s + obstruent	2: obstruent + liquid	3: obstruent + glide	4: s + liquid	5: s + glide	6: s + nasa
Mean	1564.02	1632.01	1808.98	1445.59	1541.79	1539.72
Standard Deviation	236.42	314.83	353.36	182.73	273.48	354.99
Minimum	1021.39	1202.26	1207.50	1057.25	1058.58	1131.75
Maximum	1831.97	2219.11	2251.25	1761.07	1950.25	2443.42

8.2.5 Group 2's (poor readers) performance on tasks

This section will discuss the performance of the poor readers (Group 2), in terms of the three measures introduced earlier: *percent acceptances, reaction time combined,* and *reaction time correct.*

The performance of this group was affected by condition, as is shown by significant results on ANOVAs for all three measures. An ANOVA on the *percent acceptances* measure revealed a significant effect of condition ($F(3, 27) = 28.571$; $MSe = 1882.931$; $p < 0.05$). Thus the process the word pair had undergone played a significant role in the percentage of word pairs the poor readers accepted as being correct. Table 12 shows the means which resulted in the significant effect. The highest percentage of acceptances was for the C1 deletion word pairs which was expected given the nature of the task. However, it is also interesting to note the high percentage of acceptances of the CC deletion word pairs. This is consistent with results presented earlier in indicating a higher level of difficulty for analyzing onset deletion for skilled readers. These means can be seen in Figure 8.

Table 12: Percent Acceptances For Group 2 – Effect of Condition

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Mean	74.18%	20.42%	37.13%	4.31%
Standard Deviation	20.10%	21.73%	26.72%	5.14%
Minimum	31.65%	2.38%	7.14%	0.00%
Maximum	99.26%	59.86%	82.75%	12.09%

An ANOVA on the *reaction time combined* measure also revealed a significant effect of condition ($F(3, 27) = 7.314$; $MSe = 4330153.313$; $p < 0.05$). The results indicate that the participants performed differently depending on which condition they were faced with. Table 13 shows the means demonstrating a significant effect of condition for the *reaction time combined* measure for the poor readers. An ANOVA on the *reaction time correct* measure revealed a significant effect of condition ($F(3, 12) = 5.895$; $MSe = 6684918.016$; $p < 0.05$). This significant effect is consistent with earlier results which showed a significant effect of condition and supports the influence of condition on performance, whereby the reaction time varied depending on the process involved. Table 14 shows the means demonstrating a significant effect of condition on the *reaction time correct* measure for Group 2 (poor readers).

Table 13: Reaction Time (ms) Combined For Group 2 – Effect of Condition

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Mean	3047.59	3086.59	3483.23	1807.07
Standard Deviation	1323.37	1404.61	2070.56	380.93
Minimum	1294.54	1369.04	1232.28	1280.99
Maximum	5436.80	6121.79	7290.28	2335.47

Table 14: Reaction Time Correct For Group 2 – Effect of Condition

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Mean	2996.78	3116.46	3659.84	1817.82
Standard Deviation	1161.98	1645.14	2059.60	391.04
Minimum	1448.77	1308.83	1168.40	1264.75
Maximum	5343.94	7190.41	7116.48	2401.92

The participants in this group had the longest reaction time for the CC deletion word pairs, again indicating that these were more difficult for them to analyze. The shortest reaction time was for the NO deletion word pairs (as expected since nothing had changed so it should have been very easy for the participants to determine that they were hearing the same word twice and thus no sound(s) had been removed). The reaction time for the C1 and C2 deletion word pairs was very close indicating that the ability to analyze these two processes is closely related in difficulty level. These means can be seen in Figure 9 for the *reaction time combined* measure and Figure 10 for the *reaction time correct* measure.

In contrast to the results presented earlier for the older normal readers, where there were significant effects of cluster type, the same results were not found for the poor readers. An ANOVA revealed that for the *percent acceptances* measure the effect of cluster type ($F(5, 45) = 2.449$; $MSe = 220.366$; $p = 0.048$) neared significance and that the CONDITION X CLUSTER TYPE interaction was also not significant ($F(15, 135) = 1.048$; $MSe = 238.776$; $p > 0.05$). Given that this measure was very close to being insignificant, it is likely that cluster type did not influence the performance of this group in terms of the percentage of word pairs they accepted as being correct (i.e. having the first sound of the second word removed) and this was consistent across all conditions. All of the average acceptances were within a close range; however it is again interesting to note that the highest acceptance rate was for cluster type 3 (*obstruent + glide*) while the averages for the remainder of the cluster types are much closer in range. This indicates a higher level of difficulty in analyzing this cluster type in comparison with the other five for the poor readers. The means can be seen in Figure 11.

An ANOVA for the *combined reaction time* measure also revealed that cluster type did not have a significant effect ($F (5, 45) = 1.804$; $MSe = 2019374.431$; $p > 0.05$) but in this case the CONDITION X CLUSTER TYPE interaction was significant ($F (15, 135) = 1.942$; $MSe = 1221142.929$; $p < 0.05$). This means that while cluster type did not influence performance overall, in terms of either of the reaction time measures, the lack of effect was not consistent across all conditions and for all cluster types. An ANOVA on the *reaction time correct* measure revealed that cluster type did not have a significant effect on performance ($F (5, 20) = 1.810$; $MSe = 4584132.590$; $p > 0.05$) but that the CONDITION X CLUSTER TYPE interaction was significant ($F (15, 60) = 1.970$; $MSe = 3936825.175$; $p < 0.05$). All of the average reaction times were within a close range, and again it is interesting to note that the highest reaction time was for cluster type 3 (*obstruent + glide*). This is consistent with results presented earlier in indicating that this cluster type is more difficult for the participants to analyze. These means can be seen in Figure 12 for the *reaction time combined* measure and Figure 13 for the *reaction time correct* measure.

8.2.6 Group 3's (younger normal readers) performance on tasks

This section will discuss the performance of the younger normal readers (Group 3) in terms of the three measures introduced earlier: *percent acceptances, reaction time combined,* and *reaction time correct*. While the overall performance of this group was poor, significant effects were nonetheless obtained.

The performance of this group was affected by condition, as is indicated by significant results on ANOVAs for two of the three measures. An ANOVA on the *percent acceptances* measure revealed a significant effect of condition, consistent with the results for the two other groups ($F(3, 45) = 23.194$; $MSe = 2349.665$; $p < 0.05$), and once again demonstrating the influence of deletion process on participant performance. Table 15 shows the means used to reveal the significant effect of condition for the younger normal readers on the *percent acceptances* measure. A look at the acceptance rates of each deletion process provides support for the claim that the younger normal readers performed poorly on the task. They exhibited a relatively low rate of acceptances of the C1 deletion word pairs and relatively high rates of acceptance of the C2 deletion, CC deletion and NO deletion word pairs in comparison with the other two groups, as can be seen in Figure 8. However, consistent with the other two groups, the younger normal readers' highest percentage of acceptances was for the CC deletion word pairs, the lowest for the NO deletion words pairs, and the C1 and C2 deletion word pairs were intermediate between the two. Looking at Table 15, it is evident that their performance in some instances was near chance levels indicating that they had a great deal of difficulty processing the different deletion processes presented in the forced-choice auditory cue task.[1]

Table 15: Percent Acceptances For Group 3 – Effect of Condition

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Mean	66.59%	38.27%	50.00%	10.02%
Standard Deviation	21.19%	28.71%	30.90%	14.01%
Minimum	26.12%	7.28%	6.43%	0.00%
Maximum	99.02%	85.77%	98.65%	53.53%

An ANOVA on the *reaction time combined* measure revealed another significant effect of condition ($F (3, 45) = 7.809$; $MSe = 12768076.045$; $p < 0.05$), demonstrating that reaction time was influenced by condition for this group as well. Table 16 shows the means which indicate a significant effect of condition for the *reaction time combined* measure for the younger normal readers. In continuing the pattern of performance exhibited by the other two groups, the younger normal readers also had the longest reaction time for the CC deletion word pairs, and the shortest for the NO deletion word pairs, with the C1 and C2 deletion word pairs close together in range and intermediate between the others. These means can be seen in Figure 9.

Table 16: Reaction Time Combined For Group 3 – Effect of Condition

	C1 Deletion	C2 Deletion	CC Deletion	NO Deletion
Mean	3771.45	3942.27	4553.35	2164.50
Standard Deviation	1810.01	2843.83	2476.93	687.81
Minimum	1986.40	1511.27	1672.87	1593.48
Maximum	8594.17	13563.30	10267.73	4310.60

[1] The performance of the younger normal readers was not at floor. They did indeed understand the task, as is shown by their performance during the training session and their higher acceptances of the correct answer as opposed to the incorrect answers.

In contrast to the *reaction time combined* measure, an ANOVA on the *reaction time correct* measure revealed that the effect of condition neared significance ($F (3, 15) = 3.384$, $MSe = 26372781.860$; $p = 0.046$). Given this borderline value it is thus likely that the participants do not show evidence of having more difficulty with any particular process. Given the chance level performance identified earlier, it is likely that the participants in this group did not show a significant reaction time effect because they had difficulty with all of the conditions; therefore all conditions took a relatively long time for them to analyze and provide an answer.

However, this group followed the same pattern outlined earlier with the other groups whereby the longest reaction time is for the CC deletion word pairs, the shortest for the NO deletion word pairs and the C1 and C2 deletion word pairs are close in proximity and intermediate between the two. This consistent pattern of performance reinforces the claim that the participants had more difficulty with the CC deletion word pairs than they did with the other word pair processes, as is evident by the time it took them to analyze the word pair and provide an response.

Similar to the results for the poor readers (Group 2), cluster type was not found to have a significant effect on the performance of the younger normal readers. An ANOVA for the *percent acceptances* measure revealed that cluster type did not have a significant effect ($F (5, 75) = 0.588$; $MSe = 237.609$; $p > 0.05$) and that the CONDITION X CLUSTER TYPE interaction was also not significant ($F (15, 225) = 0.400$; $MSe = 318.759$; $p > 0.05$). This means that the performance of the participants in Group 3 (younger normal readers) was not influenced by cluster type and that this lack of effect was consistent across all four possible conditions. All of the percent acceptance averages were in very close proximity in terms of range and none of the cluster types stood out as being accepted more or less than the other types. The means can be seen in Figure 11.

An ANOVA for the *reaction time combined* measure revealed that cluster type was not significant ($F (5, 75) = 1.114$; $MSe = 4885427.593$; $p > 0.05$) and neither was the CONDITION X CLUSTER TYPE interaction ($F (15, 225) = 0.853$; $MSe = 5598739.645$; $p > 0.05$). Similarly, an ANOVA for the *reaction time correct* measure supports these results in revealing that cluster type did not have a significant effect ($F (5, 25) = 2.249$; $MSe = 7297826.382$; $p > 0.05$). Furthermore, the CONDITION X CLUSTER TYPE interaction was not significant ($F (15, 75) = 0.668$; $MSe = 7445287.667$; $p > 0.05$). These results mean that the type of consonant cluster involved did not influence the participants' performance and that this was consistent across all four conditions. For the *reaction time combined* measure all of the reaction times were very close in range and none of the cluster types stood out as being easier or harder to process as indicated by the length of the reaction time recorded. However, for the *reaction time correct* measure, while five of the six cluster types were very close in terms of the length of the reaction time, cluster type 3 stood out as having a longer reaction time than the rest. This can be seen in Figure 13, and indicates, as with the results for the other groups, that this cluster type is more difficult to analyze.

8.2.7 Summary

This section will summarize the findings of this experiment for all groups combined (§ 8.2.7.1) and for each group individually (§ 8.7.2.2).

8.2.7.1 Overall findings (for all groups combined)

The results show a significant effect of group for the *percent acceptances* measure only and a significant effect of cluster type was only found for the reaction time measures. However, there were significant effects of condition for both the *percent acceptances* and the two reaction time measures.

8.2.7.2 Findings for each group

The findings for each group are summarized below in Table 17 which shows where a significant effect was and was not found for each group.

Table 17: Findings for Each Group

	CONDITION			CLUSTER TYPE			CONDITION X CLUSTER TYPE		
	% Accept.	RT Combined	RT Correct	% Accept.	RT Combined	RT Correct	% Accept.	RT Combined	RT Correct
Older Normal Readers	✓	✓	✓	✗	✓	✓	✗	✗	✓
Poor readers	✓	✓	✓	✗	✗	✗	✗	✓	✓
Younger Normal Readers	✓	✓	✗	✗	✗	✗	✗	✗	✗

For all three groups, condition had an effect on performance, with significant results having been found for all groups on the *percent acceptances* and *reaction time combined* measures, and for the older normal readers and the poor readers on the *reaction time correct* measure. The only instance where condition was not found to have a significant effect was for the younger normal readers on the *reaction time correct* measure; however it is likely that this lack of an effect can be attributed to their poor overall performance.

Cluster type was only found to have a significant effect on the performance of the older normal readers on the two reaction time measures. For the two other groups cluster type never had a significant effect.

The CONDITION X CLUSTER TYPE interaction was significant for the older normal readers only on the *reaction time correct* measure and for the poor readers on both reaction time measures. It was never significant for the *percent acceptances* measure and never for the younger normal readers.

These findings are interpreted in § 9.

8.3 Relationship between performance on tasks and spelling ability

8.3.1 Introduction

The next section (§ 8.3.2) will discuss the relationship between performance on the forced-choice auditory cue task (Task 2, § 7.2.2.3) and performance on the spelling task (Task 3, § 7.2.2.4). This section measures the correlation between each group's performance on this phoneme awareness task and spelling ability – in contrast, § 8.2 referred to the relationship between phoneme awareness and reading ability. The correlations that will be discussed correlate the average error rate on the forced-choice auditory cue task with the error rate on the spelling task. The average error rate for the forced-choice auditory cue task was calculated by dividing the number of incorrect answers on the task (both when the participants answered 'yes' and should have answered 'no' and when they answered 'no' and should have answered 'yes'), by the total number of trials, to get a percentage. Since there were two sections to the forced-choice auditory cue task (A & B, see § 7.2.2.3 in the methodology), the error rates of the two sections were averaged to provide the average error rate used in these correlations. For example if a participant had an average error rate of 10% on section A and an average error rate 20% on section B, his or her overall average error rate would be 15%. The error rate for the spelling task was calculated by dividing the number of incorrect spellings by the total number of words the participants were asked to spell to get a percentage. The main finding of this section is that there was a significant relationship between the two error rates for the two normal reading groups (Group 1 – older normal readers and Group 3 – younger normal readers); however there was not a significant relationship between the error rates for the poor readers (Group 2). These findings will be discussed next.

8.3.2 Tasks and spelling

A Pearson correlation coefficient between the average error rate on the forced-choice auditory cue task and the error rate on the spelling task for all of the subjects combined as a single group revealed a significant relationship between these two factors ($r = 0.736$; $p < 0.05$). This indicates that as a whole, if the participants had a high error rate on the forced-choice task they were likely to have a high error rate on the spelling task. Likewise if they had a low error rate on one of the measures they were likely to have a low error rate on the other. The correlation will now be discussed with reference to the three individual groups. Figure 14 is a scatter plot which shows the relationship between these two measures for all of the subjects, and is divided into three groups, each represented by a different symbol on the chart.

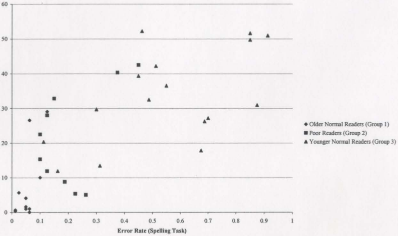

Figure 14: Pearson Correlation Coefficient Scatterplot Between Error Rates for All Groups

For the older and younger normal readers there were significant correlations between the average error rate on the forced-choice auditory cue task and the error rate on the spelling task (older normal readers, $r = 0.661$; $p < 0.05$; younger normal readers, $r = 0.569$; $p < 0.05$). For these two groups if the participants were able to perform well on the forced-choice auditory cue task they were able to accurately complete the spelling task, and if they were unable to perform well on the forced-choice auditory cue task they were unable to complete the spelling task accurately. The significant correlation tells us that there is indeed a relationship between phoneme awareness and the ability to remove phonemes, and the ability to spell.

For the poor readers, there was no significant correlation between the average error rate on the forced-choice auditory cue task and the error rate on the spelling task ($r = 0.489$; $p > 0.05$). The lack of a significant correlation here tells us that, for poor readers, phoneme awareness, as tested through phoneme removal, is not linked to their spelling ability. Thus their performance on the forced-choice task has no relationship to their performance on the spelling task and vice versa. The link between phonemic and orthographic representations (i.e. sound-spelling correspondences) is very weak in this group. The significance of this finding will be discussed in the following section.

9 Discussion

This section will discuss the findings of this study with reference to the hypotheses (see § 6) and purposes (see § 7) outlined earlier, and will interpret the main findings presented in § 8, as well as several other interesting findings.

9.1 The Roles of production and short-term memory in the forced-choice auditory cue task

This study hypothesized that a group of poor readers would still perform poorly on a modified 'Rosner' task because they have perceptual and short-term memory deficits, two components which are impossible to eliminate from any phoneme awareness task. The results (as presented in § 8) show that removing production did not improve the performance of the poor readers. The poor readers in this study still had difficulty with the phoneme awareness task (the forced-choice auditory cue task described in § 7.2.2.3), even though the production component had been removed. If production had a significant impact on phoneme awareness abilities then we would expect the poor readers to perform more comparably to the good readers. Since the poor readers performed more poorly than the older normal readers on the modified 'Rosner' task, this suggests that perceptual and short-term memory deficits underlie dyslexics' performance independently of the other deficits (discussed in § 5). Even with the production component removed, this novel phoneme awareness task still distinguished between participants with different levels of reading ability: older normal readers, poor readers and younger normal readers. These findings are consistent with the literature in showing that phoneme awareness correlates with reading ability.

The next few subsections will discuss several key findings from this study, with reference to condition (§ 9.2.1) and cluster type (§ 9.2.2).

9.2 The nature of phoneme awareness

9.2.1 Incompletely developed phoneme awareness

While phoneme awareness correlates with reading ability, the main finding of an effect of condition in all groups also provides evidence that analytic phoneme awareness does not develop completely, even in good readers. While all groups performed relatively well in terms of recognizing C1 deletion as the correct answer to the question 'is the first sound gone?', it appears they had more difficulty determining what was incorrect, and thus frequently provided the incorrect answer. Specifically, all participants, regardless of group, showed the same pattern of performance in terms of their percentage of acceptances of the four conditions (C1 deletion, e.g. *Blake-lake*, C2 deletion, e.g. *Blake-bake*, CC deletion, e.g. *Blake-ache*, NO deletion, e.g. *Blake-Blake*). All three groups correctly accepted the highest percentage of the C1 deletion word pairs. Similarly, all three groups accepted the lowest percentage of the NO deletion word pairs.

A surprising result, however, was the relatively high percentage of acceptances of the CC deletion word pairs. Even the older normal readers accepted a relatively high percentage of this condition, and the younger normal readers accepted the CC deletion word pairs at chance levels. The poor readers were intermediate between the two, indicating that their analytical abilities lay somewhere in between the abilities of these two groups. The reaction time results support the *percent acceptances* results. For both the *reaction time combined* and *reaction time correct* measures all participants (i.e. all three groups) exhibited the highest reaction time for the CC deletion word pairs. The high reaction time for the CC deletion word pairs indicates that the participants require more time to analyze this word pair condition, and thus that it is more difficult for them.

It appears that the participants, even the older skilled readers, had some difficulty analyzing the cluster into two phonemes in order to decide whether or not only the first sound had been removed. Thus, phoneme awareness had not completely developed, since the CC and C1 deletion trials are competing correct answers, even for good readers.

In summary, onset (CC) deletion competed with C1 deletion as a candidate correct answer in all groups. In contrast however, there was no such competition from the C2 and NO deletion trials which all groups quickly discarded as being incorrect (except for the younger normal readers when faced with C2 deletion). This seems to indicate that complex onsets are not robustly distinct from the first phoneme in a word-initial cluster in people's minds. Instead, it appears that the representations of both are closely linked. In contrast, this close relationship is not shared with the second phoneme of a word-initial cluster, as is indicated by the ability of the participants to correctly disregard the C2 deletion word pairs.

9.2.2 The development of phoneme awareness

As discussed in § 3.3, the literature shows that phoneme awareness develops incrementally. The findings of this study support the incremental development of phoneme awareness. The overall performance of the poor readers was intermediate between the older normal readers and the younger normal readers. The older normal readers, who should have the most highly developed phoneme awareness amongst the three groups, performed the best on the forced-choice auditory cue task. The younger normal readers, who are still learning to read, should have the least developed phoneme awareness abilities, and the poor readers, who have difficulty reading but have had as much reading instruction as the older normal readers, should and do fall somewhere in between.

Similarly, the effect of condition also provides evidence for the development of phoneme awareness: the incorrect word pairs (C2, CC and NO deletion) were accepted as correct a low percentage of times by the older good readers, were accepted more by the good readers, and were accepted even more by the younger normal readers. This indicates some level of difficulty for the poor readers and the younger normal readers, in analyzing this process, that the older normal readers do not have trouble with. The above findings are consistent with previous research such as Treiman and Zukowski (1991) in supporting the claim that there is a sequence of stages in the development of phoneme awareness.

The finding that cluster type only affected the reaction times of older normal readers also provides evidence for the incremental development of phoneme awareness:

cluster type (of which there were six, listed in § 8.2.3) only affected the performance of the older normal readers, and only in terms of their reaction times. It did not affect the performance of the poor readers or the younger normal readers on any of the measures. This indicates that the incremental development of phoneme awareness (as discussed in § 3.3) may be more specific than the ability to analyze phonemes, and may instead continue to knowledge of phonemes types (and cluster types). Since the older normal readers have the most fully developed phoneme awareness skills of the three groups tested, the fact that they were affected by cluster type tells us that they were able to analyze phonemes into more fine-grained classes, otherwise cluster type should not have an effect[2].

In summary, the findings of this study are consistent with the conclusions that phoneme awareness correlates with reading ability, develops incrementally, and develops incompletely even in good readers.

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[2] Another interesting finding was that the participants had the highest reaction times (both for the *reaction time combined* and the *reaction time correct* measures) and the highest percent of incorrect acceptances for the *obstruent + glide* (cluster type 3) word pairs, in comparison to the other five consonant cluster types. This might be partially explained in terms of the frequency of the stimuli words. The lowest average frequency of the stimuli words for the six consonant cluster types is in fact for the words used for the *obstruent + glide* (cluster type 3) cluster type. These words had an average frequency of 3.91 words per million while the other five cluster types had average frequencies ranging from 16.71 words per million (*s + liquid*, cluster type 4) to 59.27 words per million (*s + nasal*, cluster type 6) (these averages were calculated based on information obtained from Carroll, Davies and Richman, 1981). The full significance of why this cluster type was more difficult for the participants to process is something that needs further investigation.

9.3 Relationship between phoneme awareness and spelling ability

The results from this study also show that there is a strong relationship between phoneme awareness and spelling ability, consistent with the results for normal readers from earlier studies (for example, Ehri and Wilce, 1980 and Bruck and Treiman, 1990). Both groups of normal readers (older and younger) positively correlated with their phoneme awareness and spelling abilities. The older good readers who have the strongest reading abilities also had the strongest spelling abilities. The younger normal readers whose reading abilities are not fully developed nonetheless exhibited a significant correlation with their spelling abilities.

In contrast, the results from the poor readers are inconsistent with the above literature: the poor readers did not exhibit any correlation between their ability to perform on a phoneme awareness task and their spelling ability. However, consistent with previous research (for example Landerl, et al., 1996) this finding confirms that the sound-spelling correspondences of poor readers are less strongly linked than that of good readers.

In summary, the spelling results are consistent with the interpretation that phoneme awareness does not arise in the absence of knowledge of spelling.

9.4 Summary of Findings

The results of this study show that the performance of poor readers is intermediate between that of older and younger normal readers. These results support previous research which showed that dyslexics are more like younger normal readers than readers of the same age, and that performance on 'Rosner' tasks, even the modified task presented in this study, correlates with reading ability. Furthermore, the results revealed another interesting finding, that even older normal readers had difficulty distinguishing between the C1 and CC removal tasks. This shows that even good readers lack a clear understanding of the analytical nature of the 'Rosner' task. Thus, even though reading/spelling ability and phoneme awareness correlate, true (i.e. complete) phoneme awareness is not fully developed even in good readers. The findings of this study suggest that even with exposure to an alphabetic writing system, true phoneme awareness does not develop completely.

10 Conclusion

This thesis re-examined the phoneme awareness abilities of good and poor readers using a novel phoneme awareness task. This modified 'Rosner' task was designed such that the production and orthographic components were removed from the experimental design and the verbal short-term memory load was reduced.

It was hypothesized that reading ability would still correlate with the ability to perform on phoneme awareness tasks, even with the production component removed. Since the results show that this hypothesis is correct, a possible interpretation is that production does not have an affect on performance on phoneme awareness tasks. It was also hypothesized that spelling ability would correlate with performance on the modified 'Rosner' task. This hypothesis was also found to be correct and a possible interpretation is that even with production removed, this novel phoneme awareness task is still a good predictor of spelling ability.

In conclusion, this thesis has shown that production does not have a profound effect on phoneme awareness ability. When it is removed from the task participants who normally perform poorly on phoneme awareness tasks still perform poorly in comparison to other participants of differing reading abilities. Instead, the results from this study follow the same pattern as results from traditional phoneme awareness tasks that include production. Furthermore, the modified 'Rosner' task used for this study distinguishes between good and poor readers and thus, even with the production component removed, this task is still a good measure of reading ability, as traditional phoneme awareness tasks are.

References

Altmann, Gerry T. M. 1990. *Cognitive Models of Speech Processing: Psycholinguistic and Computational Perspectives*. Cambridge, Massachusetts: The MIT Press.

Ball, Eileen W. 1993. Phonological awareness: What's important and to whom? *Reading and Writing: An Interdisciplinary Journal*, 5, 141-159.

Barton, David, Ruth Miller and Marlys A. Macken. 1980. Do children treat clusters as one unit or two? *Papers and Reports on Child Language Development*, 18, 105-137.

Brady, Susan and Donald Shankweiler (eds.). 1991. *Phonological Processes in Literacy: A Tribute to Isabelle Y. Liberman*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Brady, Susan, Donald Shankweiler and Virginia Mann. 1983. Speech perception and memory coding in relation to reading ability. *Journal of Experimental Child Psychology*, 35, 345-367.

Bruck, Maggie and Rebecca Treiman. 1990. Phonological awareness and spelling in normal children and dyslexics: The case of initial consonant clusters. *Journal of Experimental Child Psychology*, 50, 156-178.

Carroll, John B., Peter Davies and Barry Richman. 1971. *The American Heritage Word Frequency Book*. New York: American Heritage Publishing Co., Inc.

Crystal, David. 1997. *The Cambridge Encycolpedia of Language, Second Edition*. Cambridge: Cambridge University Press.

Cutler, Anne. 1995. Spoken Word recognition and production. In Joanne L. Miller and Peter D. Eimas (eds.). *Speech, Language, and Communication*. San Diego, California: Academic Press Inc.

Ehri, Linnea C. and Lee S. Wilce. 1980. The influence of orthography on readers' conceptualization of the phonemic structure of words. *Applied Psycholinguistics*, 1, 371-385.

Elbro, Carsten. 1996. Early linguistic abilities and reading development: A review and a hypothesis. *Reading and Writing: An interdisciplinary Journal*, 8, 453-485.

Field, John. 2003. *Psycholinguistics: A Resource Book for Students*. London: Routledge.

Garman, Michael. 1990. *Psycholinguistics*. Cambridge: Cambridge University Press.

James, S. L. 1999. General aspects of developmental language disorders. In Franco Fabbro (ed.). *Concise Encyclopedia of Language Pathology*. Oxford: Elsevier Science Ltd, 214-224.

Joanisse, Marc F., Franklin R. Manis, Patricia Keating and Mark S. Seidenberg. 1998. Language deficits in dyslexic children: Speech perception, phonology and morphology. *University of California Working Papers in Phonetics*, 96, 135-161.

Joanisse, Marc F. and Mark S. Seidenberg. 1998. Specific language impairment: a deficit in grammar or processing. *Trends in Cognitive Sciences*, 2(7), 240-247.

Landerl, Karin, Uta Frith and Heinz Wimmer. 1996. Intrusion of orthographic knowledge on phoneme awareness: Strong in normal readers, weak in dyslexic readers. *Applied Psycholinguistics*, 17, 1-14.

Marslen-Wilson, William D. and Alan Welsh. 1978. Processing interactions and lexical access during word recognition in continuous speech. *Cognitive Psychology*, 10, 29-63.

Morais, José, Paul Bertelson, Luz Cary and Jesus Alegria. 1986. Literacy training and speech segmentation. *Cognition*, 24, 45-64.

Post, Yolanda V., Barbara R. Foorman and Merrill Hiscock. 1997. Speech perception and speech production as indicators of reading difficulty. *Annals of Dyslexia*, 47, 3-27.

Rice, Keren. 1992. On deriving sonority: A structural account of sonority relationships. *Phonology* 9(1), 61-99.

Rosner, J., and Simon, D. P., 1971, The auditory analysis test: an initial report. *Journal of Learning Disabilities*, 4(7), 40-48.

Snowling, Margaret. 1981. Phonemic deficits in developmental dyslexia. *Psychological Research*, 43, 219-234.

Snowling, Margaret. 2000. *Dyslexia*. Oxford: Blackwell Publishers Inc.

Swan, Denise and Usha Goswami. 1997. Phonological awareness deficits in developmental dyslexia and the phonological representations hypothesis. *Journal of Experimental Child Psychology*, 66, 18-41.

Tallal, Paula. 1990. Find-grained discrimination deficits in language-learning impaired children are specific neither to the auditory modality nor to speech perception. *Journal of Speech and Hearing Research*, 33, 616-619.

Treiman, Rebecca and Andrea Zukowski. 1991. Levels of phonological awareness. In Susan Brady and Donald Shankweiler (eds.). *Phonological Processes in Literacy: A Tribute to Isabelle Y. Liberman*. Hillsdale, NJ: Lawurence Erlbaum Associates, Publishers.

Troia, Gary A., Froma P. Roth and Grace H. Yeni-Komshian. 1996. Word frequency and age effect in normally developing children's phonological processing. *Journal of Speech and Hearing Research*, 39, 1099-1108.

Wolf, Maryanne. 1986. Rapid alternating stimulus naming in the developmental dyslexias. *Brain and Language*, 27, 360-379.

<u>Appendix – Consent forms</u>

Consent form as provided to parent(s)/guardian(s) of the younger normal readers:

TITLE: Reading, Perception and Removal of Consonant Clusters

INVESTIGATOR: Amanda Squires, Department of Linguistics, Memorial University of Newfoundland.

Your child has been asked to participate in a research study to investigate his/her ability to perceive consonant clusters and to remove them from words and to investigate how this relates to reading. (Consonant clusters are sounds such as 'bl' in the word 'Blake'.) Your child has been chosen for this study based on his/her reading ability. Participation in this study is voluntary. Your child may withdraw from this study at any time and withdrawal will not prejudice him or her in any way, either with the investigator, the University, or in relation to services in the school system. Should your child decide to withdraw from this study, information previously collected from him or her will also be withdrawn.

This study forms part of a masters' thesis, and as such, will become a public document. However, information obtained from your child for the purposes of this study will be kept confidential. If the results of these experiments are published they will not include any information which could potentially identify your child. The results from individuals will be combined and findings for groups of participants will be reported. If individual data are reported, either a number or a pseudonym will be used to refer to the individuals in question. All testing sessions will be recorded or videotaped. These recordings will only be heard or viewed by the researcher, her supervisor, or assistants hired to work on this project and will be used only to verify the researchers' accuracy in recording the participants' responses. When the recordings are stored, it will be stipulated that the recordings can only be listened to or watched by the researchers, their supervisors, or by designated assistants and only for data verification purposes. Recordings will be archived for a period of 5 years, after which they will be permanently destroyed.

1) Purpose of the study

The purpose of the study is to investigate children's ability to remove sounds from words and the relationship between this ability and reading achievement. This study will include several related tasks (described below).

2) Description of experimental procedures and tests

All participants will be tested on their ability to delete sounds from words. Your child will be asked about what words like 'Blake' sounds like without the 'b' sound. Your child will also be asked to say and spell real words such as 'book' Your child will have practice trials, to ensure that the instructions are understood.

Consent form as provided to the older normal readers, the poor readers, and their parent(s)/guardian(s):

TITLE: Reading, Perception and Removal of Consonant Clusters

INVESTIGATOR: Amanda Squires, Department of Linguistics, Memorial University of Newfoundland.

You have been asked to participate in a research study to investigate your ability to perceive consonant clusters and to remove them from words and to investigate how this relates to reading. (Consonant clusters are sounds such as 'bl' in the word 'Blake'.) You have been chosen for this study based on your reading ability. Participation in this study is voluntary. You may withdraw from this study at any time and withdrawal will not prejudice you in any way, either with the investigator, the University, or in relation to services in the school system. Should you decide to withdraw from this study, information previously collected from you will also be withdrawn.

This study forms part of a masters' thesis, and as such, will become a public document. However, information obtained from you for the purposes of this study will be kept confidential. If the results of these experiments are published they will not include any information which could potentially identify you. The results from individuals will be combined and findings for groups of participants will be reported. If individual data are reported, either a number or a pseudonym will be used to refer to the individuals in question. All testing sessions will be recorded or videotaped. These recordings will only be heard or viewed by the researcher, her supervisor, or assistants hired to work on this project and will be used only to verify the researchers' accuracy in recording the participants' responses. When the recordings are stored, it will be stipulated that the recordings can only be listened to or watched by the researchers, their supervisors, or by designated assistants and only for data verification purposes. Recordings will be archived for a period of 5 years, after which they will be permanently destroyed.

1) Purpose of the study

The purpose of the study is to investigate children's ability to remove sounds from words and the relationship between this ability and reading achievement. This study will include several related tasks (described below).

2) Description of experimental procedures and tests

All participants will be tested on their ability to delete sounds from words. You will be asked about what words like 'Blake' sounds like without the 'b' sound. You will also be asked to say and spell real words such as 'book'. You will have practice trials, to ensure that the instructions are understood.

Signature Page

I, ____, the undersigned agree to

participate in the research study described above.

Any questions have been answered and I understand what is involved in the study. I realize that participation is voluntary and that there is no guarantee that I will benefit from involvement in the study.

I acknowledge that a copy of this form, including a description of the research project, has been given to me.

____
(Signature of Parent/Guardian)

____ Age: ______________
(Signature of Minor Participant)

Date: ____

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To the best of my ability I have fully explained the nature of this research study, I have invited questions and provided answers. I believe that the participant fully understands the implications and voluntary nature of the study.

____
(Investigator's signature)

Signature Page

I, ____, the undersigned agree to

participate or allow my child or ward,

____, to participate in the research

study described above.

Any questions have been answered and I understand what is involved in the study. I realize that participation is voluntary and that there is no guarantee that I or my child or ward will benefit from involvement in the study.

I acknowledge that a copy of this form, including a description of the research project, has been given to me.

____

(Signature of Parent/Guardian)

____ Age: _______________

(Signature of Minor Participant)

Date: ____

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To the best of my ability I have fully explained the nature of this research study, I have invited questions and provided answers. I believe that the participant fully understands the implications and voluntary nature of the study.

____

(Investigator's signature)