NON-ORTHOGRAPHIC CONSONANT CLUSTER MANIPULATION BY GOOD AND POOR SPELLERS

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NON-ORTHOGRAPHIC CONSONANT CLUSTER MANIPULATION BY GOOD AND POOR SPELLERS

by

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Abstract

This research examined the correlations between spelling, reading ability and phoneme awareness. A group of university undergraduate students were tested on measures of reading (Woodcock Reading Mastery Test, Woodcock, 1998), spelling (Test of Written Spelling, Larsen et al., 1999), phonological processing (Comprehensive Test of Phonological Processing, Wagner et al., 1999), and finally on an experimental phoneme awareness task (Squires, 2004). The phoneme awareness task used examines phoneme awareness without the effects of production and orthography by presenting participants with auditory stimulus. In the task, participants were asked to compare two words and determine if the first phoneme or sound was deleted from the second word compared to the first. When good and poor spellers were compared in terms of reaction time and score for the phoneme awareness task, there was no significant difference found. However, there was a significant effect of deletion type in the phoneme awareness task found. Specifically, confusion of manipulation of an analytic form of phonological unit (phoneme in a complex consonant cluster) and a more holistic form of phonological unit (complex consonant cluster) was observed in all participants. Lastly, manipulation of "real" consonant clusters and "fake" consonant clusters (/s/ + obstruent) were not found to be significantly different despite structural differences. These results allow a number of conclusions to be made, including that phoneme awareness may not be the crucial element or stage in reading and spelling, that phoneme awareness itself should be viewed as a continuum of abilities with two levels (holistic and analytic), and finally that there is evidence that onset consonant clusters and initial consonant representations are somehow confused by the majority of readers and spellers tested regardless of ability.

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1 Introduction

This thesis examines the relationship between good and poor readers/spellers and analytic awareness, in particular phoneme awareness. Many studies have identified a strong correlation between (a) the ability to read or spell in an alphabetic script, and (b) an ability known as phoneme awareness. However, several studies have suggested that phoneme awareness does not develop spontaneously, even in the case of good readers. Phoneme awareness is the ability to consciously segment and manipulate individual phonemes in words, and is a subtype of phonological awareness. This study examines whether phoneme awareness is an ability that develops in skilled readers.

In order to investigate if phoneme awareness is an ability possessed by good readers, this study compared good and poor university-level readers and spellers performance on a modified "Rosner" task. The research described in this thesis uses a novel form of a traditional phoneme awareness task (a "Rosner" task) (Squires, 2004) that does not involve production or orthography. Traditionally, production and orthography are key components of this type of task. This novel task was used in conjunction with several standardized measures of reading and spelling ability. It was expected that good readers and spellers would outperform poor readers and spellers on the main experimental task due to the major findings of previous research involving phoneme awareness and reading and spelling ability.

This thesis will begin with an in-depth review of phonological awareness (§2). Section 2 will overview phonological awareness (the key component being studied here being phoneme awareness), how phonological awareness develops, as well as its correlation to reading and spelling ability. Also included in this section will be a review of literature that questions the traditional correlation proposed by the majority of literature. This section will conclude with a review of theoretical models of reading and phonological awareness that will allow the development of a hypothesis about the abilities of good and poor spellers related to phonological awareness. Also, as these groups were compared based on their ability to perform a non-orthographic, non-productive analytic awareness task involving auditory stimulus, a discussion of how speech perception relates to linguistic units that are important to phonological awareness and reading will be presented. This hypothesis (§5) will also address the potential effects of "real" versus "fake" consonant clusters in the phoneme awareness task (discussed in §4.1.4).

The description of how this hypothesis was tested will be presented next in §6, entitled methodology. This includes the testing materials, participants, and procedures used. Following this, results (§7) will be presented related to (1) groups, (2) scores, reaction times, and onset effects on the main experimental task, and (3) a discussion of statistics that help evaluate the efficacy of the main experiment task developed by Squires (2004). The section entitled discussion (§8) provides a detailed explanation of the results of this study and summarizes the most important or relevant findings. The conclusion (§9) discusses the implications of this study and how its results relate to or contradict the traditionally accepted notions of reading and spelling ability and phonological awareness.

2 Phoneme Awareness

2.1 Definition of Phoneme Awareness (A Type of Phonological Awareness)

The robust correlation of phonological awareness with reading and spelling ability has been well documented in the literature on reading and phonological awareness. (See, for example, Adams, 1990; Bradley & Bryant, 1983). These studies contribute to the accepted notion that, in order to learn how to read or spell, it is necessary to understand the underlying phonological structure of words. More specifically, the insight into the alphabetic nature of print is the key to learning to read (Adams, 1990). The alphabetic principle is achieved only when a person learns the relationship between letters in print (or orthography) and their related phonemes, which are also discernable from the spoken form of a language that has an alphabetic script. In order for readers to comprehend this alphabetic principle, it is necessary to understand the underlying phonological structures of a given language. Awareness of these phonological structures is referred to as phonological awareness. Phoneme awareness is thus fundamental in acquiring the knowledge associated with the alphabetic principle.

Phonological awareness can be defined as the ability to manipulate phonological units within words (Blachman, 1991; Goswami and Bryant, 1990: 1-4). Phonological awareness itself refers to a heterogeneous group of abilities that are related to different types of linguistic units. It is made up of different components that are relevant at different stages of development (Treiman and Zukowski, 1996). There are at least three discrete levels of phonological awareness, marked by significant linguistic units that have been identified as important in learning to read and spell: awareness of phonemes;

awareness of intra-syllabic units (onsets and rimes); and awareness of syllables (Goswami and Bryant, 1990). The diagram below shows how these forms are found in words:

	Syllable	Onset and rime	Phoneme
"mat"	mat	m - at	m - a - t
"string"	string	s - tr - ing	s-t-r-i-n-g
"wigwam"	wig-wam	w - ig- w - am	w-i-g-w-a-m

Table 1 – Words broken down into phonological components (adapted from Goswami and Bryant, 1990: 2)

For example, the word "mat" constitutes a single word or unit, and also a single syllable. This syllable can be broken down further into onsets (prevocalic units, in this case /m/) and rimes (vocalic unit(s) and postvocalic units, in this case /œt/). Finally, the word can be broken down into single sound units or phonemes (separately /m/, /œ/, and /t/.

Phonological awareness can be viewed as a continuum of abilities (Treiman and Zukowski, 1991: 67), ranging from more holistic awareness to more analytic awareness:

holistic	words
	syllables
	onsets and rimes
analytic	phonemes

Table 2 - Continuum of phonological awareness

Phoneme awareness, in general, is used as a cover term for these very different types of abilities. For example, Elbro (1996: 456) says that the term 'phoneme awareness' refers not only to awareness of the phoneme, but of awareness of onsets and rimes as well. This usage of the term phoneme awareness is inconsistent with other sources which commonly reserve the term phoneme awareness to refer to a specific type of phonological awareness. For clarification, here I reserve the term phoneme awareness for the analytic type of phonological awareness. Holistic awareness will be used when referring to the group of phonological abilities corresponding to the units larger than the phoneme, and phonological awareness will be used only when referring to the whole range of abilities described above. Phonological awareness will be reserved for the whole range of abilities shown above in table 2.

Phoneme awareness, or *analytic awareness*, can be thought of as the ability to consciously manipulate segments in a writing system. This ability involves understanding that words are composed of individual sounds/phonemes (Ball, 1993: 141). Phoneme awareness requires directing conscious attention and analytical abilities to the manipulation of the abstract units of sound, or the phonemes, of a word. Both reading and spelling ability are related to phoneme awareness in an alphabetic code, suggesting that reading and spelling abilities require phoneme awareness (Ball, 1993: 142). That is to say, in order to decode words for reading or spelling purposes, one must be able to connect letters to their corresponding sounds.

The connection between analytic phoneme awareness and reading ability has been assessed through experimental tasks. Tasks that assess phoneme awareness traditionally involve counting, adding, deleting or identifying the position of phonemes in words (Joanisse et al., 1998). Results of phoneme awareness tasks suggest that the ability to read in an alphabetic script like English correlates with awareness of the phoneme. As

Ball (1993: 141) puts it: "Phoneme awareness tasks sample a range of behaviours that require an awareness that words are made up of smaller sound segments or phonemes."

The ability to parse complex consonant clusters into separate phonemes involves a form of analytic phonological awareness. This type of parsing ability is tapped by the "Rosner" or "auditory analysis" task (Rosner and Simon, 1971). In this task, participants are asked to remove a consonant from a word and produce the result. An example of this task would be for the experimenter to ask the participant to say the word "clip." The experimenter then asks the participant to say it again without the "kuh" sound (Rosner and Simon, 1971: 386 - more details in §6.3.4). The main experimental task used in this experiment is modeled after the "Rosner". The ability to perform this type of task indicates that awareness of the individual sounds or phonemes is present.

2.2 How Phonological Awareness Develops

Development of phonological awareness progressively becomes more and more discrete or analytic. This development is linked to an increased reading proficiency. Just as the diagram above (table 2) showed that phonological awareness ranges on a scale of holistic to analytic, this is reflected developmentally as well. Thus the development of phonological awareness in general is manifested in an incremental pattern, phoneme awareness included (Ball, 1993). Phonological awareness then begins with holistic forms of phonological awareness where the whole word is not further analyzed. In normal phonological development, analytic awareness arises progressively through the hierarchy of phonological awareness reviewed in table 2. In general, the more holistic the phonological unit in question, the easier it is to attend to this level. This is in contrast to more analytic phonological units, the sensitivity to which comes less naturally, and is spurred on by progressive development through the range of phonological abilities.

There are three important stages in phonological development, namely awareness of syllables, subsyllabic units (onsets and rimes), and phonemes. The presence of these increasingly analytic abilities correlates with reading and spelling proficiency (see section 2.3). These abilities also develop in the order described here, with little to no variation observed. Table 3 below (adapted from Ball, 1993: 145) highlights the development of phonological awareness, and its landmarks:

Emerging	Simple	Complex
Correcting and regulating sound productions Sound play (spontaneous playing with or practicing the pronunciation of a word, creating nonsense syllables, rhyme and alliteration, or adding endings) Comments on or attracting attention to pronunciation Invented spellings	Rhyme - Providing Rhymes - Categorizing by rhyme - Judging Rhymes Alliteration - Providing - Categorizing by initial sound - Judging Phoneme blending Segmentation - Disks - Tapping - Sound counting Invented spellings	Phoneme manipulation - Deletion - Substitution - Reversal

Table 3 - Phonological awareness: developmental landmarks, continuum of complexity (adapted from Ball, 1993: 145)[1]

The first important stage of development in phonological awareness, detection of syllables from spoken words, has been illustrated in preliterate children's ability to tap according to the number of syllables in a given word (i.e. for a word like *hospital*, a child taps three times for each of the syllables; Treiman and Zukowski, 1996).

[1] Original sources cited by Ball (1993) have been removed.

The next stage in the development of phonological awareness is the detection of rhymes (Goswami and Bryant, 1990), which is normally manifested in songs, nursery rhymes, and rhyming games. This ability is connected to the next level of phonological development after the syllable, the ability to detect onsets and rimes. This ability appears between the stages of syllable awareness and more analytic awareness, namely phoneme awareness (Treiman, 1988). Treiman (1992) demonstrated the presence of this ability in young children as well as adults, showing they naturally break syllables into their onsets and rimes rather than across these units. This ability was observed in their tendency to combine onsets from one syllable with rimes of another syllable, and to not break up onsets or rimes to produce novel forms. For example, children and adults were found to combine onsets like *fr* from the word *frail* with *at* from the word *slat* to form the novel form *frat*, but they did not break up the rime *ail* from *frail* and the rime at in *slat* to get *frait* (*frai* + *t* = *frait*).

With particular reference to onsets, the pattern of development described has been shown to occur in children's lack of ability to analyze consonant clusters: before children can parse consonant clusters into separate sounds or phonemes, they treat clusters as a single unit (Barton et al., 1980). For example, children have been shown to judge words as beginning with the same sounds when they begin with a simple onset, or single consonant, as opposed to a complex consonant cluster onset, containing more than one consonant (Treiman and Zukowski, 1991, pg. 71). Treiman (1985) showed evidence of this in finding that kindergarten-aged children had more difficulty determining that syllables such as "flew" began with "f" than identifying a syllable such as "fool" as beginning with a "f." This finding was once again replicated using prereaders and developing readers by Treiman and Zukowski (1996), suggesting in general that there is superiority of the onset unit over the phonemes that constitute complex onsets in development.

Evidence for superiority of the onset over phonemes in development was also found by Bertelson et al., (1997) in their study involving speech segmentation and onset structures. They asked kindergarteners, first graders and second graders to perform a deletion operation on CVCC and CCVC word. The experimenter would present a word (like "berg" or "kring") and then ask the child to remove the first sound and produce the result ("erg" and "ring"). They predicted that segmentation should be easier when the onset itself consists of a single phoneme (in a CVCC syllable, for example) as opposed to when the first segment is part of a complex onset (in a CCVC syllable, for example). They discovered that first and second graders performance was higher for CVCC syllable over CCVC syllables, while the kindergartner's performance was at floor levels. This study confirms that onset segmentation has precedence over phoneme segmentation in the scheme of phonological development. Furthermore, it shows that the ability to manipulate holistic units such as simple onsets does not appear early in phonological development.

The final, most discrete stage of phonological development is witnessed in the ability to count or manipulate phonemes (Adams, 1990; Liberman et al., 1974). As previously stated, this stage marks the most analytic form of phonological awareness, and can be viewed as its peak. Phoneme awareness arises from experience in a language that uses an alphabetic script, in which words can be analyzed through letter-sound correspondences (Goswami and Bryant, 1990, pg. 271).

as more verbally mature than the other two groups). This study revealed that prereaders in general could not attend to the phonemic structure of words, and that only a small percentage of the first-grade participants could perform above chance on tasks evaluating sensitivity to phonemes. This finding indicates that the groups possessed some phonological awareness of onsets and rimes, but very little of the more analytic form, the phoneme. They were asked to identify, for example, words with similar rimes in a set like *sick*, *kick*, and *pack*. Also, they were also able to identify words with similar onsets in a set like *dry*, *fray* and *draw*. They found that 20% of kindergarteners tested performed above chance on "oddity" tasks (described above), while 60% of first-grade children, of equal linguistic maturity to the kindergarten group, were able to perform these same tasks above chance. However, the majority of participants were unable to identify when words shared a similar medial phoneme in a set like *bed*, *bit*, and *bin*. This result gives the impression that phonemic sensitivity or awareness is not present in prereaders or children in their first year of reading instruction, but also that sensitivity to the phonological unit of the phoneme is in fact developing with increased reading instruction, as witnessed in the percentage of first-graders (10%) who were able to perform the tasks evaluating sensitivity to phonemes above chance. Bowey and Francis (1991:114) point out that this result shows that phonemic awareness develops "concomitantly" with increased understanding of the alphabetic principle. The other important result of Bowey and Francis' (1991) study was seen in the tasks evaluating sensitivity to onset and rime units. The development of sensitivity to subsyllabic units of onsets and rimes increases with or promotes sensitivity to more discrete and analytic phonological units such as phonemes. These results show that phonological awareness and reading proficiency, mediated by reading instruction and experience, both go through the same stages from less to more analytic.

Similarly, Muter et al., (1998) reported that segmentation is the main predictor of reading and spelling progress. Their study examined children in the first two years of reading to determine whether segmentation or rhyming ability were predictors of reading and spelling progress. They found that rhyming did not correlate with early reading or spelling skills, while segmentation tasks, like phoneme deletion and phoneme identification, were found to be highly predictive of progress in early reading and spelling ability.

Performance on "Rosner" tasks has been shown to be highly predictive of reading and spelling ability. For example, MacDonald and Cornwall (1995: 525) performed a longitudinal study of 24 kindergarten participants who were assessed on their ability to perform a "Rosner" task. Results on this task were found to correlate with reading and spelling ability assessed 11 years later. That is to say that participant's initial performance recorded in kindergarten correlated with their reading and spelling ability measured 11 years later.

Although there is a wealth of information identifying the connection between reading and spelling ability and phonological awareness in developing readers, the most compelling evidence for this correlation comes from studies involving 'backward' readers and spellers. Morais et al., (1979) studied adult illiterates and literate adults (who had learned to read either as youth or adults) in the hopes of identifying whether awareness of phones arised during development as an indirect result of cognitive growth. Participants were taken from a poor agricultural area of Portugal, where those who were illiterate had little experience with written language. The illiterate group tested were unable to delete or add a phone to a non-word, while their literate counterparts performed the task easily. This result suggests that phoneme awareness does not develop from general cognitive development, but that this ability is mediated specifically by reading proficiency and literacy. Morais et al. (1979: 330) conclude that awareness of sounds is not a prerequisite to reading ability, but rather is a result of learning to read either as a child or adult.

In a follow-up study, Morais et al., (1986) performed a more in-depth examination of the phonological abilities of illiterates to 'ex-illiterate' adults, once again taken from a poor agricultural area of Portugal. They asked these participants to perform segmentation tasks (as in the previous study), but also included tasks evaluating sensitivity to rhymes and syllables (among other measures). Illiterates were once again unable to delete a sound from the beginning or end of a word, whereas their literate counterparts were able to perform this task. In contrast, the illiterate group in this study performed better on tasks evaluating sensitivity to rimes and syllables. However, they still performed poorer on these tasks than their literate counterparts. These results suggest that the ability to analyze speech at the syllable and rhyme level can develop without formal reading training or ability, but is still enhanced by reading instruction.

All of the studies discussed here provide strong evidence for the claim that phonological awareness and reading and spelling ability are strongly correlated and arise in a developmental sequence. To account for this relationship, Goswami and Bryant (1990: 110) reviewed various developmental studies involving these variables in order to devise models of how this relationship manifests, which is outlined in figure 1 below:

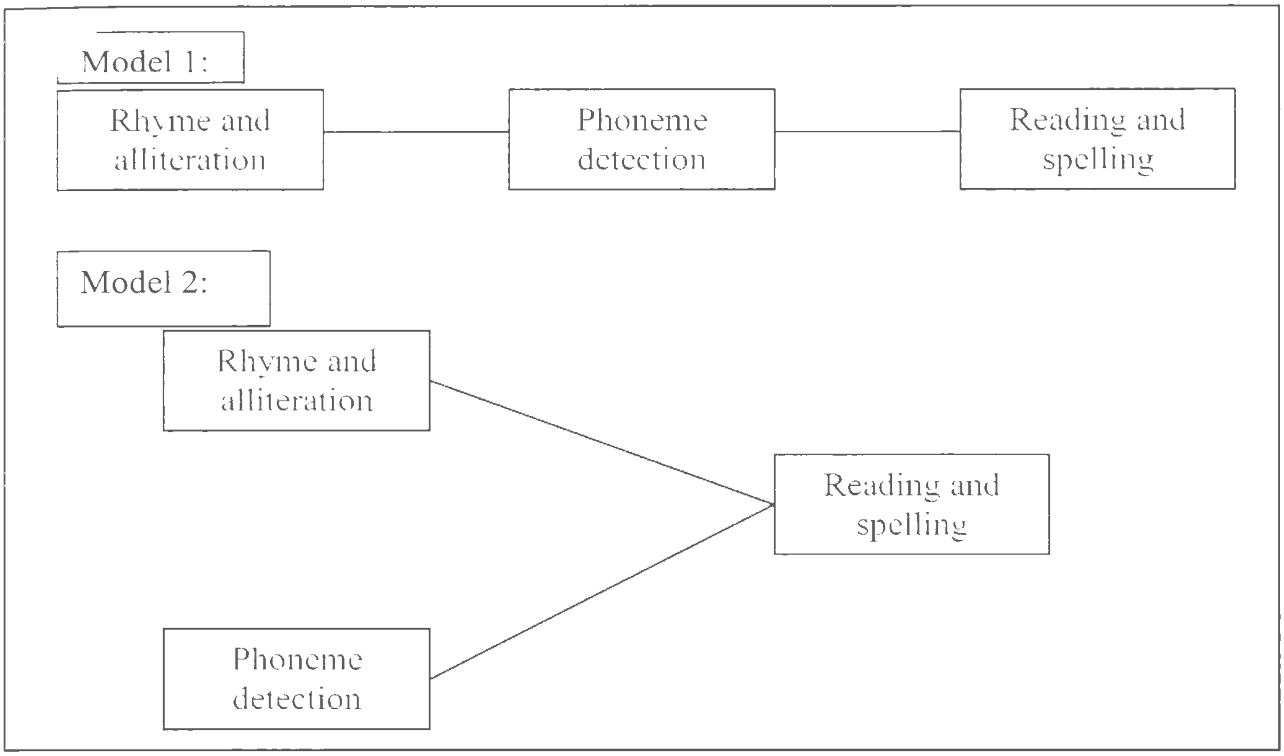

Figure 1– Two Models of the relationship between reading and phonological awareness (adapted from Goswami and Bryant, 1990: 110)

These models highlight the major findings of the research discussed here. There are two alternative interpretations of the data concerning the developmental relationship between reading and phonological awareness. Model 1 proposes a simple linear relationship. It states the order of emergence as (1) rhyme and alliteration skills, where there is awareness of the larger phonological units associated with these skills. This is followed by the emergence of (2) phoneme awareness, which arises due to the refinement of rhyme and alliteration skills. The emergence of this analytic phonological awareness then mediates understanding of the grapheme-phoneme relationship (the alphabetic principle) which, as previously mentioned, is the supposed key to reading ability.

This model, however, is slightly problematic due to studies proposing that that the ability to rhyme and alliterate is directly connected to reading and spelling ability, more specifically that performance of these skills relates to, or predicts, reading and spelling ability. For example, Bryant et al. (1990) asked four year olds to perform 'oddity' type tasks. The four year olds were asked to identify the odd word out of sets like *fish*, *dish*, and *book*. The success of these four year olds in performing this type of task was found to be predictive of reading ability.

Model 2, proposed in figure 1, accounts for these types of studies which suggest that there is not only a direct connection between phoneme awareness and reading and spelling ability, but that there is also a direct connection between (1) rhyme and alliteration and (2) reading and spelling abilities.

A review of studies examining the relationship between these variables is necessary in order to understand the theoretical underpinnings of the processes involved in the phoneme awareness task employed here and how phoneme awareness relates to reading and spelling ability. Evidence for both models will be reviewed here.

The idea that reading ability and phonological awareness abilities are highly correlated has been widely accepted; however, it is unclear if phoneme awareness is a consequence or prerequisite of reading ability. That is to say, it is unclear whether phoneme awareness leads to reading ability, or vice versa. Ehri and Wilce (1980) examined if knowledge of print words (an ability similar to that which arises from reading instruction) had any influence on children's phonological awareness. It was found that children who had seen spellings of words in print detected phonemes more frequently and accurately that those who had no experience with these print forms. This finding shows that, contrary to research that suggests that phoneme awareness must develop prior to reading and spelling ability, phoneme awareness might conceivably develop instead as a result of reading instruction and development. Indeed, phoneme awareness could be as much a consequence of reading as a prerequisite of reading in an alphabetic script (Ehri and Wilce, 1980: 380).

The emergence of phoneme awareness relative to reading and spelling ability has been attested as a precursor to and consequence of reading ability, but it appears that the relationship is reflected best in the combination of models proposed in figure 1 in the sense that phoneme awareness and reading and spelling ability develop as a result of phonological development in conjunction with reading and spelling development. With regards to the order of emergence, analytic awareness emerges last because it is either (1) contingent on learning to read, and/or (2) is the most discrete form of phonological awareness that develops last. One can propose that phoneme awareness cannot develop without reading instruction or proficiency (see studies involving nonreaders who display little to no phoneme awareness, such as Morais et al., 1979), but one also needs to consider data from disordered and non-typical systems that suggest reading instruction is not enough to stimulate the development of phoneme awareness. This all leads to the conclusion that the relationship of analytic awareness to reading and spelling as dynamic, with both variables highly correlated.

Additionally, the relationship between the development of phoneme detection and 'rhyme and alliteration' skills is also not clear. Although a number of studies (like those discussed above and in § 2.2) provide evidence that phoneme detection should follow rhyme and alliteration skills, there is evidence that rhyme and alliteration skills are not connected to the development of phoneme detection. This claim is proposed by studies showing that reading and spelling ability are not related to the abilities to segment onsets and rimes. Muter et al. (1998) found, for example, in their longitudinal study of children in the first two years of reading, that the ability to rhyme (defined by tests measuring rhyme detection and production) were not correlated with achievement in reading and spelling. In contrast phoneme identification and phoneme deletion, measures of segmentation abilities, were found to highly correlate with reading and spelling achievement. This data suggests that rhyme and alliteration plays no predictive role in reading and spelling, contrary to the second model in figure 1. This finding is in contrast to those like Bryant et al. (1990, cited on p. 15) which showed that rhyme and alliteration skills were linked to later reading achievement, suggesting that this ability has a more direct influence on the development of reading and spelling skills. This finding supports the second model supported in figure 1, highlighting the importance of integration of both these models.

As there is conflicting evidence on the role of rhyme and alliteration skills related to reading and spelling ability, the use of these models in conjunction with one another highlight a) the developmental relationship and b) the dynamic interplay between these three variables. There is empirical evidence for and against the claim that rhyme and alliteration skills aid in the development of reading and spelling ability. As well, there is evidence that phoneme awareness arises concurrently with reading instruction and proficiency, not as result of general phonological development. This evidence dictates the use of two models to explain the complex relationship between reading and phoneme awareness.

In conclusion, there is an overall strong relationship between the range of abilities referred to as phonological awareness and reading and spelling ability. The majority of research suggests that analytic phoneme awareness is the key determinant of reading and spelling ability. Finally, phonological awareness arises in combination with reading instruction and proficiency in reading and spelling.

The research discussed thus far has not motivated the connection between spelling and phonological awareness specifically, despite implying that reading and spelling abilities are considered to be the same. The next section (§3) explains in detail how these processes are similar, and how phonological awareness can then be conceptualized as a process that involves awareness of linguistic units.

3 Spelling and reading

3.1 Evidence that reading and spelling hinges upon phonological awareness

As discussed in §2.3 above, analytic awareness and reading are highly correlated. Although the majority of the research that supports this claim takes reading and spelling to be the same process, these studies do no explicitly examine spelling and phonological awareness. If the process of reading involves the recognition of phonological units and measuring the success of readers comes through evaluating their sensitivity to these phonological units, then the ability to represent these units in spelling presumably involves the same processes. This connection is established by means of research that shows that (1) performance on reading and spelling tasks are highly correlated, and more importantly, (2) spelling and analytic awareness correlate highly.

Ehri (1997: 256) reports on previously conducted studies which examined the correlations between reading words, producing correct spellings, and recognizing misspellings. The participants of the studies examined ranged from first graders to college students, thus providing analysis of these abilities at various levels and across multiple studies. In all cases, Ehri reports that the correlations between these three variables were all very strong, ranging from r = .69 to .85. These numbers indicate that these measures were highly correlated in a number of studies, and more importantly that these studies involved participants of different levels. This means that in all of the data examined, the ability to perform reading tasks and spelling tasks were very strongly connected, to the point where, for example, the ability to perform reading tasks is predictive of spelling ability as well. Thus the abilities are reliable indicators of one another, and show that very similar processes are involved in these different tasks.

Ehri and Wilce (1986) also reported on the effects of reading on spelling, claiming that reading in fact mediates spelling ability in the sense that when one learns to read words, they are able to retain this information for use when spelling words as well. This transfer effect was observed in this study using words with medial flaps which are pronounced /d/, but spelled with d or t, such as hu<u>dd</u>le and gli<u>tt</u>er. Participants (second graders) were exposed to 12 words, with an equal number of flaps spelled with d and t. Half of the participants were asked to practice saying the words but never saw spellings, while the other half were asked to practice reading the words. After a day, the group that was exposed to the words via reading outperformed the group who were asked to auditorily practice the words. These former groups produced more correct spelling than the latter group.

Compelling evidence for considering reading and spelling as operating on the same premise, namely the alphabetic principle, comes from studies examining differences in phonological awareness of good and poor spellers. Rohl and Tumner (1988) examined phoneme segmentation skill and spelling acquisition using fifth grade good and poor spellers, average third grade spellers, and good second grade spellers. Their comparison of good and average spellers with poor readers at the grade-school levels of various ages and abilities has shown that the good and average spellers have better phonemic segmentation skills than poor spellers. Participants that were identified as good and average spellers were better equipped to segment non-words up to five phonemes in length (a analytic awareness task, Rohl and Tumner, 1988: 340), as well as displaying more correct spellings of the non-words with greater phonetic accuracy. Of particular interest is the fact that the good and average readers also perform better than poor readers of a higher grade level (Rohl and Tunmer, 1988: 347). This study, and others like it, supports the idea that phoneme awareness is an ability possessed by proficient and average spellers, more so than their less proficient counterparts. This finding is crucial in showing the relationship between reading proficiency and phonological awareness (in particular phoneme awareness).

Similarly, Bruck and Treiman (1990) examined the relationship between analytic awareness and spelling, using onsets in particular. They compared first and second graders with older dyslexics who scored at first and second grade equivalents in standardized measures on phoneme recognition, phoneme deletion, and spelling. They discovered in particular that there was an effect of linguistic structure on phonological awareness and spelling. Participants of this study were asked to identify when non-words in a set began with a prespecified sound (specifically /f/ or /s/) for the recognition task, and were asked to delete the first sound in a non-word and produce the resulting word for the phoneme deletion task. When a phoneme was part of a consonant cluster (as in a CCVC syllable, for example) it was harder for all of the participants tested to perform recognition and spelling tasks, and even harder was deletion involving these types of structures. In general, two-consonant onsets proved more problematic (Bruck and Treiman, 1990: 172), and performance was better when the task involved simple onsets. The first phoneme was more difficult to operate on than the second of a consonant cluster, suggesting that initial consonants of a consonant onset are more difficult to delete. This suggests that phonemes within a consonant cluster are not equal in representation and phonological structure, with initial phonemes being given more weight within an consonant cluster onset.

Similarly, Stemberger and Treiman (1986) examined "loss" data, to determine which member of consonant clusters (first or second consonant) was more prone to be omitted in error from adult spontaneous speech. They found that there were more errors involving the second consonant of a cluster compared to the first consonant of a cluster. This result leads them to suggest that initial consonants more salient than the second of a consonant cluster (Stemberger and Treiman, 1986: 177).

The literature reviewed here shows that reading and spelling depend on the same knowledge, specifically knowledge of the alphabetic principle. Thus spelling, like reading, correlates highly with analytic awareness. The effects of phonological structure was also show here in the observed difficulty of manipulation of the initial consonant versus the second in a consonant cluster. Specifically, the first consonant is shown as more difficult to perform operations associated with analytic awareness tasks.

3.2 Evidence reading and spelling does not hinge upon analytic awareness

While the correlation between phonological awareness and reading and spelling ability is well established in the literature on the topic, there are studies that indicate the development of phonological awareness and its relationship with reading and spelling ability is not entirely straightforward. For example, Squires (2004) studied good and poor readers of the eighth grade, and younger normal readers, of either the second or third grade. She found that all groups in her study, even older good readers, took a significantly longer time to decide whether words with a whole onset removed were unacceptable answers to the question, "Is the first sound gone?", in a set like "break - ache" where the word "ache" was the target stimulus to determine if the first sound had been removed. This is in contrast to, for example, the participants ability to answer the same question when the second consonant in a cluster was removed. This effect was also observed with respect to scores - when the entire consonant cluster was removed from a word, participants likely to accept this condition as the correct answer, when the target was initial consonant deletion. Squires suggests that the representations of the entire consonant cluster and the first phoneme are closely linked; furthermore that the inability to properly analyze consonant clusters as two separate phonemes indicates that, even in good readers, analytic phoneme awareness has not fully developed. (This result is similar to the development study discussed in section 2.2 that showed that before children can segment clusters into separate phonemes, they treat them as a single unit; Barton et al., 1980).

Additional evidence that analytic awareness and reading and spelling ability are independent (even though they correlate) is that there are other methods of reading that do not involve analytic awareness or ability. Specifically, there are three possible methods that will be reviewed here:

1. Induced sublexical relations (ISRs): ISRs are an alternative phonological recoding method whereby implicit knowledge of orthographic-phonological relationships, developed from experience with print, are exploited in order to read (Fletcher-Flinn and Thompson, 2000: 182). As Thompson et al., (1999: 24) put it: "(ISRs)

compromise the child's acquisition of orthographic-phonological correspondences by induction from accumulated print word experience and, [..] acquisition formed on the letter as an initial-position grapheme common to several words." This theory proposes that experience with lexical print leads to orthographic representations of words (and letters), which not only allows recall of familiar print words, but also activates similar orthographic and phonological components. This means that people who use ISRs to read do not rely on sound-spelling correspondences on a one-to-one basis like those who use the alphabetic principle of reading, for example. Instead a form of pattern like recognition occurs where it is possible to read words base on how they "look" (in their orthographic representation). When reading a word in this model of reading, the contextual dependencies of graphemes and their relationships to other print words are exploited in order to read the word. There is then two subtypes of ISRs: the first of which involved a direct connection between a word's spelling and the word's phonological form, the second involving connecting letters on the edges of words to their phonological form. This second type of ISR is similar to an alternate form of reading called visual cue reading which relies on recognition of parts of words, where these parts trigger associations to their pronounciation (Gough and Juel, 1991).

2. Whole-word method: The whole word method of reading, or "reading by eye," relies on a direct connection between whole words and their corresponding semantics. There is no phonological interface assumed in this model or reading, as readers do not require sound-based inference (Crystal, 2003: 211-213).

3. Glass analysis method: This method of reading relies on the usage of distinctive clusters of graphic representations and their related particular sounds. Specifically, observed regularities between onsets and onsets are applied to decoding new words. This is significantly different from the operation of dissecting a word sound by sound, and is specifically taught through the "glass analysis" approach to reading instruction where the segmentation of onsets and rimes is made apparent as a decoding procedure (Miccinati, 1981: 140). This method has been shown as a good method of teaching decoding skills, especially to those who are deficited phonologically.

ISRs and whole-word decoding are significantly more holistic, or "implicit", alternative models of reading are in contrast to the traditionally cited analytic, or "explicit", model. The glass analysis method described above is slightly more explicit, as it relies on the phonological units of onsets and rimes to make clear redundancies between specific spelling group correspondences and their related phonological representations. Some elaboration on these models is provided here, with specific reference to studies providing empirical evidence in favour of these models.

A particular study that shows how the usage of ISRs proceeds comes from Fletcher-Flinn and Thompson (2000). Their case study was of a very advanced reader aged 40 months, with the word reading age of 8 years 6 months. The participant of their case study was extremely fast and accurate with reading words and non-words as well. The most interesting component of the advanced reading ability of this 3 year old was the lack of phoneme awareness skills. The participant of their study possessed well-developed lexical orthographic representations in the absence of phoneme awareness. Thus, their study challenges the notion that reading requires complete mastery of analytic awareness.

Fletcher-Flinn and Thompson (2000) suggest that this data poses a problem to the traditional theories of the relationship of analytic phoneme awareness to reading ability. What has been discovered by this and other studies is that there is another form of phonological recoding - what is referred to as induced sublexical relations (ISRs); there are others that have been proposed, including visual-cue reading and whole-word reading, see §4.1.1

Similarly, Penney et al. (in press) report a case study of a backward reader who showed levels of "phonetic cue reading" in the absence of being able to read and spell. Although the participant was unable to remove individual sounds from words, he could match a spoken word to a written word by associating letters and letter-sound associations - an ability known as visual-cue reading. The participant of their case study was able to perform this identification based on initial simple onsets or final simple codas. After two years of tutoring, the participant was unable to read most words, but he was able to match spoken words to their print counterparts even if he was unable to read them. The reader described in this case study appears to be relying on ISR's, as described by Flecther-Flinn and Thompson (2000), in so much that the participant of Penney et al's case study appears to be exploiting orthographic-phonological correspondences in identifying word-initial and word-final phonemes. It is also possible that the participant of this case study was using visual-cues, specifically letter-sound associations, to match spoken words to their written counterparts.

The success of reading instruction involving onset-rime segmentation also challenges the relationship between analytic awareness and reading and spelling abilities. Penney (2002) reports having success in teaching reading decoding skills to 33 poor high school readers using onset-rime segmentation as opposed to phonics or other "sound-based" methods. 21 of the participants were given sessions (approximately 18 sessions) in which they were instructed on the "Glass Analysis" method of decoding while the remain poor spellers received no special instruction outside their normal school circulum. These groups were compared prior to and after the tutoring program on standardized measures evaluating reading ability. This comparison showed that the group that received tutoring involving onset-rime segmentation training improved all on measures. This finding suggests that awareness of the phoneme is not crucial in teaching decoding skills, and thus that it may not be crucial to the process of reading.

All of these findings suggest that the correlation between (a) analytic awareness and (b) reading and spelling ability might not be as clear-cut as has been traditionally suggested. It appears, then, that analytic awareness might not be required for learning to read and spell. The studies presented here challenge traditional notions of reading and spelling which stipulate that progress is defined by the phonological decoding ability of learning and using sound labels for letters, or in plain language directly associating letters and letter names with their respective sound profiles (alphabetic principle or analytic awareness).

The literature reviewed so far demonstrates that in order to describe reading and spelling ability, an understanding of phonological structures and reading methodology is required. Additionally, the role of memory in reading and spelling is important and its related components needs to be reviewed. These factors have not been explained in-depth. The remaining portion of this literature review (§4) describes factors relevant to understanding the relationship between analytic awareness and reading and spelling ability. This includes an account of how reading works with reference to a cognitive model, as well as some theoretical models relating phonological structure to the cognitive processes being reading (§4.1.1). This is followed by an account of how auditory perception proceeds cognitively as well as relative to phonological structure as well (§4.1.2). The main experimental task involves auditory stimulus, and thus this auditory stimulus must be related to phonological structures similar to those that define reading and spelling ability. Finally, the phonological theory behind onset consonant clusters is described in the attempt to discover the typologies of these phonological structures, and in the hopes of formulating a hypothesis concerning the effects of these structures on an analytic awareness task.

4 Theoretical Models

In order to study how phoneme awareness is related to reading and spelling ability, theoretical models of reading are required. These theoretical models are necessary to explain clearly how the process of reading relates to phonological awareness. Additionally, a model of speech perception must be included to account for how participants process the auditory stimulus that was presented in the main experimental task. With these models in place, further elaboration is required on how phonological processing of reading and speech perception occurs (described in §4.1.3) Finally, as this experiment examines analytic awareness relative to onset consonant clusters, a discussion of the phonological theory surrounding these units is required to determine if structure and constraints placed on permissible consonant clusters could plausibly affect the responses of participants.

4.1.1 Theory of Reading

Proficient reading depends on an automatic capacity to recognize frequent spelling patterns visually and to translate them phonologically. Adams (1990) suggests that it is only pre-readers acquiring phoneme awareness who learn to read successfully in an alphabetic language. This point in particular highlights the importance of phonological processing in learning to read. Phonological processing helps readers maintain speed and accuracy in recognition of words in print. Most importantly, the conversion of print into sound-based processing is crucial for developing word recognition, and essential for optimal reading performance.

The following model of reading proposed by Adams (1990) shows the connection between semantics, orthography, and phonology in reading:

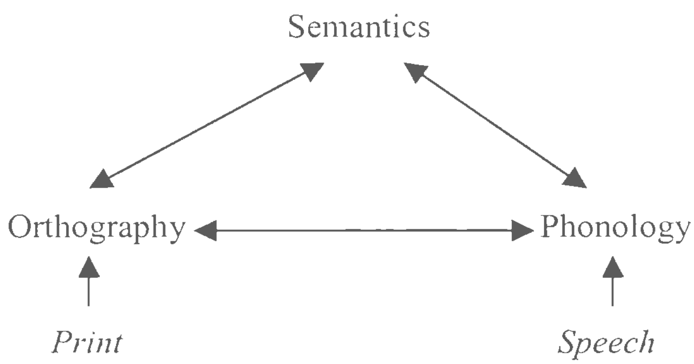

Figure 2 - The connection between semantic, orthography and phonology in reading (adapted from Adams, 1990: 158)

The arrows connecting semantics, orthography, and phonology are dual direction arrows, illustrating the chains of activation that occur in reading and speech perception. Print in this model is perceived through the orthographic (visual) processor, while speech is perceived through the phonological (auditory) processor.

When the accomplished reader encounters a meaningful word in print, one that s/he has read many times before, the orthographic processor will respond quickly to interpret the meaning of the word. In this situation, the meaning of words is retrieved from a direct connection between orthography and semantics. This type of reading is what Crystal (2003: 211-213) refers to as the "whole word" method of reading. In the initial stages, the sounding-out method of reading is more relied upon, but after several exposures to a word, a direct print-meaning pathway is established.

In contrast, when the accomplished reader encounters less familiar words, s/he makes use of the phonological processor. That is to say, in order to read an unfamiliar word, accomplished readers convert orthographic units to phonological units, allowing them to "sound-out" words. This is in contrast to reading of common familiar words described above, where no sound interface is used. This second method of reading in an alphabetic script is what Crystal (2003: 211-213) calls the sounding-out method of reading, or "reading by ear." This method relies on the associations between letters and sounds to decode words for meaning. These smaller units, phonemes, are used by readers to form larger units in the decoding processes.

Adams' (1990) model can also be used to describe the processes in spelling words in an alphabetic script. The process of spelling spoken words in this model can be traced from the perception of speech through the phonological processor, then to the orthographic processor where the speech stream is converted into letter-sound correspondences. Likewise, spelling without auditory cues can be performed through the use of the orthographic and phonological processors.

Although reading and spelling are often described as similar processes, Ehri (1997: 264) points out there are obvious differences between reading and spelling. Spelling undoubtedly requires more working memory as it involves a series of correct responses in the correct sequence, while reading involves only one correct response retrieving the pronunciation-meaning amalgam. Thus more demands are places on memory when spelling as opposed to reading. Given this distinction, it makes sense to use spelling as the main basis of comparison when examining phonological awareness and its supposed underpinnings, because if one can be classified as a good speller one is presumably proficient in recognizing analytic phonological units, not to mention being able to handle the demands spelling places on working memory.

In summary, the process of reading can be described in two ways: a *whole word* method and a *sounding-out* method. Both of the models outlined by Crystal (2003) are used by proficient readers in alphabetic languages. The model used in this research is that of "reading by ear" because this is the method that is presupposed to be relevant for analytic phonological knowledge. In other words, analytic phonological awareness itself is a facet of sound-based decoding.

To explain the process of reading from a cognitive perspective, with the inclusion of a memory component, a model of reading which summarizes the translation of graphic signal into a message can be adapted from Garmen (1990):

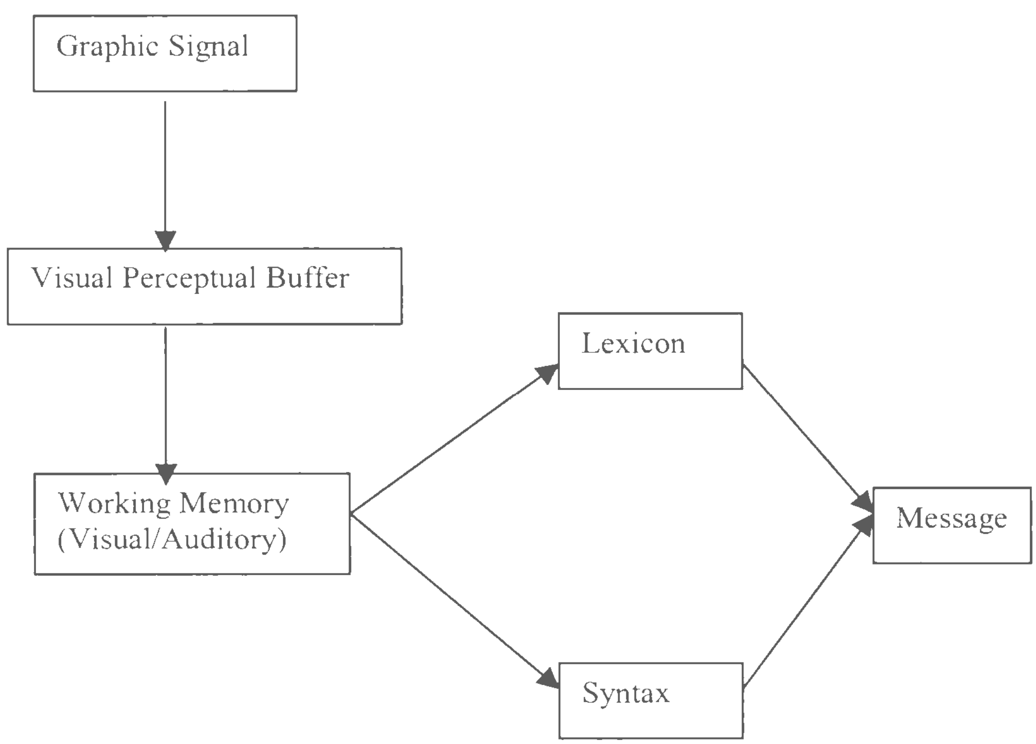

Figure 3 Model of reading adapted from Garmen (1990: 182)

This model begins with the perception of graphic signal by the visual perceptual buffer, which fixates on graphic signals in the visual field and performs pattern recognition based on recognizable properties. Once the meaningful graphic signal has been perceived by the visual perceptual buffer, the information is then sent to working memory, which is also known as short-term memory.

It is unclear how much visual or auditory processing of graphic code takes place in working memory. That is to say, in accordance with Adams' (1990) model of reading, the graphic code can be interpreted using a graphic or orthographic-semantic relationship, where the actual word form can trigger lexical access. Also in accordance with this model, it is possible that orthography can be translated into phonological units for lexical access (see §4.1.3 for further discussion of this type of process).

Baddeley (1999) proposes that there are two components to working memory: an "articulatory (or phonological) loop" and a "visuo-spatial scratch-pad". The articulatory loop, in particular, is proposed to contain information from the visual buffer that is translated into a phonological form; translation is achieved through subvocal rehearsal. Subvocal rehearsal maintains the items in memory using subvocal speech, which is used to convert nameable but visually presented stimuli, such as letters or words, into a phonological code. The phonological loop has been attested as playing a crucial role in learning to read. The visuo-spatial scratch-pad, in contrast, is involved in reading where phonological interpretation would not be required and where word meanings are retrieved solely based upon graphic representation. Either way, the short-term memory's decoding of the graphic signal, either phonological or holistic, retrieves lexical and structural information from long-term memory stores (here labeled lexicon and syntax), which then allows the message to be decoded based on interpretation made possible by forms held in long-term memory. The processes of phonological or orthographic forms activating lexical selection are of particular interest for this research because they are involved in processing speech as well as in decoding text for reading purposes.

The discussion of theoretical models of reading provided above characterize the process relative to phonological awareness. These models provide the necessary background to link reading and spelling abilities to phonological awareness, a component of which formed the independent variable in the experimental design of this research.

4.1.2 Theory of Auditory Perception

Analytic awareness tests using auditory samples where participants are asked to manipulate phonemes in words do not rely on visual or orthographic cues. In the task used in this research, participants were asked to recognize the presence or removal of a prespecified phoneme presented in auditory stimulus, and answer accordingly. It follows then that the process of auditory perception must be related to phonological units, specifically phonemes, in order to properly represent the process involved and develop a resulting hypothesis based on the relationship between the two. Auditory perception involves pattern recognition where forms are matched to stored representations that have results from prior experiences. In order to account for the process of auditory perception involved in the experimental task, the TRACE model (McClelland and Elman, 1986) of spoken word recognition will be used to explain how words are accessed from the mental lexicon. As well, portions of the cognitive model of reading proposed by Garmen (1990) will be used to explain the perceptual processes involved in processing speech signal.

The TRACE model is a complex multiple-level connectionist model. It includes three levels of interconnected nodes, representing cognitive units, that operate using previously stored knowledge about distinctive features, phonemes, and words. The model assumes that speech is processed in small time slices that are connected to the preceding ones. This allows information to be combined with previous input for elaborate interpretation. The units of time slices are interpreted sequentially for (1) features, (2) phonemes, and (3) words.

When speech is perceived, it activates nodes on each level of the model. Node activation on the same levels are inhibitory or in competition with one another, while nodes in different layers of the model exhibit levels of complementary transfer and in a bidirectional (bottom-up and top-down) manner. The model is referred to as the TRACE model because spoken input is analyzed by means of traces of analysis at each of the three levels. At the level of features, there are several distinct types of feature detectors, referred to as acuteness, diffuseness, and vocalic, that are representative of the various dimensions of speech sound. This first stage of speech perception analyzes features of speech stream, which are then analyzed at the phoneme level, where there are detectors for each of the phonemes in an inventory. The strings of phonemes analyzed are then mapped on to similar word detectors at the word level of the model.

With a theory of speech perception in place, the cognitive processes in speech perception need to be addressed. To do so, the psycholinguistic model of speech perception described by Garmen (1990) will be used:

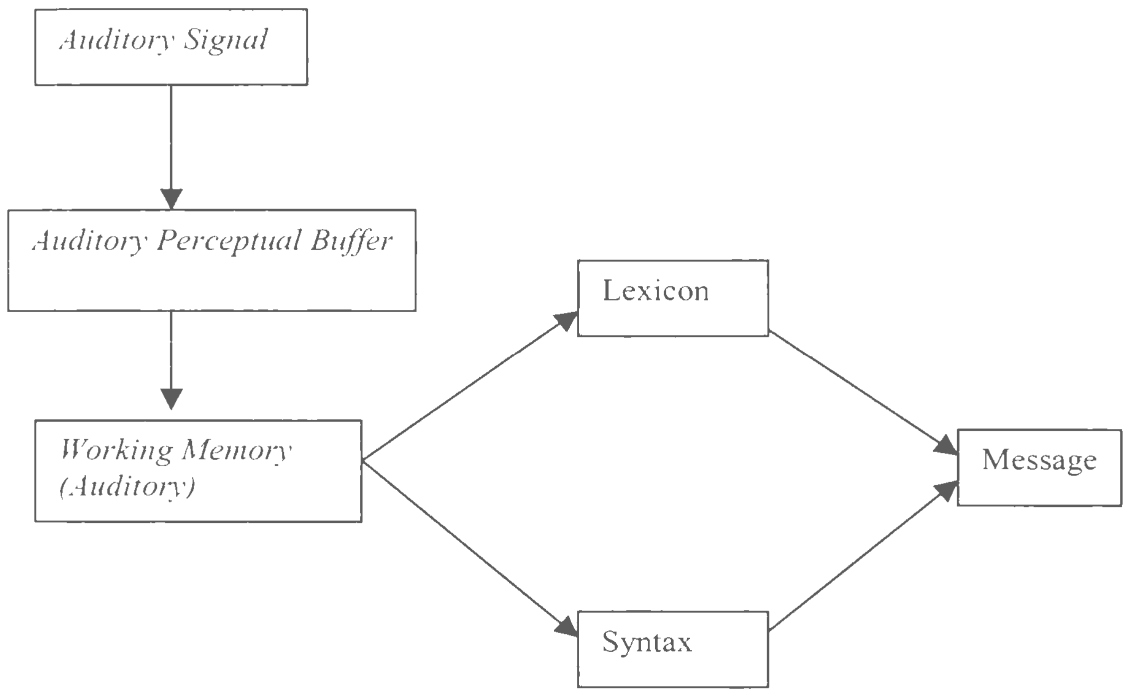

Figure 4: Model of speech perception adapted from Garmen (1990: 182)

This model is very similar to figure 4 above, but with some differences (shown in the figure in italics). In this model speech perception begins with an auditory signal that is first processed through the auditory perceptual buffer. The auditory perceptual buffer is similar to the visual perceptual buffer described above, both of which are sensory stores. The function of this first processor is to retain an "echoic" trace of the recognizable speech signal for initial pattern recognition. It also maintains as well a longer lasting trace that allows re-evaluation the interpretation of the speech signal (Field, 2003: 18). From this first processor a second type of memory analyzes the speech stream. It is called working memory (auditory) and is commonly known as short-term memory. Both of the terms used reflect the temporary "working" status of this memory store. This store works as a mediator between the environment (in this case, the speech stream) and long-term memory, and contains information and input from both. The most important portion of working memory in speech perception is the *phonological loop*. This portion of working memory is similar to the articulatory loop cited in the model of reading in §4.1.1, in that the phonological loop retains the speech stream via subvocal rehearsal.

Next, short-term memory matches the signal to existing forms stored in long-term memory in order to decode the stream for meaning. This process, commonly referred to as pattern recognition, recalls familiar stored patterns that link the speech stream to semantics (the message). From long-term memory we see two distinct stores: the lexicon and syntax. The lexicon node of long-term memory specifically contains word information while the syntax node of long-term memory contains information about structural patterns and prepositional structures of language. Once the process of pattern recognition has taken place, the message can be extracted from the speech signal.

In the model of speech perception discussed above, the previous process of lexical access discussed via the TRACE model can be conceived of as occurring between short and long-term memory. The temporal slices of information would be processed through short-term memory, analyzing chunks for features and other phonological structure, which would then be interpreted using matched information about lexical entries from long-term memory.

4.1.3 Phonological processing and phonological awareness

The most crucial components of working memory involved in the processes of reading and spelling as well as speech perception are found within the set of abilities commonly referred to as phonological processing. It is these modules that are responsible for the coding and retrieval of phonological information, which are key in processing models of reading and spelling, and in speech perception, which rely on phonological information.

Wagner et al. (1999: 5-7) provide a good overview of the components of phonological processing, which are outlined in figure 5 below:

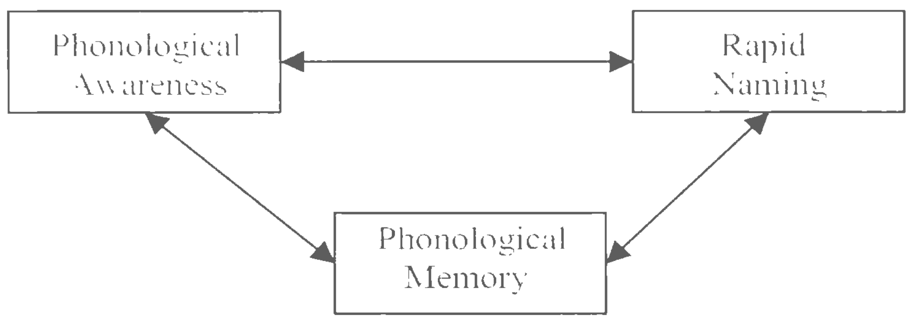

Figure 5- Model of phonological processing (adapted from Wagner et al., 1999: 7)

These three types of phonological processing are distinct but strongly correlated (as the arrows in the diagram indicate). Phonological awareness, defined in § 2.1, requires no further elaboration here.

Phonological memory, an important part of working memory models, cited here in other models, of reading and speech perception, refers to the coding of information into phonological units for temporary storage in working and short-term memory. This component of phonological processing is important when decoding new words (Wagner et al., 1999). The third type of phonological processing, rapid naming, refers to the retrieval of information from long term or permanent memory. Related to reading, this is the portion of phonological processing that allows readers to: (1) retrieve phonemes associated with letters or letter pairs, (2) pronunciations of common word segments, and

(3) pronunciations of whole words. Consequently, people who show deficits in rapid naming appear to have greater difficulty with reading. The same goes for phonological awareness – those identified as deficit in this area of phonological processing are presumably affected in the form of lower reading ability. The relationship between phonological awareness and memory in particular is very strong, but all three forms of phonological processing are correlated.

4.1.4 Syllable Structure

This study, an examination of analytic awareness, involves subsyllabic units in particular. The main experimental task itself involves the type of analytic awareness pertaining to onsets, and the phonemes that make up these onsets. With this in mind, it is necessary to describe syllable structure in English, with specific reference to the typology of syllables, and onset structure within English syllables.

The construct of the basic syllable is outlined below (Kenstowicz,1994: 253):

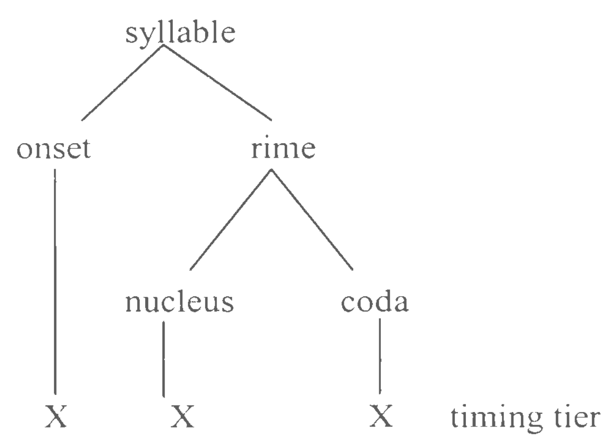

Figure 6 - Phonological structure of a syllable (Kenstowicz, 1994: 253)

The nucleus of a syllable is a single phonemic constituent: a vowel. There is a possibility of having more than one phoneme in onsets or codas of a syllable. Where there is more than a single phoneme in onsets or codas, the latter units are referred to as complex. Here the discussion will be limited to the typology of onset structure in English syllables, as onsets are the particular subsyllabic structure relevant to this study.

The structure of onsets, as well as other subsyllabic units, is determined by the Sonority Sequencing Principle (Clements, 1990). The Sonority Sequencing Principle (SSP) is a universal principle that governs what specific sequences of consonants are permissible in a syllable. It stipulates that syllables in general rise in sonority moving towards the nucleus, and decrease moving away from the nucleus into the coda. Below is a sonority hierarchy, outlining the classes of sonority (adapted from Gierut and Champion, 2001: 887):

-voi stop	+voi stop	-voi fricative	+voi fricative	nasal	liquid	glide	vowel
least sonorous							most sonorous

Figure 7 – Sonority class scale (adapted from Gierut and Champion, 2001: 887)

In the table above, there are four classes of sounds relative to sonority, the first being obstruents, under which stops and fricatives can be grouped. This is followed by nasals, liquids, glides, and finally the most sonorous sound, vowels. The SSP stipulates that sonority rises towards the nucleus of a syllable, and falls after the nucleus. For onsets, this means that a string of consonants contained within an onset must rise in sonority. This means that initial consonants in an onset have to be less sonorous than the second.

The Minimal Distance Constraint (MDC) also limits what consonants can occur in a complex onset. In English, the MDC is stipulated as at least two sonority degrees in a typical (canonical) onset. The table below outlines permissible prevocalic consonant clusters consisting of two consonants, some of which are not onsets (Kenstowicz, 1994: 256):

	w	y	r	l	m	n	p	t	k
p	-	+	+	+	-	-	-	-	-
t	+	+	+	-	-	-	-	-	-
k	+	+	+	+	-	-	-	-	-
b	-	+	+	+	-	-	-	-	-
d	+	+	+	-	-	-	-	-	-
g	+	+	+	+	-	-	-	-	-
f	-	+	+	+	-	-	-	-	-
θ	+	+	+	-	-	-	-	-	-
ʃ	-	-	+	-	-	-	-	-	-
s	+	+	-	+	**+**	**+**	**+**	**+**	**+**

Table 4 - Word-initial consonant clusters (two consonants, based on Kenstowicz, 1994: 256)

There are instances in the table provided here (see the bolded regions in table 4) of English prevocalic consonant clusters where the MDC is not obeyed (sm, sn, sp, st, sk; /s/ + obstruent consonant clusters), yet these forms are found in English words. These clusters cannot be syllabified in the same manner as the other clusters listed in this table, as explained below. These onsets can be called "fake" onsets.

Consonant clusters in English that obey the MDC and the SSP form branching onsets, Some examples are provided below in figure 8, these will be called "real" onsets:

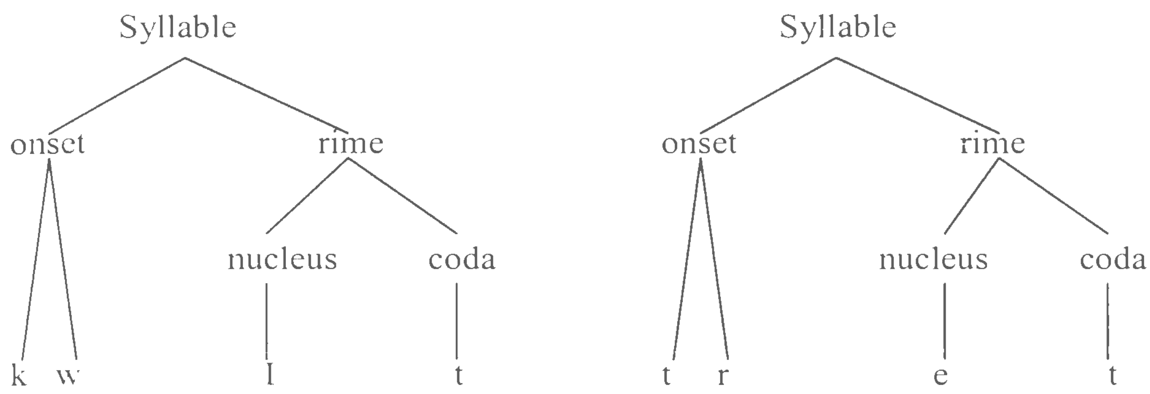

Figure 8 - Branching onset clusters in English

The consonant cluster onsets, which violated the MDC (/s/ + obstruent), cannot be placed in structures like those outline above. The reason why these consonant clusters cannot be syllabified into a branching onset is because in English consonants syllabified in an onset must differ by at least two steps of sonority (due to the MDC), which most of the /s/-initial clusters do not obey. In the case of instances like /s/ + obstruent, there is no distance between the two consonants, while in /s/ nasal consonant clusters, there is only one step of sonority distance between them.

There is some debate on how to treat these types of onset clusters; it has been suggested that in some instances these types of onsets can be treated as affricates (Barlow and Dinnsen, 1998:3). Such an account allows an explanation for the violations that /s/ + obstruent clusters produce with respect to the SSP and MDC. However, another proposal on how to deal with these onsets is to treat the /s/ as an appendixed unit that is linked to the syllable level:

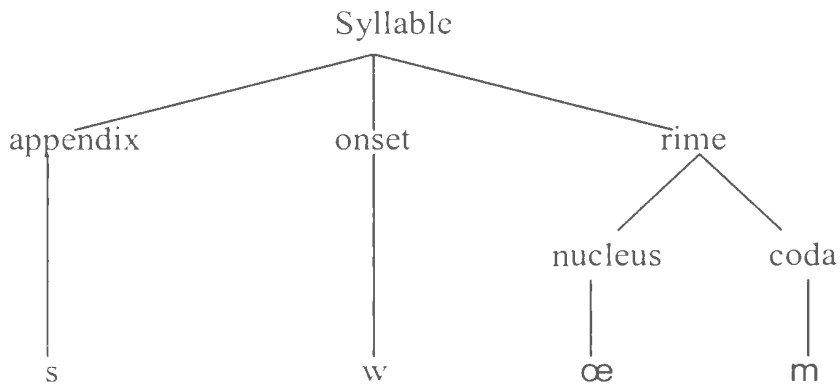

Figure 9 – Non-branching consonant cluster in English

In either analysis, /sp, st, sk, sm, and sn/ clusters are not considered as real onsets, but either as a simple onset with an appendixed unit, or as a simple onset containing an affricate. Under the "appendix" view, the consonant following a word initial /s/ is the same as a consonant appearing in a simple onset (Harris, 1994: 59). This latter theory has been more accepted.[2]

In order to explain further this distinction of onset clusters, the branching/non-branching onset structure proposed in the framework of government phonology provides an account for describing the phenomenon. The application of such a theory to English consonant clusters results in those that are syllabified into a single branching onset (such as "pl") and those deviating from such a branching onset structure (such as "sp"). Well-formed onset clusters then, can be defined according to government relationships. In onset clusters, the first timing tier unit (A) must govern the second timing tier (B) unit, (Rice, 1992: 70). That is to say the first (less sonorous) consonant governs the second (more sonorous) consonant, and allows for a branching onset. However, when principles

[2] Selkirk (1982) also points out this distinction (thanks R2 for pointing this out).

and parameters of government phonology, and MDC are not obeyed, as is the case of /s/ + obstruent clusters, a branching onset structure is the result.

O'Brien (2002) and Mugford (2002) found that dyslexics treated onset clusters that are classifiable as branching (i.e. obstruent+liquid) differently than those non-branching (i.e. /s/ +obstruent), in so much as they had difficulty performing tasks involving the non-branching clusters. This type of study is inconsistent with the phonological analysis, as one would suspect that /s/ + obstruent clusters would be easier to manipulate due to the fact they do not belong to a single constituent.

5 Hypothesis

The literature reviewed thus far in this thesis provides enough information to sensibly predict a number of outcomes of a study examining phoneme awareness, specifically examining differences between good and poor spellers. Based on the discussion of phonological awareness provided above, there are a number of conclusions that contribute to general perceptions of phoneme awareness tasks relative to reading and spelling ability. To reiterate, as stated above, both the processes of reading and speech perception are linked to phonological awareness, as the models and theory discussed above illustrate. These models and theories operate specifically using phonological units, and the processes these models represent supposedly are linked to proficiency in reading and spelling. This linkage shows again the theory behind testing the proposed relationship between the independent variable of phonological awareness compared to what formed the dependant variables, reading and spelling ability. With specific reference to Squires' (2004) analytic awareness task, the theoretical models of speech perception described here relates the process to phonological awareness, much like the models of reading. Speech perception has additionally been shown to relate to the dependant variables in terms of their supposed usage of phonological units. This study also addresses the apparent gap found in the literature, in terms of studies of phonological awareness involving adult good and poor readers and spellers. Much of the literature that examines phonological awareness looks specifically at children rather than adults.

The main issue under investigation here is whether analytic awareness develops fully even in good readers and spellers. In general, the results of the testing outlined here are expected to confirm or refute whether phoneme awareness develops fully in all readers.

Given the large amount of data that supports the claim that phoneme awareness is linked to proficient reading and spelling ability (see section 3), it is logical to expect that test results on measures of reading and spelling ability should pattern with scores on tasks evaluating phoneme awareness. In other words, higher-level spellers and readers are expected to outperform lower level readers and spellers on phoneme awareness tasks.

Secondly, if analytic awareness does not fully develop, even in good readers and spellers, then participants should have difficulty performing an analytic awareness task. For example, in the task employed here which requires participants to distinguish between an analytic phonological unit, such as the initial phoneme of an onset, and a more holistic one, such as the entire onset. This might be observed in increased error rates or reaction times if participants are asked to determine if the first sound of an onset consonant cluster, such as the 'b' in 'blake', was present or absent when the stimulus presented was 'ache'.

Congruent with the theory on syllable structure (see §4.1.4), it seems logical to expect a difference between participants' treatment of fake clusters (which are not units) and real clusters which are onset units. As previously stated, studies have found that the distinction between these structures affected performance on phoneme awareness tasks (O'Brien, 2002; and Mugford, 2002).

6 Methodology

This section will cover the methodology for testing the hypotheses formulated above in section 5. Included in this section is a discussion of the participants that formed the corpus of the experiment. More specifically, §6.1 outlines how this corpus was analyzed and grouped according to measures of reading and spelling ability in order to determine if there was any differences in performance of experimental tasks by these groups. As this study involved human participants, it is necessary to address ethical considerations; discussion is provided here in §6.2. These sections are followed by a detailed description of what experimental tests and measures were used in order to measure relevant variables under examination here, namely reading and spelling ability, and the non-orthographic analytic awareness task in §6.3. The logistics and execution of this experiment are discussed throughout this entire section.

6.1 Participants

In order to compare good and poor spellers' performance, this study used an independent groups experimental design. In this design, both groups receive the same stimuli, training, and procedures and are compared on several experimental measures.

The grouping of participants into good and poor spellers was made post-hoc based on participants' scores on standardized measures of reading and spelling ability. (These tests are described in §6.3.1.) A median score (the middle score of a distribution) was picked as the basis for this post-hoc split.

As this study aimed to compare good and poor mature spellers' and readers' performance on an analytic awareness task, it was decided that participants would be pooled from the undergraduate body of Memorial University. The participants for this study were recruited through posters placed throughout the campus, aiming to attract people self-identified as bad spellers/readers as well as good readers/spellers (N = 30, mean age = 19 years, 8 months, range = 18 years, 2 months to 21 years, 6 months). The total number of participants tested ensured that the results would be statistically viable, with more than 10 participants per group. Additionally, participants were screened prior to testing to ensure they had no prior linguistic knowledge that might influence their responses or inform them as to the linguistic units being tested.

6.2 Ethical Approval

Ethical issues pertaining to this type of research included confidentiality, anonymity, and disclosure of the purpose of this research. Before the study commenced, this research was presented to Memorial University's Interdisciplinary Committee on Ethics in Human Research (ICEHR). The committee granted this research full ethical approval in August of 2004. Information about how ethical guidelines were met are provided in Appendix A.

6.3 Experimental Tests and Measures

All participants of this study completed three experimental components. They are: (1) pretests and measures of reading, spelling, and phonological disorders, followed by (2) a piloting session to teach participants what a sound is; and finally (3) the experimental task. Each component is described below.

6.3.1 Pre-Tests

To assess reading ability, the Word-Identification and Word-Attack subtests of the Woodcock Reading Mastery Test (WRMT, Woodcock, 1998) was used. These two subtests are designed specifically to assess reading ability, and were used as the criteria for forming the independent groups used in this experiment.

In the Word-Identification portion, participants were shown lists of words on a flip chart and asked to quickly read the words aloud. Their scores were used on a normative scale using age as the basis to generate a standardized score on this measure. The Word-Attack portion also used a flip chart and asked participants to read aloud non-words that conformed to English phonotactics. Again, in the results of this test, age was factored into standardized scoring.

To assess spelling ability, the Test of Written Spelling (TWS, Larsen et al., 1999) was administered. The TWS is commonly used as a measure for research efforts designed to investigate spelling, as is the case here. It assesses written spelling ability and was used to identify students as good or poor spellers. The test itself involves two batteries, with 50 words in each. The first battery tests predictable spelling, while the second tests unpredictable spelling ability. Raw scores on this measure were converted to standardized scores using a normative scale. It makes sense to use spelling as the main basis of comparison when examining phonological awareness and its supposed underpinnings, because if one can be classified as a good speller, they are presumably proficient in recognizing analytic phonological units, not to mention being able to handle the higher demands which spelling places on working memory.

In the development of this research project, the issue of accounting for phonological disorders was brought up as a potential concern for the interpretation of the results. The issue itself is that a possibly confounding factor that has to be accounted for within this experimental design is that of phonological disorders. This factor is problematic because it lends itself to the interpretation that lower levels of performance on the "Rosner" style might be due not to levels of reading and spelling ability, but to phonological disorders. However, it was decided that removing certain participants from the data set based upon lower levels of phonological processing would be too exclusive and not give a good general vision of the phonological abilities of university level readers and spellers. In an attempt to limit this confounding effect, all participants were asked to report if they had dyslexia or had been identified with a phonological disorder.

Initially to handle the potentially confounding effect of phonological disorders, the Comprehensive Test of Phonological Processing (CTOPP, Wagner et al., 1999) was considered to identify those with low or disordered phonological skills. Although the measure was not used in the analysis to discard those participants results identified as phonologically disordered, the measures of the CTOPP were used to evaluate the efficacy of Squires' (2004) non-orthographic, non-productive, analytic awareness task. The CTOPP provides a number of tasks that evaluate processes related to phonological processing such as phoneme awareness, rapid naming, etc. As Wagner et al. (1999) state: "Phonological processing refers to the use of phonological information, especially the sound structure of one's language, in processing written language (i.e. reading, writing) and oral language (i.e. listening, speaking)." Correlation of these measures with Squires' (2004) task might help in identifying what her task taps in terms of phonological processing, as well as how the task itself works in terms of its purpose.

The CTOPP as administered here involves (for 7 - 24 year olds) 10 batteries that are used in the measure of the three types of calculation of phonological processing outlined above in §4.1.3. Four composite scores are calculated from these separate subtests: phonological awareness, phonological memory, rapid naming, and alternate phonological awareness. Use of these composite scores in correlation analysis with scores on the analytic awareness task used here might specifically help in identifying what types of phonological processing are being tested by the task.

6.3.2 Training Session

This study included a training task to teach participants what a sound is. Squires (2004) found that participants were initially unable to perform the experimental task described in §5.2.4 because they were not able to understand what constituted a "sound." To eliminate this task-effect, Squires developed a pre-test training section for her experiment in order to instruct participants as to what constituted a sound. Following the administration of the training session, the participants were able to perform the phoneme awareness task.

Squires' findings about participants' lack of knowledge concerning a sound is were replicated in this study: before this research commenced, three pilot participants (mean age = 20.67 years, range = 19-22) performed the analytic awareness outlined in

§5.2.3. This pilot group displayed the same difficulties outlined by Squires (2004), indicating that the sound training session would also have to take place for this study.

Training participants as to what constitutes a "sound" took place prior to the computer-based experiment in this research. This training was based on Squires' (2004) method; Squires, in turn, referred to studies that described methods of teaching participants what a sound is (Barton et al., 1980, Morais et al., 1986, Rohl and Tunmer, 1988, Troia et al., 1996). There were a number of methods used in the present study, including lengthening the sounds of the words and asking participants to segment the sounds, and through demonstrations where a designated item (like a block) is assigned to each sound in a word. For example, in a word like "cat", participants could be shown three blocks to specifically represent each of the three sounds contained within the word. Additionally, participants were asked to pay specific attention to exaggerated articulatory gestures to make clear the distinction between sounds. Participants were then asked to perform these same procedures on their own, using a number of strategies, outlined below:

(1) Lengthening the production of words to clearly enunciate and exaggerate each sound, then asking the participant to segment the words based on this pronunciation (Barton et al., 1980). During this procedure, participants were also asked to be aware of the articulatory shapes produced by words, and instructed that this indicated distinct sounds.

(2) Providing examples of how sounds go together to make up words, and providing corrective feedback when participants segment words on their own

(Morais et al., 1986). This strategy was used with words whose onsets could be expanded through the addition of phonemes (such as rap – trap – strap).

(3) Using a designated item (such as pennies or wooden blocks) to demonstrate the presence of individual sounds in words (Troia et al., 1996). For example, after an example, participants were presented with a word and asked to represent each sound by a single item (i.e. four items for each sound in the word "trap").

The strategies were used in conjunction with one another to ensure that participants understood the concept of a sound . None of the stimuli used in this session were used in the main analytic awareness task.

6.3.3 Production Task

Before the experimental task was administered, participants were also asked to perform a task in which they produced words containing the consonant clusters tested in the experimental task. The purpose of this task was to ensure that participants could in fact produce the consonant clusters, which in turn suggested that they perceived the sounds in the words properly. To perform this task, participants were asked to listen to an audio clip of the words one at a time and repeat afterwards. The stimuli for this task was a complete list of words (n=80) with unaltered consonant clusters that participants were tested on in the experimental task. These words were played for participants from the computers used for the main task and fitted with headphones to ensure they were not affected by external auditory interference. None of the participants tested in this study made any errors. If they had, the protocol would have been given three separate chances to correctly produce the word before they would not have been asked to complete the main task.

6.3.4 Experimental Task

In order to test for analytic awareness, the task developed by Squires (2004: 42-44) was used in this experiment. This task evaluates the manipulation of complex consonant clusters in onset position. The ability to parse complex consonant clusters into separate phonemes involves analytic awareness. This type of parsing ability is similar to that of the "Rosner" task (Rosner and Simon, 1971) which asks participants to remove a consonant from a word and produce the result. An example of this task would involve the experimenter asking a participant to say the word "clip." The experimenter would then ask the participant to say it again without the "kuh" sound (Rosner and Simon, 1971, pg. 386). The main experimental task employed here is markedly different from the traditional "Rosner" method of evaluating phoneme awareness, in the sense that production and orthography were eliminated.

Squires (2004) developed this experimental task after conducting a review of traditional phoneme awareness tasks. Traditionally, phoneme awareness tasks involving a production component (see Bruck and Treiman, 1990) adds an additional task, namely that of production. This production component involves motor planning and production of phonological representation, which might in fact hinder the performance of poor readers since they experience verbal short-term memory deficits (Squires, 2004: 35). Additionally, Squires (2004) identified another component of traditional phoneme awareness tasks that should be removed, namely that of orthography. Orthography can undoubtedly make phonemes more transparent or salient, but at the same time can also be misleading in the case of affricates, making it desirable to test for awareness of these linguistic units without the effect of orthography.

Squires' analytic awareness task relies on the aid of a computer program that presents a "Rosner" style task involving phoneme segmentation without the influence of orthography. Participants were presented with sets of words that have been prerecorded through a computer program that presents the auditory stimulus. This task requires participants to mentally perform the "Rosner" task and identify the correct corresponding auditory stimulus when presented.

Of the two words presented in each trial, the first is a word with an unaltered complex consonant cluster onset, and the second word presented was altered in some manner. Participants were asked to answer the question "Is the first sound removed?" by pressing a keypad with "yes" and "no" buttons. To represent these buttons, stickers with "yes" and "no" directly printed on them were placed on the designated keys to avoid any potential confusion. Examples of stimuli that were used are shown in Table 5 (Squires, 2004: 41):

Stimulus 1	**Stimulus 2**			
Original Word	C1 Deletion	C2 Deletion	CC Deletion	No Deletion
Blake	Lake	Bake	Ache	Blake
Crate	Rate	Kate	Ate	Crate
Twin	Win	Tin	In	Twin

Table 5 - Sample Stimuli from the analytic awareness task

The initial word (in table 5 labeled stimulus 1) presented in a trial has a two member consonant cluster, while the second stimulus presented has either the first phoneme removed (i.e. ‘crate’ ‘rate’), the second phoneme removed (i.e. ‘crate’ – ‘Kate’), the whole onset removed (i.e. ‘crate’ – ‘ate’) or no removal at all (i.e. ‘crate’ ‘crate’). In the ‘stimulus’ trials, the operations outlined in table 5 produced real English words – no non-words were produced. The words given in the C1 deletion column here are the correct answers to the question posed in the experimental task. The remaining possible second stimulus outlined above are incorrect answers to the question posed to participants.

All participants were asked to complete 496 trials (360 stimulus + 136 foils), over two sessions. In the task, a total of 80 monosyllabic CCVC real words were used (constituting the stimulus labeled ‘1’ above). As Squires (2004: 40) explains: "Non-words were not used [in the analysis] as these are problematic for all types of participants… and cause unnecessary stress on verbal short-term memory."

Squires (2004) also included foils, not included in the data, in order to prevent participants from developing strategies that would help them complete the task, such as looking for real-word answers and as well to prevent participants from fully determining the purpose of this task. A total of 24 foils were used. They consisted of monosyllabic CCVC real-words that would not produce real-words when participant to any of the removal conditions outlined above (with the exception of the "no deletion" column). Table 6 below provides some examples of foils used in this task:

Stimulus 1	**Stimulus 2**			
Original Word	C1 Deletion	C2 Deletion	CC Deletion	No Deletion
Crisp	Risp	Kisp	isp	crisp
Scarf	Carf	Sarf	arf	scarf
Prove	Rove	poove	oove	prove

Table 6 Sample foils from the analytic awareness task

The task was administered to the participants using the computer experiment program PsyScope, version 1.2.5, run on either an Apple eMac or iBook, depending on location of testing and availability. In order to maintain participants' attention during the lengthy task, Squires (2004) devised for each trial to be preceded by a beeping noise while a series of five dots flashed on the computer screen. As well, participants wore Sony MDR-V600 headphones during the task to prevent distractions.

The task itself was presented in two separate sessions (A + B), each session consisting of four blocks of 62 trials. Each block consisted of an equal number of the 'stimulus 2' conditions outlined above, specifically 10 each of C1 deletion, C2 deletion, CC deletion, and no deletion. In addition, a total of 12 foils were presented in these separate blocks. All stimuli and trials were generated randomly by the Psycope program, and no particular word pairs were repeated. If a pair was presented once in a block, it did not appear anywhere else in that session. All stimuli were randomly generated in the program, with no repetition of any particular set of words. That is to say, once a particular set was presented once in the task, it occurred nowhere else in the task. Additionally, in order to prevent participants from becoming overly familiar with any particular word that would be presented as stimulus 1, within each block no stimulus 1 was repeated.

Between trials, participants were given the opportunity to take a rest break at their discretion. The influence of ISRs also leads to further interest in removing orthography from phoneme awareness tasks, as done here, to potentially eliminate the influence of orthographic experience. If ISRs are used as an alternate method of phonological recoding, the elimination of orthography from such tasks may enhance the validity and accuracy of phoneme awareness tasks.

7 Results

This section will outline the major findings of the research conducted. The research and experiment performed here yielded a large data set, with multiple variables for each of the thirty participants. This data was analyzed through statistical procedures (such as ANOVAs, Pearson correlations, and general descriptives) to test the hypothesis formed in §5. Specifically, it was expected that reading and spelling ability would be found to predict performance on an analytic awareness task.

First, the data that was used as the criteria for the post-hoc split between good and poor spellers will be discussed (§7.1). This consists primarily of discussing the results of the TWS and WRMT and the median scores which formed this criteria. Second, general statistics summarizing the scores of all thirty of the participants will be discussed (§7.2), followed by discussion of the reaction times on the analytic awareness task (§7.3). Due to the prediction that onset type would have an effect on the performance of the analytic awareness task, not to mention being able to handle the higher demands spelling places on working memory, section 5.4 discusses both scoring and reaction time relative to the distinction made here between "real" onsets and "fake" onsets (specifically /s/ + obstruent clusters). Performance on the main task here relative to the CTOPP (Wagner et al., 1999), will be discussed next to determine the efficacy of this experimental task (§7.5). Finally, a brief summary of the data collected in this study is provided (§7.6).

7.1 Groups

The group of 30 was split into two groups: 16 good spellers and 14 poor spellers (mean age = 19 years, 8 months, range = 18 years, 2 months to 21 years, 6 months). This division was made through identifying the median (middle score) of the Test of Written Spelling (TWS, Larsen et al., 1999). The scatterplot below in figure 10 depicts the distribution of the Test of Written Spelling and Word Identification (WRMT, Woodcock, 1998) scores:

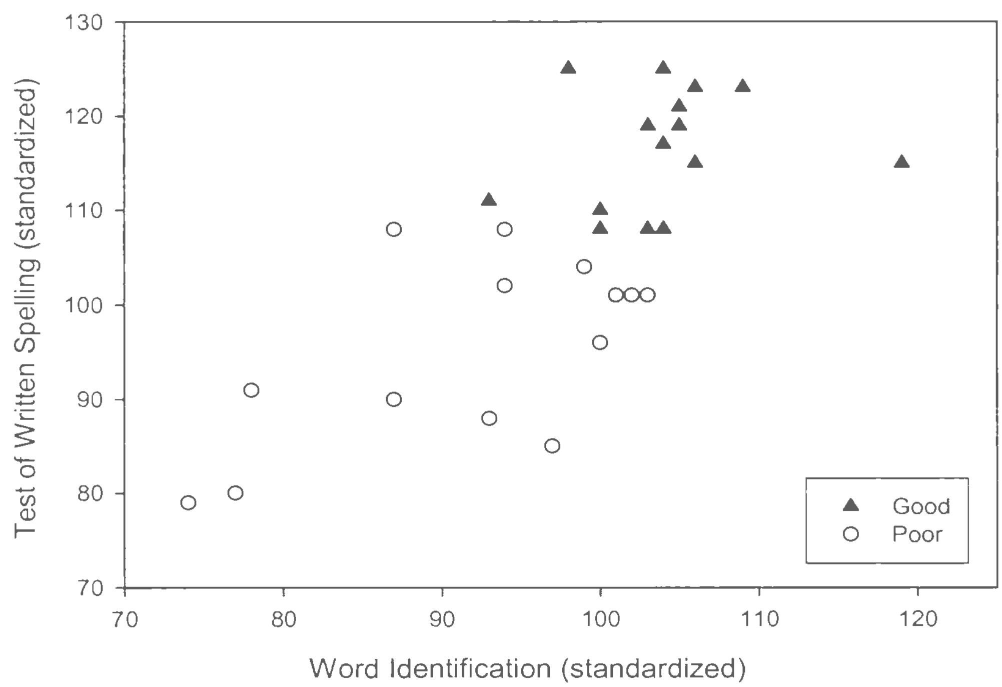

Figure 10 - Scatterplot of Test of Written Spelling and Word Attack scores for good and poor spellers

The scatterplot diagram below shows the distribution of the Test of Written Spelling scores and Word Attack scores:

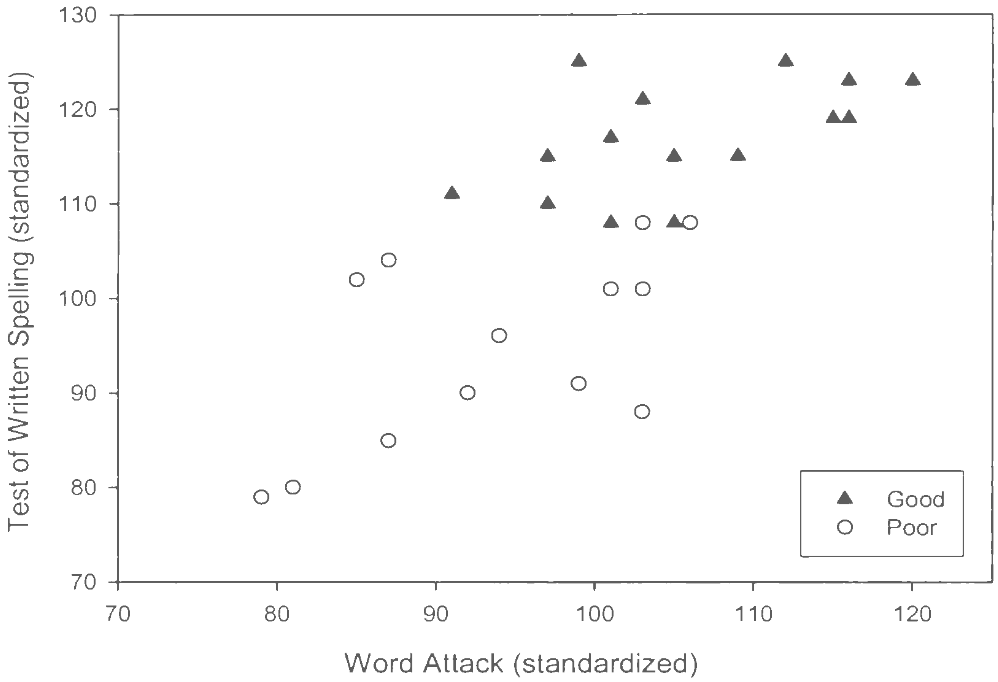

Figure 11 – Scatterplot of Test of Written Spelling and Word Attack scores for good and poor spellers

5 of the 30 participants scored at the median score of 108.00. For these 5 participants, their scores on the Woodcock-Johnson Reading Mastery Test batteries for "Word-Identification" and "Word Attack" were also used in order to sort the 5 participants into the "good" and "poor" groups.

The post-hoc split made between good and poor spellers was found to be significant ($F(1,28) = 51.526$, $p = .000$). The average scores on the standardized measures are presented below in Table 2:

	TWS scores	WRMT Word Identification scores	WMRT Word Attack scores
Good Mean	116.37	104.06	105.50
Std. Deviation	6.09	5.50	8.32
Poor Mean	95.28	91.85	94.35
Std. Deviation	9.79	9.78	9.13
Total Mean	106.53	98.36	100.30
Std. Deviation	13.29	9.84	10.25
Median	108.00	100.00	101.00

Table 7- Standardized tests data

The results of the tests used for the purposes of creating a post-hoc split, and for further comparisons involving phonological awareness, yielded a good distribution of spelling and reading abilities. As stated above, this split was found to be significant, signaling that there was enough difference between the scores of these two groups to consider them as distinct. Further evidence for this distinction was later observed when the good spellers scoring data produced correlations similar to those one would expect congruent with the literature. The good spellers' scores on the task were found to correlate with phonological awareness composite, suggesting that, as forwarded by the literature, proficient spelling ability depends on phonological awareness. This is in contrast with the poor spellers who produced no such correlations.

7.2 Experimental scores

Participants' scores were calculated as "percentage correct" by dividing the total number of correct responses for each participant by the total number of responses for each participant in the experimental task. The means of these calculations are shown in Table 8:

	C1 deletion	C2 deletion	CC deletion	No deletion	OVERALL
Good Mean	.9429	.9359	.8883	.9828	.9375
Std. Deviation	.0620	.2171	.2445	.0493	.0857
Poor Mean	.8982	.9464	.8035	.9776	.9062
Std. Deviation	.1275	.1059	.2358	.0697	.1097
Total Mean	.9220	.9408	.8487	.9804	.9229
Std. Deviation	.0984	.1716	.2358	.0586	.0972

Table 8 - Analytic awareness scoring data

The scores of participants are shown with respect to each of the four possible stimulus 2 conditions, as well as overall average response. These calculated averages show that, in general, regardless of group, scores were lowest when the task involved CC deletion, as compared to the other three possible conditions. Thus, this condition was the hardest for participants to correctly answer. A repeated measures ANOVA revealed no significant difference in overall scores between good and poor spellers ($F(3, 84) = .668$, $p = .500$).

Another ANOVA was used to determine if condition (C1 deletion, C2 deletion, CC deletion, and no deletion) in the task had any effect on participants' scores. This ANOVA revealed a significant difference between conditions in the experimental task: the accuracy of response in all participants was affected by condition ($F(3, 84) = 4.666$, $p = .017$). A further repeated measures ANOVA revealed that there was a significant difference between scores of CC deletion compared to the average of the other three conditions ($F(1, 28) = 5.533$, $p = .026$).

7.3 Reaction Time Data

Reaction time data is shown below in Table 9:

Reaction Time Data (milliseconds)	C1 deletion	C2 deletion	CC deletion	No deletion	OVERALL
Good mean	1933.8391	1754.6273	1914.0040	1331.4766	1713.7998
std. Deviation	875.9727	625.6019	785.4561	223.2484	558.9595
Poor mean	2522.6473	2480.7905	2799.4071	1469.2022	2330.7878
std. Deviation	1496.5208	1629.7934	2093.8096	455.4074	1370.0258
Total mean	2208.6163	2093.5035	2327.1921	1395.7485	2001.7275
std. Deviation	1220.6986	1236.4979	1576.7716	351.6157	1049.2941

Table 9 - Reaction time data

Reaction times were automatically recorded by Psyscope in milliseconds between the end of the presentation of the second stimulus and the point in time when the participant provided an answer.

In order to determine if reaction times were different between good and poor spellers, a repeated measures ANOVA was conducted. It showed that there was no significant difference between 2 groups of good and poor spellers ($F(3, 84) = 1.814$, $p = .181$).

Another repeated measures ANOVA indicated that there was an effect of condition on reaction times in the main experimental task ($F(3, 84) = 12.869$, $p = .000$). In order to determine if reaction times were in fact significantly different for the CC-deletion condition, a third repeated measures ANOVA was conducted. When CC deletion reaction times were compared to averaged reaction time for the remaining three conditions, there was a significant lag in reaction time for CC deletion condition ($F(1, 28) = 8.178$, $p = .008$). That is, it took longer for all participants to decide whether only the first sound had been removed, when the participants were given a word in which the entire onset had been removed.

7.4 Effect of onset type ("real" vs. "fake") on performance

In order to examine if there was any effect of consonant cluster structure on performance of the analytic awareness task, scores for all thirty participants were averaged for the two main types of consonant clusters. The first type in this categorization was /CC/ clusters (or "real") clusters, and the second /sC/ (or "fake") clusters, congruent with the literature on phonological theory that shows there is a fundamental difference between these two types of onsets (see §4.1.4). /CC/ refers, of course, to those onsets which are classified as branching, and /sC/ refers to /s/ + obstruent clusters, which cannot be classified as branching due to violations related to phonological theory. once again, reaction times reported below are in milliseconds as recorded by Psycope, and scores were calculated by dividing the number of correct responses on the experimental task by the total number of trials in the task to yield a percentage. The averaged reaction times based on the relevant distinction made here are given below; in this table % correct CC and % correct /sC/ refers to scores based on the conditions of /CC/ and /sC/ accordingly, while RT /CC/ and RT /sC/ refers to reaction times for /CC/ onsets and /sC/ onsets:

Onset Type Data	% Correct /CC/	% Correct /sC/	RT /CC/	RT /sC/
Good mean	.9381	.9363	1715.6810	1766.6148
std. Deviation	.0849	.0908	568.1284	606.6505
Poor mean	.9054	.9084	2346.6802	2341.7303
std. Deviation	.1138	.1036	1484.1849	1285.3382
Total mean	.9228	.9233	2010.1475	2035.0020
std. Deviation	.0990	.0964	1121.1283	1008.0240

Table 10 Onset type data

A repeated measures ANOVA revealed that there was in fact no significant difference overall between scores on /sC/ and /CC/ clusters ($F(1, 28) = .015$, $p > .05$) for the entire corpus used in this study. A second ANOVA revealed that neither good nor poor spellers displayed a significant difference in their scores for /sC/ versus /CC/ clusters ($F(1, 15) = .203$, $p > .05$). The group of good spellers showed no significant difference between /sC/ and /CC/ scores ($F(1, 15) = .045$, $p > .05$), nor did the poor spellers ($F(1, 13) = .230$, $p > .05$).

When the reaction times of the all the participants of this study where compared using the /sC/ versus /CC/ distinction, there was no significant difference found ($F = 1, 28) = .391$, $p > .05$). When the groups of good and poor spellers were compared in terms of reaction times on the distinction of /sC/ and /CC/ clusters, there was also no significant difference found ($F(1, 28) = .577$, $p > .05$). More discrete comparison of good spellers alone using the distinction of branching versus non-branching onset consonant clusters also revealed that there was again no significant difference ($F(1, 15) = 2.008$, $p > .05$), as did the comparison of poor spellers using the same criteria ($F(1, 13) = .005$, $p > .05$).

In conclusion, the results of statistical analysis revealed that all participants, regardless of groupings, did not treat /sC/ and /CC/ clusters significantly differently.

7.5 Role of phonological processing on performance

In order to determine the effectiveness of the main experimental task employed here, which was designed to test phonological awareness, correlation statistical procedures were conducted. Reaction time and percent correct recorded in the experimental task (Squires, 2004) were compared with scores from the CTOPP (Wagner et al., 1999). The first set of correlations between 1) average score and average reaction time and 2) CTOPP composite scores revealed only a few significant correlations. The

CTOPP composite measuring rapid naming was found significantly correlated with average score ($r(30) = .431, p < .05$) for all of the subjects tested. The other significant correlation found was between the composite measuring alternate phonological awareness and the experimental task average score ($r(30) = .416, p < .05$).

The same correlations were carried out next by comparing good versus poor spellers. When good spellers' measures were compared alone, there were additional correlations found that did not show up in the overall data set. First, average reaction time on the analytic awareness task was found to significantly correlate with the CTOPP composite measuring phonological awareness ($r(30) = .584, p < .05$). Average reaction times by the good spellers were also found to correlate with the CTOPP composite measuring rapid naming ($r(30) = .550, p < .05$). In contrast, when the good spellers' average score on the analytic awareness task was compared to their CTOPP composites, only one significant correlation was found with the composite measuring rapid naming ($r(30) = .520, p < .05$). Pearson correlations revealed that among poor spellers in particular there was no significant correlations between the experimental task and the CTOPP composites.

In order to identify what types of phonological processing were related to the analytic awareness task used here, a factor analysis was conducted between average reaction time and average score to the four CTOPP composite scores measuring phonological processing. The results of this factor analysis are presented below in table 11.

7.6 Summary

No significant differences were found between good and poor spellers' analytic awareness ability, as evaluated by the main experimental task used here. Scores on the experimental non-orthographic analytic awareness task were lower for lower level spellers and readers across the board. The same applies for the reaction time data, as the reaction times are higher for poor spellers in comparison to good spellers (although this difference was not significant). There might not have been a significant difference between these groups due to the higher levels of standard deviation displayed by the poor spellers, as compared to the more homogeneous results of the good spellers. The observed differences indicate that poor spellers had more difficulty with this task as good spellers scored higher.

An effect of condition was identified on the main experimental task when the task involved CC deletion. This is shown in the lower scores and higher reaction times of all participants where the CC deletion occurred in stimulus 2. This observed difference was proved to be significant by means of ANOVAs. The findings of Squires (2004) related to the effect of responses involving CC deletion were replicated here.

There was little difference observed between data involving /sC/ and /CC/ clusters in general, and this was reflected in the ANOVA which revealed no significant difference between "real" onsets and "fake" onsets. The data involving /CC/ and /sC/ were almost identical overall, but the scores of good and poor spellers revealed some small differences. Namely scores were lower in both conditions for poor spellers, and reaction times were higher. This difference was not found to be significant, however.

Finally, there were some correlations found between CTOPP measures and performance on Squires' (2004) analytic awareness task. Specifically, scores on the experimental task were correlated with rapid naming and alternate phonological awareness composites on the CTOPP. These correlations dissappeared for the poor spellers, whose data revealed no significant correlations. The final efficacy measure, a factor analysis involving the analytic awareness task and CTOPP composites, revealed two interesting components. The first linked average percent correct on the analytic awareness task to all types of phonological processing, while the second linked average reaction time to phonological awareness and phonological memory in particular. These cumulative factors account for roughly half of the variance in the data.

8 Discussion

This section will provide an overall discussion of the interpretation of the data collected in this study.

8.1 Lack of group effects

The results of this preliminary data showed that, in general, there was not a significant difference between good and poor spellers on an analytic awareness task. Thus the initial hypothesis that reading and spelling ability would correlate with performance on the analytic awareness task was not observed in this study. This suggests that the nature of the relationship between analytic awareness and reading and spelling ability is not straightforward.

Another prominent set of figures from this data set is the much larger standard deviation numbers for poor spellers. This set of numbers indicates that there was a greater amount of variability in reaction times among the poor spelling group, whereas the good spelling group's standard deviation rates indicate that they are more homogenous as a group, and thus might account for discrepancies between what the literature suggests and the results found here.

8.2 Effect of condition on scores and reaction times

Deletion type in the non-orthographic phoneme awareness task significantly affected scores of all participants. Regardless of spelling or reading ability, participants in this study showed difficulty performing an analytic awareness task when an entire onset (a holistic phonological unit) was deleted. Reaction times recorded for all the participants revealed that all spellers did in fact take longer on average to answer the question, "Is the first sound gone?" In some conditions, the difference is larger than in others. For example, when there was no deletion in the task, participants' reaction times were almost identical, compared to other conditions where the time difference is nearly an entire second (however, the differences observed in reaction time between good and poor spellers were not significant). Also interesting is the reaction times observed for good spellers when the initial consonant of a consonant cluster was deleted. This was, in fact, the instance where, on average, reaction times were highest. This result might suggest that the lag in reaction time (on the correct condition in the experimental task) might say something about the possibility of the initial consonant being the most salient member of a consonant cluster and thus more difficult to delete (congruent with Stemberger and Treiman, 1986).

The results involving entire consonant cluster deletion suggests that even good readers and spellers do not possess fully developed analytic awareness. This observation supports the hypothesis that there are alternative ways to read that do not involve analytic awareness. Specifically, theories such as ISRs and whole-word theories might play a larger role in reading and spelling proficiency. Evidence suggests that analytic awareness might not be as crucial in acquiring reading and spelling ability.

8.3 No effect of "real" vs. "fake" onsets on experimental measures

The results of the analysis involving the branching versus non-branching onset consonant clusters are inconsistent with phonological theory. If the theory is applied to this study, one expects that there should be some observed differences between the revealed that all spellers did in fact take longer on average to answer the question, "Is the first sound gone?" In some conditions, the difference is larger than in others. For example, when there was no deletion in the task, participants' reaction times were almost identical, compared to other conditions where the time difference is nearly an entire second (however, the differences observed in reaction time between good and poor spellers were not significant). Also interesting is the reaction times observed for good spellers when the initial consonant of a consonant cluster was deleted. This was, in fact, the instance where, on average, reaction times were highest. This result might suggest that the lag in reaction time (on the correct condition in the experimental task) might say something about the possibility of the initial consonant being the most salient member of a consonant cluster and thus more difficult to delete (congruent with Stemberger and Treiman, 1986).

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8.3 No effect of "real" vs. "fake" onsets on experimental measures

The results of the analysis involving the branching versus non-branching onset consonant clusters are inconsistent with phonological theory. If the theory is applied to this study, one expects that there should be some observed differences between the distinction of "real" versus "fake" onsets in the sense that the phonemes in non-branching onsets would be more transparent and easier to manipulate. Alternatively, the reverse could be possible, where /s/ + obstruent clusters could prove more problematic for the operations required by the main experimental task, similar to those found by Mugford (2002) and O'Brien (2002). Instead these results provide a case against the usage of implicit phonological representations in the experimental task, and potentially also in reading and spelling.

When the data involving scores on the analytic awareness task were compared using the split between /sC/ and /CC/ clusters, it revealed that there was no difference in the ability to manipulate these onset types in the experimental task. This is surprising due to the fact that one suspects that these structures should be treated differently in the sense that literature on government phonology predicts that /sC/ clusters would be easier to segment because they do not conform to branching onset constituent structure, potentially making them more salient.

The lack of significant difference between /sC/ and /CC/ clusters could possibly be the result of task effects. Alternately, subjects may be assuming that all word initial consonant clusters are onsets regardless of sonority relations, which are then divided into phonemes.[3]

8.4 Phonological processing effects on performance

In evaluating the efficacy of the analytic awareness task compared to standardized measures of phonological processing, there was evidence that there is a difference

[3] Thanks to R2 for highlighting this insight/interpretation.

between good and poor spellers. This evidence was observed in the correlations found between the experiment task and phonological processing measures for the good spellers, most notably on phonological awareness, while there were no correlations observed for the poor spellers. This correlation could be the result of lower levels of phonological awareness, or due to a task effect, such as the high memory load demanded by the task, as reflected in the factor analysis where rapid naming was identified as the strongest factor related to a large percentage of the variance in the data.

The Pearson correlations and factor analysis conducted on the results of the experimental task and CTOPP composites are inconclusive. While there was significant correlations found, it was suspected that more straightforward correlations would be discovered. In general, average score on the non-orthographic, non-productive analytic awareness task was found to be correlated to rapid naming and alternate phonological awareness. This result is a little confounding because it is expected that performance on the phonological awareness task should appear as correlated to this measure as well, due to the fact that this task was created to test analytic awareness. However, this expected correlation does show up in the good spellers' data, which might indicate that this task does in fact test what it is supposed to test.

The results of the factor analysis tells us that the ability to answer the question in Squires' (2004) analytic awareness task is related to all components of phonological processing - in particular, rapid naming - as reflected in the first component identified, accounting for approximately 1/3 of the variance displayed in the data. Interestingly, the second component leads us to think that response time on Squires' (2004) task involves phonological awareness (as measured by the alternate phonological awareness component) in particular. This makes sense as reaction time undoubtedly hinges upon the ability to process of both stimuli into phonological units (presumably phonemes) involves phonological awareness to analyze speech stream into phonological units. Rapid naming, the portion of phonological processing attributed with the retrieval of phonemes associated with letters or letter pairs, did not appear in this second component, but weighed heavily on the first. This portion of phonological processing is very important to reading proficiency, giving the impression that this test is in fact a good indicator of reading or spelling proficiency. In general, further testing and analysis beyond that presented here may be in order to determine the true efficacy of this test. These preliminary results provide evidence that the test does serve its mandate, however, minus the data concerning poor spellers.

8.5 Non-straightforward relationship of analytic awareness to reading and spelling ability?

It is possible that this study says something about the relationship between phoneme deletion and reading and spelling ability, but not about phoneme awareness in general. Bruck and Treiman (1990: 174) report in their study of analytic abilities related to onsets that phoneme deletion tasks were not related to spelling ability. However, they did find that recognition was related to spelling (and presumably reading) ability, allowing them to postulate that there is a distinction between the types of abilities these tasks tap. They state: "Although performance in one type of phonological awareness test (phoneme) recognition – might be related to spelling ability, performance in another type of phonological awareness test – deletion – does not seem closely related." If one examines the results here in conjunction with Bruck and Treiman's (1990), it becomes plausible that there might be a distinction made between the types of phonological knowledge that deletion tasks require, and specifically models of reading and spelling should require revision to state that recognition, and not deletion, are critical measures of the development of proficiency of these two abilities.

9 Conclusion

The experimental analytic awareness task employed here showed no significant differences between good and poor spellers. While disproving the hypothesis formed here based on relevant literature, the result is significant with task effects previously reported. Consistent with the hypothesis formed here was the observed interference of CC deletion type when participants were asked to identify C1 deletion in the non-orthographic analytic awareness task was found observed in both good and poor spellers. In general, the results of the poor spellers indicate the relationship between reading and spelling ability and the phonological ability here referred to as analytic awareness may not be straightforward. If they were, the results here would have found significant differences between groups, as well as more homogenous, categorical results among poor spellers and readers. Instead the results show a greater range and variability among poor spellers, and no differences between the groups. These findings provide evidence against the notion that analytic awareness and the ability to read and spell in an alphabetic script are clearly related.

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APPENDIX A

Consent Cover Letter

To Whom It May Concern:

You have been asked to participate in a study about abilities related to reading. This study will be conducted by Luke Power, a masters' student in the Department of Linguistics at Memorial University of Newfoundland, and will be used as his MA thesis. Please find attached to this letter a consent form explaining the ethical considerations of this study as well as information concerning what the study is about and what would be involved should you chose to participate.

Sincerely,

Luke Power

Consent Form

TITLE: Non-Orthographic Consonant Cluster Manipulation by Good and Poor Spellers

INVESTIGATOR: Luke Power, Department of Linguistics, Memorial University of Newfoundland.

You have been asked to participate in a research study which will examine your ability to remove consonants from words. In addition, you will also be asked to take several widely-used tests which measure your ability to read, spell, and recognize sounds. Participation in this study is voluntary. You may withdraw from this study at any time and withdrawal will not prejudice you in any way.

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. These results will only be 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 results are archived (stored), it will be stipulated that the recordings can only be accessed by the researcher **(Luke Power)**, his supervisor **(Dr. Carrie Dyck)**, or by designated research assistants and only for data verification purposes.

1) Purpose of the study

The purpose of the study is to investigate your ability to manipulate and recognize complex consonant clusters.

2) Description of experimental procedures and tests

All participants will be tested on their ability to identify words with portions of a consonant cluster removed or otherwise manipulated. Your ability to read and spell will also be assessed using a standardized set of tests.

3) Duration of the participant's involvement

Testing will take place during two sessions, at a time convenient for you.

4) Potential benefits

Participants can receive a written report on the results of their testing upon request. There will probably be no direct benefit to participants.

5) Liability statement

Your signature indicates consent for your participation in the project. It also indicates that you have understood the information regarding the research study. In no way does this consent waive your legal rights nor does it release the investigators from legal and professional responsibility.

6) Additional information

If you wish to discuss the implications of participation in this research study with an individual who has no involvement with the project, you may contact Dr. Margarite Mackenzie, Head, Department of Linguistics, Memorial University of Newfoundland, at 737-8134.

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.

____

(Participant's signature)

Date: ____

****

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)