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Deaf Children's Awareness of Phonological Structure: Syllable, Rhyme and Phoneme

by

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Abstract

The purpose of this dissertation was to investigate whether the well-documented difficulties that deaf children encounter in learning to read may arise from underlying deficits in the accuracy and the segmental organization of the phonological representations of words in their mental lexicons. The study attempted to address the issue of representational quality by investigating (a) awareness of phonological structure at three levels of linguistic complexity: syllable, rhyme and phoneme in children and adolescents with a severe to profound, prelingual hearing loss, (b) the extent to which matching judgments across the phonological awareness tasks are influenced by the perceptual status (acoustic, tactile, visual) of distracter items, and (c) whether age and/or reading ability would differentially affect the performance of deaf children and adolescents on the phonological awareness tasks. Using a within subjects design, three phonological awareness tasks were administered to 52 children (ages 6 19 years) attending two provincial schools for the Deaf in Western Canada. Performance accuracy was analysed at each level of phonological structure and compared across stimulus conditions using repeated measures ANOVA. Insensitivity to phonological structure was observed at all three levels of linguistic structure in the presence of average IQ, across all ages and within good and poor reader groups. Moreover, the data revealed that the ability to make syllable, rhyme and phoneme level judgements may not be tied to 'phonological' facilitation as it is with hearing learners. The study's findings are inconsistent with the conventional 'qualitatively similar' hypothesis that the cognitive processes supporting reading acquisition are similar in deaf and hearing individuals.

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And finally, the heart of this project is captured in the words of the French scientist Louis Pasteur (1822-1895) who wrote "When I approach a child, he inspires me in two sentiments: tenderness for what he is, and respect for what he may become". This dissertation is dedicated to the teachers in my life who have motivated and inspired me to take risks and test my abilities:

- To my parents, Jim and Betty, who taught me that '*learning*' is about being open to seeing possibilities and '*teaching*' is about creating memories.
- To the deaf children who started me on this journey and whose lessons to me shaped my questions and continue to keep me focused on the possibilities.
- To my family and friends who stood in faith of God's promise of a 'safe landing' and whose unconditional love and support walked with me throughout this entire journey.

I have been truly blessed – and I thank you!

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CHAPTER 1: INTRODUCTION

Deaf children face significant challenges in learning to read an alphabetic script. In this context, deaf children are those with a congenital or early-acquired severe to profound hearing impairment (e.g., greater than 70 dB in the better ear). A survey of the published literature on deafness quickly reveals that the field has been engaged in long-standing debate over the 'best' way to teach deaf children to read. Disagreements over the relative importance of either spoken language or sign language in the development of English literacy skills in deaf learners lie at the centre of the debate. Historically, research has demonstrated that most deaf individuals find reading difficult and seldom attain reading achievement levels on par with same-aged hearing peers (see reviews in Marschark & Harris, 1996; Musselman, 2000). According to the most recent data published by the Gallaudet Research Institute, less than 8 % of the deaf population reads at or above a grade eight level by the time they leave high school (Holt, Traxler, & Allen, 1997). Moreover, more than 60% of deaf learners leave high school reading at or below a 4th grade reading level (Holt et al., 1997; Paul, 1998; Traxler, 2000). Paul (1998) notes that the results reported on these general reading achievement batteries are similar to those reported in the early 1900's and cautions that the "true reading achievement levels of most students in special-education programs may be even lower than the levels reported" (p. 24). While these more recent statistics may not reflect the reality of all deaf children, they indicate that the 'best' way remains elusive for the vast majority of deaf learners. It has long been proposed that reading acquisition processes are 'qualitatively similar' between hearing and deaf learners. The present study tests one aspect of the 'qualitatively similar' hypothesis with a specific focus on the role that phonological awareness plays in word reading acquisition.

Claims that spoken language deficits (e.g., vocabulary, syntax, discourse) and phonological processing deficits (e.g., insensitivity to phonological information) are the relevant factors contributing to difficulties in reading for deaf students have long dominated research and educational approaches to the development of language and literacy skills in deaf learners (see reviews in Chamberlain & Mayberry, 2000; Leybaert, 1993). But empirical data that unequivocally support these attributions are lacking. In fact, the literature reveals widely discrepant findings. Fuelling the debate is evidence that spoken language skills are predictive of reading skills in deaf children who communicate orally (Geers & Moog, 1989), alongside evidence that deaf adults (including profoundly deaf native signers) who read far above the 4th grade average demonstrate more efficient use of phonological information (Hanson & Fowler, 1987; Hanson, Goodell, & Perfetti, 1991; Lichtenstein, 1998). Complicating this picture, however, is evidence revealing a lack of phonological mediation in most deaf children's reading prior to the fourth or fifth grade (age 9-11 years) (see reviews in Marschark & Harris, 1996; Padden & Hanson, 2000) together with recent findings that the most significant characteristic differentiating good and poor deaf readers is not phonological processing of spoken language but rather, primary language skills in American Sign Language (ASL) (Hoffmeister, 2000; Padden & Ramsey, 2000; Strong & Prinz, 1997).

Furthermore, there is evidence that deaf readers appear to use multiple codes (e.g., sign-based, speech-based, grapheme-based) in processing print (Harris & Moreno, 2004; Hirsh-Pasek, 1987; Hirsh-Pasek & Treiman, 1982; Leybaert, 1993; Locke &

Locke, 1971; Merrils, Underwood, & Wood, 1994; Miller, 1997; Shand, 1982) and may do so selectively depending on the demands of the task (Hamilton & Holzman, 1989; Lichtenstein, 1998; MacSweeney, Campbell, & Donlan, 1996; Treiman & Hirsh-Pasek, 1983). Although there is some evidence to suggest that the use of these codes may change in functional importance as reading skills develop (Lichtenstein, 1998), there is uncertainty regarding which of these codes is the more critical early on in the development of deaf readers. Simply, no clear explanation of why reading is so difficult for the majority of deaf learners yet attainable by a few has emerged (Chamberlain & Mayberry, 2000; Harris & Moreno, 2004; Marschark, 2001; Mayberry, 2002).

The ability to derive meaning from print is the defining characteristic of skilled, fluent reading performance (Caravolous, 1993). The central skill enabling fluent reading is fast and accurate word identification (see review in Smith, Simmons, & Kameenui, 1998). Processing automaticity at the word level is a primary source of difference in comprehension between skilled and less skilled readers. Among beginning readers, the ability to convert graphemes to a phonological code has been shown to be a critical supporting subskill underlying automatic word recognition. A relatively new hypothesis related to phonological processing deficits in reading disability suggests that the availability of sublexical units for analysis is dependent upon the representational quality of underlying phonological representations in the mental lexicon (see reviews in Swan & Goswami, 1997; Morais, 2003).

There is now a compelling body of evidence that indicates that hearing children who have difficulty in word reading tend to have phonological representations that are underspecified and lack segmental organization (Chard, Simmons, & Kameenui, 1998;

Chiappe, Chiappe, & Siegel, 2001; Goswami, 2000; Mody, Studdert-Kennedy, & Brady, 1997; Mody, 2003; Morais, 2003; Snowling, 2000, Stanovich, 2000; Swan & Goswami, 1997). Conventional thought about the nature of the reading task for deaf learners is based on the theoretical assumption that the word processing strategies between deaf and hearing learners are 'qualitatively similar' (see review in Paul, 1998). Thus, the question of whether deaf individuals do or do not access and use a phonological code in reading tasks has received much research attention. As outlined earlier, the evidence for and against this question is mixed. Importantly, however, asking whether deaf learners access phonology in reading is different than asking about the degree to which deaf learners develop sensitivity across the range of phonological structures of English. The former question may provide insight into whether word forms (representations) in the mental lexicon have *some* global phonological qualities. However, it is evidence related to the latter question that provides insight into the degree of phonological specification in word formation (segmental organization of phonological knowledge) and thus, importantly, an understanding of what phonological strategies are likely to support deaf readers with graphemic parsing of text.

At present, we have very little empirical understanding of the perceptual and cognitive mechanisms that underlie phonological abilities in deaf children whose primary language is English (Mussleman, 2000). We have even less empirical understanding of the perceptual and cognitive mechanisms that underlie the phonological abilities of deaf children whose primary language is American Sign Language (ASL). Consequently, although reading acquisition may indeed involve similar cognitive processes in both hearing and deaf learners, at this point, we can only *assume* them to be similar. To support (or refute) the hypothesis that word reading processes are 'qualitatively similar' for deaf and hearing learners it would be important to first verify that, similar to hearing children, deaf children are sensitive to phonological units in English and further, that this sensitivity leads to the development of a robustly specified lexical system of representation that will then support efficient word reading strategies. In other words, demonstrations of the existence of some phonological sensitivity is not sufficient to show that deaf readers are able to make use of phonological information to support word reading. To provide a more precise indicator of the quality of phonological representations within the lexicon it is also necessary to demonstrate the extent to which deaf readers develop sensitivity across a range of phonological awareness levels (syllable, rhyme and phoneme). Increased understanding of the quality of the phonological structure of lexical representations is important in determining what word reading strategies are likely to support deaf learners. The scarcity of information about the nature of deaf learners' phonological knowledge represents a significant gap in our understanding of the factors that are supportive of reading skills development in this population. Such a gap in empirical knowledge can lead to theoretical misunderstandings and thus hinder effective program development for these learners.

Purpose of the Research

The primary intent of this dissertation is to investigate whether deaf children and adolescents with a prelingual, severe to profound hearing loss have awareness of phonological structure at the three levels of linguistic complexity: syllable, rhyme and phoneme. If deaf children show similar sensitivity in their performance patterns across levels of structure (syllable, rhyme and phoneme) as do hearing children, insight is gained into what may constitute accessible phonological units to support word reading for deaf children. If deaf children show differential sensitivity in their performance patterns across levels of phonological structure while still demonstrating competence in reading, the 'qualitatively similar' argument is weakened and alternative explanations for the reading progress of deaf individuals would be warranted. Increased understanding of the underlying phonological abilities of severely and profoundly deaf children is clearly important if reading tuition for deaf children is to be educationally prescriptive.

Finally, it is acknowledged that a selective focus on deaf learners' awareness of phonological structure clearly ignores other big questions of word reading acquisition. For example, this study will not attempt to address the role of morphological awareness, or the use of syntactic and semantic context in the acquisition of word level reading. While clearly important areas of enquiry for any coherent theory of word reading acquisition, they are beyond the scope of this study. It is hoped that an examination of whether the well-documented difficulties that deaf children encounter in learning to read may arise from underlying deficits in the accuracy and the segmental organization of the phonological representations of words in their mental lexicons may offer some insight into how deaf children construct the representations that provide the foundation for such further linguistic development.

Definition of Terms

The research literature on concepts such as phonological development entails highly technical language. For purposes of clarity, the following definitions are offered as a guide to how these terms are used in this dissertation.

Phonological processing: Phonological processing as a global construct refers to the use of phonology (the sound structures of spoken language) to process verbal information in oral or written form in short and long term memory (Wagner & Torgeson, 1987). More specifically, the construct of phonological processing includes the following components: phonological awareness, phonological recoding in lexical access and encoding and storage of phonological information in memory (Burgess, 2002; Catts & Kahmi, 1999; Wagner & Torgeson, 1987; Wagner, Torgesen, Laughon, Simmons & Rashotte, 1993).

Phonological Awareness: A variety of terms are employed throughout the literature as synonyms with phonological awareness such as phonetic awareness, acoustic awareness, auditory analysis, sound categorization, phonemic segmentation, phonological sensitivity, phonemic analysis, and phonological coding. In this dissertation, phonological awareness is used in a generic sense to refer to an individual's sensitivity to the sound structure of words independent of their meaning or syntactic role (Blachman, 1994; Cunningham, Perry & Stanovich, 2001; Smith, Simmons, & Kameenui, 1998). Sensitivity to sound structure includes the ability to detect, discriminate, make judgements about, and manipulate different sizes of phonological units including syllable units, rhyme units, onset-rime units and phoneme segments (Mody, 2003; Stanovich, 1991). Mody (2003) proposes that "each of these phonological units has its own cognitive demands and its own developmental time course" (Mody, 2003, p. 22).

Phonological units: Refers to the size of the sound units (e.g., phonemes, onset-rimes, syllables, words).

Phonological coding: "The representation of information about the sound structure of verbal stimuli in memory" (Torgesen, Wagner, Simmons, & Laughon, 1990, p. 236).

Decoding: Translating individual letters or groups of letters into sound structure to access the pronunciation of the word.

Phoneme: Refers to the smallest meaning-distinguishing unit in the sound system of language; that is, a speech sound pattern that contrasts or distinguishes one word from another (e.g., the vowel sound distinguishing "pet" from "pit").

Phonemic: Concerned with the meaning-distinguishing (contrastive) function of sound and serving to distinguish phonemes or distinctive features.

Phonetic: Concerned with the motor act of producing a sound (articulation)

Phonetics: The study of speech sounds utilized by all human languages; it provides the means for describing how those sounds are produced, transmitted and perceived" (Federmeier & Kutas, 2000, p. 3).

Phonetic Inventory: The range of physical speech sounds in languages which are made using the human vocal apparatus (articulatory phonetics) and the physical properties of the acoustic signal (acoustic phonetics).

Phonological system: Refers to the child's understanding of the set of phonological rules or patterns which govern how phonemes may be combined to form syllables, morphemes, and words. The phonological level of speech is concerned with the cognitive work that goes into organising the speech sounds into patterns of sound contrasts (phonemic contrasts /v/ vs. /b/) so that we can make sense of them.

Lexicon: Symbolically referred to as a 'mental dictionary' or a storehouse of words in the head of a language user and "hypothesized to contain all of the information that we know about a word, including its sounds (phonology), meaning (semantics), written appearance (orthography), and the syntactic roles in which it can partake" (Harley, 1995, p. 31).

Deaf and Hard of Hearing: Throughout this dissertation an audiological definition of hearing loss is utilized. Such definitions are traditionally expressed in terms of speech reception thresholds. Degree of hearing loss is "defined as the average of the pure tone thresholds at 500Hz, 1000 Hz, and 2000 Hz in the better ear, expressed in decibels with reference to normally hearing thresholds" (Flynn, Dowell & Clark, 1998, p. 286). As defined by Moores (1996), an individual with a hearing loss (70 dB or greater) that precludes the perception and understanding of speech through the ear alone, with or without the use of a hearing aid is referred to as deaf. An individual with less severe hearing loss (less than 70dB) that makes difficult, but does not preclude, the perception and understanding of speech through audition alone, with or without a hearing aid is referred to as hard of hearing. Deaf learners, or those children without sufficient residual hearing to perceive speech, are the primary focus in this dissertation.

Overview of Chapter Organization

The dissertation is organized as follows: Chapter 2 provides a review of the literature relevant to the present study. A statement of the problems and research questions that are addressed in this study follows the review. The methods, measures, and procedures are outlined in Chapter 3. Chapter 4 presents the results of the deaf participants' performance on three phonological awareness tasks. Chapter 5 discusses the findings within the context of the research questions and relates the outcomes to those of previous studies with deaf and hearing children. Finally, the limitations of the study and the implications this research has for practice and future research are addressed.

CHAPTER 2: REVIEW OF THE LITERATURE

The review of the literature is organized as follows: Section one begins with a brief summary of the theoretical assumptions that have historically guided reading research with deaf learners. Following this summary, an overview of current perspectives on the construct of phonological awareness is presented. This overview is intended to develop a framework for a review of the literature outlining the role of phonological awareness abilities in the development of spoken word recognition and in turn, in the development of written word recognition. Section two follows with an examination of the nature of phonological development in deaf children which leads to a review of the available evidence on deaf children's phonological awareness abilities. A statement of the problem and the research questions to be investigated in the present study are also outlined in this section.

Historical Perspectives on Reading and Deaf Learners

The relationship between primary language processes and learning to read has generated a great deal of research in relation to deaf learners. To date, such investigations have been largely confined to processes associated with the relationship between spoken language and reading. That impeded auditory access presents deaf and hard of hearing children with multiple encoding and retrieval challenges in attempting to master the phonological system of a spoken language is well documented (see reviews in Musselman, 2000; Paul, 1998). Marked differences between literacy levels of deaf and hearing individuals have been attributed primarily to inequities related to learning phonology with or without the benefit of hearing (Alegria, 1998; Beech &

Harris, 1997; Hanson, 1991; Leybaert, 1993; Lichtenstein, 1998; Perfetti & Sandak, 2000).

Models of reading in the normally hearing population demonstrate a predictive relationship between spoken language phonological skills and reading (see review in Adams, 1990). Throughout history, models devised to explain a particular phenomenon in hearing people are assumed to be appropriate for deaf people (Rodda, Cumming, & Fewer, 1993). This assumption is particularly evident in models of reading acquisition. Traditional explanations arising from these models suggest that deaf readers process information about written words in qualitatively similar ways to hearing readers. To date, reading instructional practices for deaf learners continue to be developed on the basis of these explanations (Power & Leigh, 2000; Webster, 2000). At the same time, overwhelming evidence indicates that while a comparatively small number of deaf and hard of hearing children do develop adequate reading skills; the majority do not, irrespective of mode of instruction (speech or sign) or degree of hearing loss (Harris & Beech, 1995; Marschark & Harris, 1996; Marschark, Lang, & Albertini, 2002; Paul, 1998). In relation to deaf learners, Paul (1998) notes that reading achievement levels reflect "an annual growth rate of only 0.3 reading grade level per year with a levelling off or plateau occurring at the third- or fourth-grade reading level" (p. 23). The average 18-year old deaf learner leaves high school with reading skills comparable to a typically achieving 10-year-old hearing child (Allen, 1986; Paul, 1998; Wilbur, 2000). The gap in reading achievement between deaf and hearing children is striking because it spans over a century of different sound-based approaches to teaching language and reading skills to deaf children (see review in Power & Leigh, 2000).

As noted, the dominant view on reading instruction for deaf learners is premised on the assumption that reading is scaffolded on spoken language and the sound system in qualitatively similar ways as it is for the hearing child (see discussion in Perfetti & Sandak, 2000). Advocates of this position argue that the achievement of English literacy is only possible if the deaf child acquires a representation of the spoken language in a visual form (Luetke-Stahlman, 1990; Mayer & Wells, 1996; Paul, 1998, 2001). In an attempt to provide visual representations of the spoken language as input, artificial word-coding systems have been created that incorporate signs borrowed from ASL, the word order of English, and additional invented manual sign supplements to convey morphological elements such as plurals and affixes (e.g., swim +'s'; run + 'ing'; develop + ment). There are several types of manual word-coding systems in existence, each with its own rules and variations (e.g., Seeing Essential English (SEE 1), Signing Exact English (SEE 2), Signed English, Conceptually Accurate Signed English (CASE), Pidgin Signed English (PSE) (see review in Drasgow & Paul, 1995). Collectively, these various word-coding systems are often referred to by a generic descriptive term Manually Coded English (MCE) (Drasgow & Paul, 1995; Goldin-Meadows & Mayberry, 2001; LaSasso & Metzger, 1998; Paul, 1998, 2001; Stewart, 1997) and the same convention will be followed in this dissertation.

Unlike natural Sign Language(s) (e.g. ASL, LSQ), MCE systems do not have their own grammar or syntax and generally follow the word order of spoken English. As a result, MCE systems can be used simultaneously with spoken English. Common to all systems of MCE, morphemic contrasts in the English language are represented by the manual sign. When MCE systems are used simultaneously with speech, phonological information is conveyed by the speech stream and perceived by deaf children via speechreading (lip-reading). Perception and production of English through morphologically-based MCE systems is thought to develop English vocabulary, an understanding of the grammatical system of English, and provide a more direct mapping to the printed form of English. From the 'qualitatively similar' perspective, proponents of MCE systems argue that manipulation of the conversational form of English using MCE is a necessary condition for establishing a 'bridge' to the print form of English (see discussion in Mayer & Wells, 1996). The majority of deaf children in North America are currently educated in programs utilizing spoken language supplemented with some form of MCE system for communication and instruction.

There are several views in the literature outlining the relative advantages and/or limitations of MCE systems in the education of both deaf and hard of hearing children (e.g., Stewart, 1997; Supalla, 1991; Wilbur, 2000). Specific to reading achievement however, several researchers have noted that reading levels of deaf students today are virtually the same today as they were in the mid-60's when MCE systems were first introduced widely into the educational arena (see reviews in Paul, 1998; LaSasso & Mertzger, 1998; Stewart, 1997; Wilbur, 2000). As Stewart (1997) outlines, the failure of MCE systems to impact more significantly on reading levels is related to multiple factors. For the present study however, the central point of reference is that MCE systems convey no phonemic information about English. Thus, for students whose hearing loss is so great as to preclude auditory perception of speech, whether Oral, MCE or Sign educated, access to the 'continuous phoneme stream' of the English language is mediated through visual perception.

English Language Development and Deaf Children

Convergent findings from decades of research indicate that the absolute levels of linguistic attainment in English across all language domains (phonological, syntactic, semantic, and pragmatic) for the majority of deaf learners are generally low, lagging far behind chronological and mental age expectations (see reviews in Bochner, 1982; Paul, 1998, 2001; Wilbur, 2000). Deaf children tend to be less advanced in both vocabulary and communicative skills when they enter school (Andrews & Mason, 1986; Griswold & Commings, 1974) and are significantly older than hearing children before they acquire much of the phonological, syntactic and semantic aspects of English (deVilliers, deVilliers, & Hoban, 1994; Marschark, 2001). Though there are exceptions, deaf individuals acquiring English (with or without manual sign supplements) as a primary language tend to exhibit limited syntactic abilities (deVilliers, de Villiers, & Hoban, 1994; Kelly, 1996; Quigley, Power, & Steinkamp, 1977; Quigley, Wilbur, Power, Montanelli, & Steinkamp, 1976; Wilbur, Goodhart, & Fuller, 1989), reduced breadth and depth of vocabulary knowledge (Bochner, 1982; Griswold & Commings, 1974; Paul, 1996; Waters & Doehring, 1990), and limited reading comprehension levels (LaSasso & Davey, 1987; Marschark & Harris, 1996; Vernon, 1972). Careful reading of the literature suggests that the nature and characteristics of the errors demonstrated in both spoken and written language performance are pervasive and persistent across the lifespan despite intensive and long-term remedial instruction (see review in Wilbur, 2000). Moreover, a 3rd to 4th grade plateau or levelling off in skill development in syntactic abilities, vocabulary growth, and reading comprehension has been consistently reported in the literature *for most students with hearing loss* (see review in Paul, 1998; Traxler, 2000).

Implicit in most models of reading acquisition is the expectation that the acquisition of primary language structures should be well established prior to the beginning of reading instruction. It is clear that for deaf children acquiring English as their primary language these assumptions are seldom met. In contrast, deaf children exposed to early, accessible, and completely specified phonological input through natural sign language(s) (e.g., ASL, LSQ) acquire sign language along parallel developmental timelines as hearing children acquire spoken language (Bellugi, 1991; Bonvillian, 1999; Morford & Mayberry, 2000; Pettito & Marentette, 1991, Singleton & Newport, 2004). However, ASL is a language that is independent of English and reflects neither the structure nor the orthography of English. Thus, while these deaf children may acquire their primary language structures before beginning reading instruction, these structures are different from the structures of the language they must learn to read and write. Nevertheless, a robust finding across all existing investigations is that deaf children who have had early and consistent exposure to a natural sign language consistently outperform deaf children who have not had this exposure on all measures of reading achievement (Geers & Schick, 1988; Strong & Prinz, 1997; Stuckless & Birch, 1966; Vernon & Koh, 1970). It is important to clarify that earlier findings of an association between reading achievement and American Sign Language were confined to discussions of deaf children of deaf parents. However, evidence of an association between reading achievement and fluency in American Sign Language has been replicated across several recent investigations (Hoffmeister, 2000; Nover, Christensen, & Cheng, 1998; Padden & Ramsey, 1998, 2000; Prinz & Strong, 1998; Singleton, Supalla, Lictchfield, & Schley, 1998, Strong & Prinz, 1997). Results of these studies converge with the earlier findings (Geers & Schick, 1988; Vernon & Koh, 1970) and demonstrate that increases in ASL proficiency are positively associated with reading development, speech skills, academic achievement, and more recently, in comprehension of MCE (Hoffmeister, 2000; Mayberry, Waters, & Chamberlain, in press). Importantly, the associated benefits of early exposure to ASL have been found to hold regardless of parental hearing status (Strong & Prinz, 1997) and indicate that even moderate levels of ASL proficiency positively affects deaf children's English literacy skills (Hoffmeister, 2000; Strong & Prinz, 1997).

In a recent review, Mussleman (2000) notes, however, that the bulk of the research in deafness has been devoted to individual aspects of spoken and written language development of deaf individuals. Much of this research has tended to be descriptive or evaluative of the products or outcomes of English language development (oral vocabulary and language skills) and of the performance of deaf children in comparison to hearing children. There is no comprehensive theory to date to account for the distinctive characteristics of these products. Specifically, questions concerning what might preclude skill development in syntactic abilities, vocabulary growth, and reading comprehension beyond 3rd to 4th grade levels have not been systematically investigated. However, new developments in research are suggestive of an intimate relationship between early phonological development and lexical development (Brady, 1997; Chiat, 2001, Fowler, 1991; Goswami, 2002, Metsala, 1999) and thus may provide an initial perspective through which to explore these questions. Specifically, a growing body of research incorporating a broad range of findings indicate that the effects of lack of exposure to a language's explicit phonological patterns in a comprehensible form may limit lexical acquisition and, in turn, the acquisition of linguistic representations associated with later stages of linguistic development (Carlisle, Gugisberg, Strasser, & Patton, 2002; Federmeier & Kutas, 2000; Jusczyk, Hohne, & Mandel,1995; Nittrouer & Burton, 2005; Plunkett & Schafer, 1999; Skipper, Nusbaum,& Small,2005).

A brief review of current perspectives on the construct of phonological awareness is presented next in an attempt to develop a framework from which to explore two theoretical accounts of the development of phonological representations in spoken word recognition. The application of these accounts to written word recognition will then follow. A clear understanding of phonological development in deaf learners has particular relevance given the significance of spoken language phonological processes in cognitive accounts of reading disability in the hearing population and the assumption that these accounts fully explain deaf children's reading difficulties and abilities.

Phonological Awareness

Many researchers have argued that phonological awareness is a precursor to reading (Bradley & Bryant, 1983; Hulme, Muter, & Snowling, 1998). Others have argued that phonological awareness is a co-requisite of reading (Liberman, Shankweiler, & Liberman, 1989; Share & Stanovich, 1995) and still others suggest it is a by-product developing as a consequence of reading (Ehri & McCormick, 1998; Wagner & Torgesen, 1987). While these views appear to be in opposition, recent research into the construct of phonological awareness suggests that all are compatible with the view that the nature of the relationship between phonological awareness and reading is determined by the level of phonological awareness under consideration (Goswami, 2000; Stahl & Murray 1994; Stanovich, 2000; Yopp, 1988).

Phonological awareness has mostly been examined at three linguistic levels of complexity. These are the levels of the syllable, the rhyme and the phoneme. Syllables are considered to be the organizing units for sounds. Each syllable can be divided into its initial phonemes (onsets) and the remaining part of the word (rime) which further consists of a vowel (nucleus) and the remaining consonants (coda). The ability to determine and signal differences in meaning through speech sounds, or the awareness of phonological structure, develops gradually as a child acquires a phonetic inventory and a phonologic system (Fowler, 1991; Mody, 2003; Stanovich, 1991). Studies indicate that preschoolers are able to segment those components of language with the greatest acoustic salience (syllables) better than phonological units without this salience (phonemes) (Liberman, Shankweiler, Fischer & Carter, 1974). Many preschoolers are not able to segment words (recurrent syllable sequences) into smaller units (MacLean, Bryant & Bradley, 1987; van Kleeck & Schuele, 1987) although by age four, children are beginning to attend to the internal structure of words such as phonologic similarities and syllable structure (Owens, 2005). Rhyming activities increase children's awareness of syllables and smaller units. Knowledge of rime and then onset emerges from sensitivity to syllables and rhymes (Goswami, 2002). Consequently, as Carlisle et al., (2002) outline, it is possible to pose a continuum or developmental sequence for the emergence of phonological awareness. That is, young children's performance on phonological awareness tasks provides evidence that sensitivity to larger structures (e.g., syllable and intrasyllabic units) that are in place prior to reading instruction precedes sensitivity to phonemic units, which is more likely to emerge after the child has begun to read (Adams, 1990; Bradley & Bryant, 1985; see review in Goswami & Bryant, 1990).

Stanovich (1991) suggested that phonological awareness should not be viewed as a discrete state but rather as encompassing a continuum of emerging phonological control that ranges from shallow to deep sensitivity of phonological structure. Shallow sensitivity refers to understanding of the sound structure of language at an implicit or tacit, automatic level and describes early sensitivity to larger word components. For example, realization of rhyme entails an appreciation of a large phonological unit (e.g., the stressed vowel and the remainder of the word); whereas realization of phoneme identity in a word requires a more fine-grained appreciation of each individual phoneme. In that sense, awareness at the phoneme level requires more conscious and elaborate phonological knowledge, or deep sensitivity to phonological structure, than does appreciation of larger and more salient word components such as rhyme. Accordingly, it is proposed that the passage from implicit phonological sensitivity to explicit phonological sensitivity may reflect a developmental hierarchy of children's sensitivity to language units and their abilities to strategically and explicitly manipulate these phonological units (Goswami, 2002; Mody, 2003; Morais, 2003; Stanovich, 1991). Children's performance on phonological awareness tasks measuring, for example, the ability to count syllables, to generate and recognize rhyming words, to separate the beginning of a word from the end of a word, or to identify each of the phonemes in a word may thus reflect differing levels of control of phonological structure.

As research has led to a more detailed understanding of the progression in development of phonological awareness across linguistic levels of complexity, so too has more interest been generated in attempting to clarify basic processes underpinning the development of phonological awareness abilities. These are perceptual awareness, or perceptual sensitivity to phonological input, and cognitive awareness, or analytical knowledge applied to the phonological input. Perceptual awareness of phonological units is considered an underlying and critical component that supports coding of spoken language phonological information in memory (Fowler, 1991; McBride-Chang, 1995a; Morais, 2003). That is, the ability to phonologically encode lexical items originates in perceptual sensitivity to the sound structure of language, or auditory speech perception (Jusczyk, 1996; Paul, 2001).

Perception refers to a developing skills continuum moving from the easiest level of sound detection to discrimination then identification and finally to comprehension of phonological units in the speech signal (Ling, 1989; Paul, 2001). Importantly, perceptual sensitivity involves hearing a difference (e.g., that 'cat and mat' are different words) whereas phonological sensitivity entails a level of analysis of the constituent sounds (e.g., being able to describe and think about how 'cat and mat' are similar but different). Taken together, perceptual awareness and phonological awareness of the phonological units of speech lend phonological structure to the lexicon in the representation of syllable, rhyme and phoneme-level information (Fowler, 1991; McBride-Chang, 1995a; Swan & Goswami, 1997). The representation of multiple layers of phonological information is thought to be important in spoken vocabulary development (Metsala, 1999; Walley, 1993) and provides the perceptual/cognitive foundation to then support hearing children in written word recognition (Goswami, 2000, 2002; Metsala & Walley, 1998).

Findings from a large body of research converge to suggest that children who are adept at processing the phonological units of spoken language have an easier time with reading acquisition and subsequent reading achievement than children for whom this is problematic (see review in Smith, Simmons, & Kameenui, 1998). Understanding the phonological processing components of awareness, coding and retrieval that singularly or in combination may disrupt reading development has thus been the focus of increasing research attention. In a review of the hearing literature, Catts and Kamhi (1999) noted that no variable has been shown to be as consistently related to word recognition as phonological awareness over the last 25 years. Still, the relationships among a child's implicit perceptual and productive phonological knowledge and the emergence of explicit phonological awareness skills is not well understood (Morais, 2003). Importantly, to support conclusions that spoken language phonological awareness abilities similarly explain deaf individuals' difficulties or abilities in reading is not satisfactory unless phonological awareness abilities have been clearly defined with respect to capacities that support spoken word recognition on the one hand and capacities supporting written word recognition on the other hand. This will be the focus of the next section.

Phonological Awareness and Spoken Word Recognition

The mental lexicon is often referred to symbolically by psychologists as a storehouse of information akin to a dictionary where the meanings of words and their sound structures are linked (Jusczyk, 1996). In a recent review of the established theories of how speech perception capacities evolve to support the development of the mental lexicon, Jusczyk (1996) suggests that at a minimum, the abilities related to speech recognition include segmentation of the speech signal into the appropriate units, identification of the sequences of sounds in the units, and some capacity for retention of a description/representation of the sound structure associated with a particular meaning. Importantly, this representation must be distinctive enough to allow words to be distinguished from similar sounding words in order to extract meaning from the signal during speech recognition.

It is evident then that an important part of the recognition process depends on the encoding of the sound properties of words into long term memory (Jusczyk, 1996; Morais, 2003). However, while reference to encoding 'information' about the sound structure of words (phonological coding) is often discussed in the literature in a global manner; a description of what such 'information' may include is mostly left unspecified. Recent behavioral and brain imaging studies have challenged the historical view of perception as a modular function with different sensory modalities operating independently of each other (Shimojo & Shams, 2001). Thus, it seems reasonable to suppose that a representation of sound structure would be derived from the neurophysiologic encoding of all stimulus sources of information - auditory, visual, tactile - in the speech signal. Recent event-related functional magnetic resonance imaging (fMRI) data indicate that there is vigorous interaction among the sensory modalities and that integration of the multimodal sources of information may in turn establish a fully specified sensory representation of sound structure (Shimojo & Shams,2001;Skipper, Nusbaum & Small, 2005).

Assumptions about the relationship between sound units in an abstract/symbolic domain, and the gestural (articulatory) and auditory (acoustic) domains that give physical realization to these abstract units is the source of much debate in the literature (see review in Jusczyk, 1996; Nearey, 1997). Where the predominant theories of speech perception diverge is in their assumptions about the nature of the relationship between the two underlying physical domains (acoustic and articulatory) and how they support the ability to determine and signal differences in meaning through speech sounds (Nearey, 1997). Several of the key points in this debate find expression in two main theoretical positions regarding the origins of the phoneme segment for phonological development and lexical development: i) an accessibility account (see Liberman & Mattingly, 1985) and ii) an emergent account (see Fowler, 1991; Metsala & Walley, 1998).

In the early literature, the accessibility account was the most popular view of how infants learn to discriminate speech sounds. From this perspective, the capacities that underlie speech perception are argued to be highly specialized and separate from other auditory capacities. The main assumption of this position is that the phoneme segment is a fixed, preformed linguistic unit of speech processing that is part of children's natural endowment for language (Liberman, 1999; Liberman, Shankweiler, & Liberman, 1989; Morais, Cary, Alegria, & Bertelson, 1979). Thus, it is argued that children are born with a specific ability to perceive and discriminate phonemes. Although the ability to determine and signal differences in meaning through speech sounds is argued to be an innate ability, accessibility to the phoneme is dependent on the child's realization that the phoneme exists. Realization of the phoneme is thought to be accomplished by reference to the kinds of articulatory movements used in its production (Liberman, 1999). That is, some experience producing speech and linking the sounds with particular articulatory movements is necessary in order for the child to perceive differences and similarities in speech sounds. Essentially, the accessibility perspective posits that we perceive speech in terms of how we produce speech sounds. Predicated on the child's realization of the phoneme, spoken language development then proceeds from the smallest preformed phonological unit, the phoneme, to larger units like the word.

At the representational level in the mental lexicon, it is proposed that the early words of the child are segmentally structured (encoded by phonetic properties) analogous to adult-like representations of lexical items. Metsala and Walley (1998) observed that "this position is largely adevelopmental in that the perceptual units that support speech processing are viewed as essentially preformed" (p. 91). From the accessibility perspective, the ability to reflect on spoken language forms (metalinguistic abilities) is seen as the basis of phonological awareness (for a detailed discussion of both accounts see Fowler, 1991; Jusczyk, 1996). Children's task in written word recognition parallels their task in spoken word recognition, which is conceptualized as one of becoming 'aware of' or gaining access to the phoneme.

In more recent years, the bulk of developmental research on speech perception and spoken word recognition in infants and children has pointed to the need for a reevaluation of the traditional accessibility position (see discussions in Greenberg, 1996; Metsala & Walley, 1998). Growing recognition of a developmental progression in spoken language acquisition starting from fairly holistic recognition of words toward more segmental recognition of words (Chiat, 2001; Ferguson, 1986; Jusczyk, 1992; Locke, 1997) has led to the proposal of an emergent account of the phoneme segment (Fowler, 1991; Walley, 1993; Metsala, 1999). The emergent account argues that spoken language is initially perceived at a more general auditory level as opposed to a linguistic level as argued by accessibility theorists. Research in infant speech perception has documented evidence that the rhythm of speech, or the distribution of stress across a chain of syllables, that the child hears plays a key role in the understanding of speech (Chiat, 2001; Greenberg, 1996; see review in Jusczyk, 1996). Infants are sensitive to prosodic/rhythmic patterns, syllable sequences and the segmental consistency in co-occurring sound patterns (Chiat, 2001; Peperkamp & Mehler, 1999). These studies indicate that words are first recognized on the basis of their overall acoustic shape or prosodic structure commonly referred to as the suprasegmental structure of language (Joulet, Goulet, & Hannequin, 1990; Morford & Mayberry, 2000).

It has been proposed that perception of the rhythmic patterns of language may provide the 'trigger' which enables infants to learn that sound sequences carry distinct meanings (Metsala & Walley, 1998). Such learning, in turn, may provide the listener with the means by which to begin parsing the continuous speech stream into increasingly smaller linguistic units such as clauses, phrases and words (Jusczyk, Hohne, & Mandel, 1995). The rationale behind this proposal comes from analyses of fluent speech which suggest that changes in prosodic structure (e.g., increases in syllable duration, pausing, drops in fundamental frequency) mark the boundaries between important grammatical units such as clauses and phrases (Jusczyk, 1996). Similarly, analyses of child-directed speech in turn reveals that parents tend to exaggerate prosodic markings in sentences which may be useful in providing infants with necessary information for segmenting speech into the units required for grammatical analysis. Jusczyk (1996) and Jusczyk, Houston, and Newsome (1999) report several studies that clearly establish that infants do respond to the presence of these rhythmic markers in fluent speech.

Although research on how infants perceive sound contrasts and how this contributes to the development of the mental lexicon is still at an early stage, it is now acknowledged that there is little empirical evidence to support the notion that early representations of the infant within the first few months are structured in terms of phonetic segments as argued by accessibility accounts (see review in Jusczyk, 1996). Rather, research investigating early word representations in young infants and children demonstrate that young children initially have a relatively sparse spoken vocabulary that appears to be represented in the internal lexicon by way of rather global phonological features quite different from adult-like representation (Ferguson, 1986; Fowler, 1991; Jusczyk, 1992; Studdert-Kennedy, 1987). That is, categorization of sound sequences that carry meaning and storage of these sound sequences are based initially on a globally represented phonological pattern of the word rather than on the individual phonemes involved (Chiat, 2001; Peperkamp & Mehler, 1999). These findings have led to the proposal that the word, rather than the phoneme, serves as the point of entry to the segmental level of one's native language (Henderson, 1992; Metsala & Walley, 1998).

Theoretically, it is suggested that entry to this segmental level of language might be accomplished in the following way. There is a high degree of acoustic similarity among words in spoken English (e.g., 'pin, pen, pan' or 'pan, man, ran'). As children rapidly acquire more words throughout the preschool years, words that overlap in their acoustic properties may place an increasing load on memory. Thus, there would be considerable developmental pressure on the brain to begin to discriminate between similar sounding words in order that they be stored in long-term memory in an easily distinguishable form (Swan & Goswami, 1997; Walley, 1993). Attending to increasingly finer acoustic distinctions (segmental differences) among spoken words helps children differentiate the unique phonological features (acoustic and articulatory) that characterize each spoken word. It is proposed that as children begin to attend to the similarities and differences among words that 'sound alike', and begin to specify these phonological discoveries more distinctly in their representations, their vulnerability to both discrimination errors (in an acoustic sense) and production errors (in an articulatory sense) between words is reduced. Through such lexical restructuring, it is thought that accurate and efficient retrieval of words in the internal lexicon may be accomplished easier. In a recent study, Nittrouer and Burton (2005) tested the hypothesis that children derive phonetic structure from the acoustic signal through examining the effects of diminished access to sound in a group of young children with histories of early chronic ottis media (OME). They reported that in comparison to typically hearing controls, the children exhibited marked delays in speech perception, phonological processing and comprehension of sentences with complex syntax. Nittrouer and Burton (2005) concluded that when "the acquisition of language appropriate perceptual strategies is delayed, the child will be delayed in learning to recognize phonetic structure efficiently and so will have more difficulty storing and retrieving words in working memory " (p. 57).

According to the emergent position, phonological awareness is thus viewed as a protracted process that proceeds gradually from an awareness of larger segments to an awareness of smaller ones (Gombert, 1992; Goswami, 2000). The path of acquisition is shaped first by the suprasegmental structure of language and then by the segmental structure of language. The process of increasing refinement of lexical representations allows for more efficient storage and retrieval of lexical items (Goswami, 2000) and in turn supports more efficient articulation (Studdert-Kennedy, 1987). It is of interest that parallel patterns of acquisition are reported in the literature in relation to perception and production of American Sign Language (see reviews in Bonvillian, 1999; Morford & Mayberry, 2000).

From an emergent perspective, the phoneme segment "emerges first as an implicit, perceptual unit that is used in basic speech processing, and only later as an explicit unit that can be deployed for reading-related activities" (Metsala & Walley, 1998, p. 91). Accordingly, individual differences in the representation of segmental phonology can be attributed to differences in the extent to which lexical restructuring has taken place (Goswami, 2000). The extent to which phonological representations are segmentally organized is thought to be determined by the extent of phonological specification (accuracy and precision of coding) of the underlying representations

(Brady, 1997; Carlisle et al., 2002; Chiappe et al., 2001; Elbro, 1996; Fowler, 1991; Goswami, 2000; Metsala & Walley, 1998; Morais, 2003; Snowling, 2000; Stanovich, 2000; Swan & Goswami, 1997). In this way, several researchers propose that the extent of lexical restructuring of a word's phonological representation in the lexicon and in working memory influences the development of the child's phonological awareness, which in turn, may influence the development of word recognition strategies. Difficulty in disambiguating sound contrasts and similarities in the speech stream may result in words being learned as unanalyzed units which may limit the child's ability to learn letter-sound relations across letters, letter clusters, syllables, and morphemes (Brady, 1997; Carlisle et al., 2002; Morais, 2003; Swan & Goswami, 1997).

At the perceptual level of sensitivity, the accuracy or specificity with which phonological information in the speech signal is encoded may be affected by several factors. As discussed previously, speech perception is multisensory (e.g., Goldinger, Pisoni & Luce, 1996; Kishon-Robin, Haras & Bergman, 1997). Not only do spoken English words overlap significantly in their acoustic properties as previously noted, there is also a high degree of overlap in the visual properties of spoken words. For example, speechreading phrases like "elephant shoe" and "I love you" are indistinguishable on the basis of visual speech information alone. Many experiments show that visual information can enhance the understanding of speech suggesting an integration of the visual with the auditory signal for typically hearing individuals (see review in Massaro & Cohen, 1999). While seldom discussed in the literature, on the production end in spoken English, there is also a high degree of tactile similarity among words in their patterns of articulatory contact. For example, words like "pint" and "bent" although acoustically distinct, have the same pattern of tactile stimulation or articulatory contact and are thus, quite indistinguishable on a purely tactile or "felt speech" basis. It is likely that sensory information from the tactile modality further supports children who can hear in the integration of auditory and visual information (Geers & Brenner, 1994, Shimojo & Shams, 2001).

While there is no agreement in the literature as to which source of information (auditory or articulatory) holds primacy in defining the task of speech perception, there is general agreement that all sources of sensory input (auditory, visual, motor) and the coding systems that support them are in close communication with each other (Jusczyk, 1996; Nearey, 1997). The importance of sensory integration across multiple input sources has been recently highlighted in neuroimaging studies of motor-cortical activation during speech perception (Skipper, Nusbaum & Small, 2005). Skipper et al., (2005) suggest that children's experience as listeners and talkers "reinforces the relationships among acoustic, visual and propioceptive sensory patterns and between sensory patterns and motor control of articulators, so that speech becomes an 'embodied signal' rather than simply an auditory signal" (p. 77). Difficulties in sound perception, at any level along the speech perception continuum (e.g., detection, discrimination, identification, comprehension), could thus be expected to interfere with the construction of an 'embodied' or accurately specified phonological signal. As a consequence, segmental analysis of the correct form of a word may be hampered because a 'crystallized' phonetic (acoustic and articulatory) code is not available (Swan & Goswami, 1997).

To summarize, in defining the task of spoken word recognition and the capacities that support this process, some researchers take the position that the capacities underlying perceptual awareness are highly specialized, specific to speech, and that children and adults have phonological systems of the same type. That is, it is supposed that phonological representations are specified as early as birth and are equivalent to adult forms (encoded by phonetic properties). From an accessibility perspective, it is argued that the articulatory domain supports the detection of similarity and differences in meaning which leads to awareness of the pre-existing phoneme. Others have taken the position that capacities supporting perceptual awareness are more general and are a part of general auditory processing capacities. That is, they do not suppose that "the mechanisms underlying speech perception already possess the structures they are supposed to represent. The representations are not innate, just the computational resources necessary to build them" (Ingram, 1999, p. 68). From an emergent perspective, it is argued that acoustic perception of sounds signal differences in meaning and both the construction and the specification of phonological representations are conceived as progressive processes, starting in early childhood and lasting until explicit access to phonemic awareness is facilitated by beginning literacy (Wesseling & Reitsma, 2001).

In essence, and regardless of the debates on the origin of the phoneme segment - acoustic tuning, the whole to part refinement process proposed by the emergent account, or articulatory tuning, the part to whole assembly process proposed by the accessibility account - both perspectives posit that the essential first step in interpreting and organizing lexical information lies in reducing the number of degrees of freedom in the overall language system in order to simplify the task of word meaning acquisition. Goswami (2003) refers to this process as leading to the establishment of the 'cognitive precursor skills' for reading.

Phonological Awareness and Written Word Recognition

Knowledge of the words of one's language is embodied in an internal lexicon. Information about the word's meaning, sound and pronunciation, syntactic identity, and orthographic (spelling) identity is represented in the internal lexicon as a lexical entry (Ehri, 1991). In written word recognition, to extract meaning from the written symbol, an individual needs to access words in the internal lexicon. There is widespread agreement in the literature that orthographic, phonological, syntactic category and semantic information contribute to word processing in reading. There is much less agreement about when and how each of the information sources is utilized. In the early stages of word reading acquisition, however, there is general agreement that entry to the lexicon or the access route is typically phonological in nature (see review in Adams, 1990; Berninger, 2000; Mayberry, 1995). In skilled word reading, the role of phonological information in activating word meanings is much less clear (Damian & Martin, 1998).

For skilled readers, there is some evidence that phonological intervention may not be a *required* process for achieving access to a written word's meaning in long-term memory (see reviews in Baddeley, 1979; Lichtenstein, 1998). From this perspective it is argued that semantic information in the internal lexicon may also be accessed directly on the basis of orthographic, visually obtained information (Ellis & Young, 1996). Experimental studies failing to consistently obtain phonological effects in word processing (see review in Damian & Martan, 1998) and data from the neuropsychological literature documenting cases of patients who have somehow lost access to phonological information about a written word but can still access the meaning of the word (Campbell and Butterworth, 1985; Homes & Standish, 1996; Stothard, Snowling & Hume,1996) indicate that access to meaning in visual lexical access can occur without speech recoding.

The direct visual route to semantics has been challenged by a number of recent eye-movement experiments that indicate that lexical access for written words in silent reading may be manditorily mediated by their phonological codes. For example, Pollatsek, Rayner and Lee (2000) demonstrated that phonological codes are involved in accessing the meaning of words in silent reading of both English and Chinese, two orthographies often thought to discourage phonological coding in going from print to meaning, and argue that such findings offer strong evidence for the primacy of phonological codes in word recognition. Paralleling the arguments forwarded earlier for the development of phonological representations of spoken language, it is proposed that experience with written words may similarly reinforce the relationship among orthographic and phonological patterns establishing an 'embodied signal'. Thus, it is argued that the reading of familiar words requires the retrieval and analysis of an existing phonological representation, whereas for unfamiliar words, phonological representations must first be assembled based on knowledge of orthographic-to-phonological mappings. Recent fMRI data indicate that "known words have a facilitated and possibly direct route to phonology" which minimizes demands on the phonological control processes and that the phonological system may contribute to the formation of durable word representation in the course of the assembly of phonological representations from orthographic inputs for novel words (Clark & Wagner, 2003, p.314). In this way, proponents arguing for an obligatory role for phonological codes in activating a word's meaning suggest that the appearance of an independent route leading from orthography to meaning resolution may in fact be an artifact of an 'embodied signal' for known words (Pollatsek, Rayner & Lee, 2000).

In summary, existing evidence indicates a mandatory role of phonology in visual lexical access in some studies but not in others (Damian & Martin, 1998). In taking a middle ground between those arguing for a direct orthography to meaning connection and those arguing for an exclusive role for phonological codes, Daneman & Reingold (2000) suggest that the extent to which phonology is implicated in activating a word's meaning is mediated by several factors including predictability, word frequency, and reading skill. Additional research is needed to clarify whether lexical access for written words is manditorily mediated by phonological codes or whether there is a more limited role for phonological codes in lexical access. It is reasonable to suppose however, that the consequences for word processing resulting from an inability to use a grapheme-phoneme conversion route or from a loss of phonological processing capability may be quite different than the consequences for word processing if phonological processing capabilities were never acquired.

The role of a word's orthographic structure is not fully understood (Vellutino, Scanlon, & Tanzman, 1994). Lukatela and Turvey (1994) suggest that if "a word's phonology constitutes the initial or primary code by which a word accesses its representation in the internal lexicon", the role of a word's orthographic structure "figures most significantly in processes that reduce the noise in the lexicon following activation by the word's phonological code" (p. 333). Paralleling the arguments forwarded in the previous section concerning the high degree of perceptual similarity (acoustic/visual and kinaesthetic/tactile) in spoken English words, there is also a high degree of visual similarity among letters and words in written English. For example, the letters "p, b, q" differ only in their orientation, similarly words like "bear and bean" differ only in the final letter. Thus, as children add more and more words to their reading vocabulary, the visual similarity among words in written English makes the use of whole-word word recognition strategies a very resource-intensive process because of the load placed on visual memory (Vellutino et al., 1994). When faced with printed words that have letters in common then, the child needs a way to reliably discriminate between printed words that 'look alike' in order to reduce visual discrimination errors. Attending to the letters of a word and learning to associate the sound that maps to these letters supports the beginning reader in this process (see reviews in Adams, 1990). Similarly, this ability to recode, or translate printed symbols into their underlying phonological patterns supports readers in identifying unfamiliar words in print as well (Share, 1995).

Learning to locate and identify initial consonants is one of the first ways children attempt to disambiguate and use print cues in reading. Another step in using print cues is locating and identifying final consonant sounds. It is generally easier for children to identify initial and final consonants in sounds than it is to identify medial vowel sounds (Moats, 2000). Vowel sounds are usually in the middle of a word which is the hardest position for children to hear, thus medial vowel sounds tend to be more difficult to discriminate and remember than consonant sounds. To decode sequentially children need to be able to recognize vowels sounds. In print, one vowel sound may be represented by multiple letters (e.g., tr*ee*, k*ey*, m*ea*t, cook*ie*) and one vowel letter can have several different sounds (e.g., come, comb, cough) which increases the complexity of establishing vowel letter-sound associations for beginning readers. Some researchers suggest than an intermediary strategy that could be used by children to read an unfamiliar word is to compare an unfamiliar word such as *pun* to a known word like *sun*. In making this analogy children need to be able to recognize rhymes and to segment the words into onsets and rimes (e.g., r-un, p-un). In the early stages of learning to read it may be easier for children to make onset-rime analogies than to decode a word one letter at a time (e.g., p-u-n) because of the increased demands that sequential decoding places on auditory sequential memory (Goswami, 2002). Berninger (2000) suggests, then, that there are multiple ways in which beginning and developing readers learn to associate written symbols (familiar and unfamiliar orthographic patterns) with known (over-learned and familiar) phonological representations in the internal lexicon. It may be through knowledge of individual letter-sound correspondences (Ehri, 1991), through rhyme or analogies (Goswami, 1998) or through onsets and rimes (Goswami, 2002; Treiman & Zukowski, 1996).

At the word level, a primary source of word recognition problems lies in the accuracy and the speed of retrieval of lexical forms. A recent hypothesis that is gaining support among reading researchers suggests that difficulties in both accuracy and speed of retrieval of lexical items may be more centrally tied to the quality of initial encoding of the underlying lexical representations of speech than has been traditionally assumed.

In this sense, quality pertains to differences in the amount of phonological information used to represent items in the lexicon. According to this hypothesis "if the underlying representations of words are imprecisely specified, then their lexical structures will not be segmentally organized and available for inspection at any phonological level" (Swan & Goswami, 1997, p. 22). This argument suggests that poor performance on phonological awareness tasks may not reflect a lack of phonological analysis skills per se, but rather that retrieval strategies that are premised on fine-grained representational structure are not available because the structure has not been developed to support such analysis (Swan & Goswami, 1997; Goswami, 2000; Morais, 2003).

In sum, much of the discussion in this chapter thus far has been aimed at showing in a very broad way how phonological awareness in the service of spoken word recognition is related to phonological awareness in the service of written word recognition. Current contributions from the speech perception/production literature suggest that the progression of phonological awareness development supporting spoken word recognition in typically developing hearing children culminates in the establishment of segmentally organized and distinctly specified phonological representations of spoken vocabulary (e.g., Morais, 2003; Walley, 1993). Such development establishes what Goswami (2002) refers to as the 'cognitive precursor skills' for reading. Current contributions from the reading literature offer insight into how these cognitive precursor skills in turn support the development of an efficient written word recognition system. Importantly, efficiency in the use of word recognition strategies is premised on an a priori understanding that a child has an underlying representational system that consists of phonological units (syllables, onset-rimes and phonemes); a conceptual grasp of the fact that these phonological units can be mapped to written words and finally, that spoken units are composed of individual speech sounds (phoneme awareness). For hearing children then, a central contribution of phonological awareness (both perceptual and cognitive) lies in its role in reducing ambiguity in the overall spoken language system and written language system. Learning which sounds are used contrastively in language and which sounds reflect pronunciation rules helps define for children what is predictable in the spoken language system. In turn, this learning supports the discovery of predictable patterns in the written language system. Understanding how deaf children acquire phonology and the manner in which their phonological systems develop is therefore important in developing an understanding of reading-related phonological processes for these learners. One test of the utility of spoken language phonological awareness to reading for deaf learners must lie in its ability to serve the same central function of establishing predictability in the language systems and thus reducing the learning load for these learners as it does for hearing children. This will be the focus of the next section of the chapter.

Nature of the Phonological System in Deaf Children

Loss of hearing sensitivity in young children alters the nature and character of their linguistic intake (Bochner, 1982; Conrad, 1979). Deaf children have reduced access and therefore less sensitivity to the auditory aspects of speech input (Conrad, 1979). Speech perception studies of deaf individuals indicate that the integrity of linguistic intake is associated with the severity (decibel loss) and configuration (shape of loss across a range of frequencies) of a child's hearing loss (Conrad, 1979). In turn, the development of both the receptive and productive aspects of the phonological system may be compromised to varying degrees. Perception of most consonants and vowels lie within a normal hearing threshold of 20 dB to 60db. Severe (70- 89 dB loss) and profound (greater than 90dB loss) hearing losses preclude auditory perception of conversational speech, which is accessed at around 60dB (Flynn et al., 1998; Mussleman, 2000). Speech reception data for deaf individuals generally indicate that the reception of spoken language patterns is often distorted in some way with, for example, whole syllables missing from what is perceived (Ling, 1989).

Developments in the productive aspects of a phonological system are also tied to degree of hearing loss. Generally, speech production studies indicate that children with varying degrees of residual hearing demonstrate consistent simplifications of the sound system in their productions (Osberger & McGarr, 1982). Types of speech errors for these children appear closely related to the acoustic value attached to the phoneme. That is, phonemes that do not provide strong acoustic cues or that are acoustically similar are particularly difficult to produce (Osberger & McGarr, 1982). Descriptions of profoundly deaf children's speech production errors, in contrast, reveal that errors are made based on the complexity of the articulatory gestures involved rather than on their acoustic value (for a full description of speech errors see Dodd, 1976 and Smith, 1975).

While it is acknowledged that impeded auditory access to spoken language will limit deaf children's ability to learn spoken language phonology through hearing its sound, it is widely assumed that deaf children can develop phonological competence through alternate non-auditory means (Alegria, 1998; Dodd & Campbell, 1987; Hanson, 1982; 1991; Leybaert, 1993, 1998). For example, it is suggested that phonological learning may occur via the visual information acquired through speech reading (Dodd, 1976; Dodd & Hermelin, 1977) and through the articulatory feel of words that comes through intensive speech training (Marschark & Harris, 1996). Fingerspelling (Campbell, Burden & Wright, 1992), learning to write (Hanson, 1989), and extended experience with words in print (Hanson & Fowler, 1987) are also proposed as sources that can develop increased awareness of phonological information for deaf individuals. While it is generally agreed that no one source of information alone is sufficient, it is argued that in combination these sources of information contribute to developing the phonological representations that underpin the coding of words in the mental lexicon for deaf individuals (see review in Perfetti & Sandak, 2000). Because such assertions are central to an understanding of what may be helpful in producing a representation in deaf learners that is supportive of memory processes, comprehension, and print-to-phonology recoding, they will be outlined in more detail below.

Non-auditory Links to Phonology

Jusczyk (1996) notes that the form a speech perception/production model takes depends critically on the assumptions of the model's formation. As outlined earlier, one such assumption is the nature of the input to the model. Underlying any discussions on the development of a phonological system in deaf individuals is the proposal that the acquisition of phonological knowledge is not exclusively dependent on auditory input (see review in Perfetti & Sandak, 2000). Dodd and Campbell (1987) have argued that most theories of speech perception consider it to be a purely auditory capacity and as a result, ignore the substantial role played by vision in speech processing. In support of this argument, they note that evidence from extensive investigations of lip-reading indicate that hearing children internalize cues from both visual (seeing speech) and acoustic (hearing speech) input sources to map their spoken output (articulation). They further argue that both sources of input make independent contributions to the gestural (articulatory) domain of speech processing. The central tenet of the argument posits that both auditory and visual representations of stimuli are retained in the same input phonological buffer in short term memory (Campbell, 1987, p. 146). It is proposed then that both visual and auditory speech input share a common phonological metric which is phonetic (see Leybaert, 1993). On this basis, it is argued that vision plays a similar interpretive role as sound in speech comprehension.

In reference to profoundly deaf learners, this argument proposes that the phonology of a word is essentially derived as a function of vision (speechreading). Premised on the assumption that the visual lip-reading signal is interpreted as linguistically meaningful, it is argued that seeing speech (speech reading) will provide deaf children with access to some of the phonological contrasts in spoken language (see review in Leybaert, 1993). The observation that orally educated deaf children's speech development follows the acquisition patterns of hearing children, though at a much-delayed rate, is offered as evidence for the internalization of phonological information provided by visual (lip-reading) speech (Campbell, Burden & Wright, 1992; Dodd, 1976). Dodd and Campbell (1987) have demonstrated that only about 20-25% of individual speech units can be usefully distinguished in 'seen speech' because most of the articulators that support discrimination are hidden behind the teeth and thus invisible to the eye. For example, speechreading the articulatory movements of even the easiest labial sounds /b/, /p/, /m/ or "bat, pat, mat", would be difficult to discriminate in isolation because of the hidden voicing and nasalation features. Similarly, in continuous speech, the ability to effectively discriminate the articulatory movements of speech requires a highly supportive context. The ability to effectively use context in this instance would be premised on an individual having well developed language skills and that all of the words following are also not highly confusable. Because of the high visual confusability between lip-read items, Campbell (1997) suggests that representations of lip-read stimuli can be expected to be underspecified and abstract in comparison to representations of auditory stimuli.

In recent years there has been renewed interest in proposals that Cued Speech (a system that uses a series of hand-shapes along with speech to help disambiguate lip-read cues) may provide deaf learners with clearer visual access to the phonological contrasts in speech (see discussion in LaSasso & Metzger, 1998; Leybaert & Charlier, 1996). While there is some suggestion that very early and consistent use of Cued Speech may improve speech understanding in some deaf children (Alegria, 1998; LaSasso, Crain & Leybaert, 2003) improvements in speech production skills have not been similarly reported (Campbell, 1997). To my knowledge, systematic studies of the effect of Cued Speech (CS) on the deaf child's understanding across all levels of phonological complexity (syllable, rhyme, and phoneme) have not been undertaken. Thus, the effect of Cued Speech on the refinement of lexical representational structure remains an open question that warrants further investigation. Of interest, a recent visual hemifield experiment revealed that deaf children exposed intensively to CS displayed similar left hemispheric specialization for semantic processing of written language as did hearing children; however, the deaf children did not display left lateralized processing of rhyme. The investigators suggest that more research involving brain imagery is needed to clarify the extent to which lateralization in processing sub-lexical phonological units of the language is dependent on hearing the sounds of language (D'Hondt & Leybaert, 2003).

Articulatory feedback is proposed as another possible route to developing phonological awareness in deaf learners. Marschark and Harris (1996) suggest that attending to their own tactile feedback as they articulate a word may allow deaf children to represent their articulation as a speech-motor pattern. No explication as to how a motor-based representation becomes linked to phonology for profoundly deaf individuals has been forwarded, suggesting perhaps that this claim may be premised on the earlier assumption that vision (lip-reading) serves to establish the phonological representational base for deaf learners. The only evidence offered in support of the claim that articulation provides a connection to phonology is correlational data relating reading ability and articulation ability (Hanson, 1986; Marschark & Harris, 1996).

Similarly, it is argued that fingerspelling and learning to write support the development of phonological representations in deaf learners (Campbell et al. 1992; Leybaert, 2000; Perfetti & Sandak, 2000). It seems uncontroversial to suppose that for those children with an established underlying phonological foundation, learning to write would support refinement of their understandings of sound-to-print connections (see discussion in Adams, Treiman, & Pressley, 1997). Likewise, it is clear that fingerspelling, which provides a manual representation of the letters of the alphabet, could provide a strong link to orthography; however, the proposed connection to phonology is again not clearly obvious without a presumption of a phonological base.

To summarize thus far, arguments for non-auditory links to phonology for deaf learners are premised on the theoretical claim of a common 'phonetic' code shared by vision and audition. Arising from this claim are arguments that vision (lip-reading speech) and articulating speech serve to establish the phonological foundation and representational base from which it is argued that the reading system for deaf learners can be developed. Such a phonological foundation has yet to be clearly established in the literature hence, there is little empirical data available to evaluate the claims for non-auditory links to phonology for prelingual, severely to profoundly deaf individuals. Without clear evidence of a phonological foundation for deaf learners, the possibility is open that the nature of any learning that takes place through speechreading, articulatory feedback, writing, or fingerspelling may in fact be of quite a different kind.

Of note, in a series of recent experiments with hearing and deaf college students, Wu (2002) failed to find evidence to support Campbell's hypothesis of a single capacity phonological buffer for heard and seen (lip-read) speech. Rather, Wu's experiments provided additional support for Martin and colleagues' proposal that stimuli are retained in separate input and output phonological short-term memory buffers according to whether phonological information is directly available in the stimuli and automatically accessed (input buffer) or whether phonological information must be internally generated because there is no phonological information in the stimuli (output buffer) (Freedman & Martin, 2001; Martin, Lesch, & Bartha, 1999; Martin & Saffron, 1997). Of particular relevance to this dissertation, it was found that both users of spoken language (heard speech) and users of American Sign Language responded to probes related to the input phonological buffer when presented with natural language input consisting of spoken or signed stimuli. In contrast, when presented with lip-read stimuli (seen speech), along with print and nameable picture stimuli, the spoken language users responded to probes related to the phonological output buffer. Unfortunately, this latter task with lip-reading and picture stimuli was not conducted with the deaf participants.

Nevertheless, evidence that seeing speech (lip-reading) did not directly activate phonological representations along parallel lines as hearing speech for the hearing participants raises three immediate concerns regarding traditional assumptions that non-auditory sources of input (lip-reading and/or articulation) for deaf individuals can provide a link to phonology and lead to the establishment of phonological representations. First, if phonology from non-auditory stimuli must be internally generated as Wu (2002) demonstrated for lip-read and print materials, there is clearly a presumption of an underlying phonological foundation from which the phonology can be derived. In other words, to reach a phonological representation of a word from a lip-read source, that word must first be established in phonological form. As noted, there have been few investigations to date exploring the precursor abilities in phonological awareness in profoundly deaf learners. Importantly however, the traditional argument in the deafness literature is rooted in claims that lip-reading *is* the source of phonology that develops the representations.

A second concern that is raised by Wu's results relates to speculation that articulation of their own speech provides deaf children with links to phonology. Articulation, or an utterance to be produced, is represented in a motor program, and critically, the execution of a motor program depends on its content (Kent, Adams & Turner, 1996). It is clear that for typically hearing children, there is an acoustic goal to be achieved by articulation. That is, “a phoneme is associated with a set of phonetic features and a phonetic feature is associated with one or more acoustic cues” (Kent, Dembowski, & Lass, 1996, p.199). In this way, the speech production system gives realization to each phoneme in turn. Interestingly, the available evidence outlined earlier has demonstrated that speech production errors for profoundly deaf individuals are linked to the complexity of motor patterning (articulatory gestures) involved and not to the acoustic values in the input as is seen in children with some residual hearing. At the very least then, a strong dissociation between auditory (acoustic) and gestural (articulatory) integration in the two physical domains of speech processing is indicated for these learners. More significant perhaps, if the execution of a motor program can not be clearly linked with phonological input to speech production, as Wu’s results suggest, then the question is raised as to what the content is of the motor program that is executed for profoundly deaf individuals. To clarify, as noted earlier, there is a high degree of tactile/kinaesthetic similarity among spoken words in their articulatory patterns of contact. For example, the articulation pattern for words like “pin and Ben”, “time and name” or “kite and gun” have the same pattern of tactile/kinaesthetic (articulatory) contact and are indistinguishable on a purely tactile or ‘felt speech’ basis. The phonological features that provide contrast and thus convey meaning are invisible to the eye and are realized acoustically. Clearly, if acoustic information is not available in the input for profoundly deaf individuals, and if phonological information is not directly available in the input of seen speech as Wu has demonstrated, it is possible that the articulation program that is generated for profoundly deaf individuals is derived from a tactile trace with no links to a phonological source whatsoever.

The third concern has direct implications for the word reading strategies that would be available to the deaf learner. In relation to audiovisual integration between acoustic and articulatory events for hearing individuals, Wu (2002) suggests that "while lip-read movements may directly activate output phonological representations for words, they can only modify the input phonological representation when there is simultaneously compatible auditory information" (Wu, 2002, p. 131). This argument converges with the emergent account of the phoneme segment and models of speech perception that argue that acoustic information is what lends phonological representations their shape. That is, changes in the characteristics of individual words due to familiarity and neighbourhood density support the shift from holistic to segmental processes in the structuring of the lexicon (Metsala & Walley, 1998; Goswami, 2002). The primary point of interest is the conclusion that visual and heard input sources are interdependent and interactive rather than independent (see also Shimojo & Shams, 2001). Consequently, and taken together, these arguments suggest that it is unlikely that visually perceived lip-read movements or motor articulation movements alone could help modify or refine any input representation that might be established by deaf individuals. These arguments hold implications for deaf learners not only in terms of reading development but also in relation to language learning in general. That is, without access to a phonological input source, words may be learned as unanalysed units. Restriction in the quality of representational structure may in turn affect the quantity of representations that can be established and, in that way, limit vocabulary learning. Holistic word representational structure or organization could in turn limit deaf readers to more global and thus resource demanding word reading strategies.

In a recent review of models of speech production, Kent, Adams and Turner (1996) conclude that "many speech production models virtually ignore perception of the acoustic signal as a determining influence. Indeed, some of them neglect audition to the degree that we might suppose that speech is produced in a world of silence" (p. 38). Further research is needed to clearly explicate the nature of the stimulus information that is available in the visual and articulatory speech stream for deaf learners. Without such empirical evidence, caution in the generalizations of a visual or motor pattern link to 'phonology' for deaf individuals with no residual access to acoustic speech information is warranted.

Awareness of Phonological Structure in Deaf Learners

There is surprisingly little direct evidence available regarding the representation of phonological structure in deaf children and adults. For the most part, investigations to date have attempted to determine if individuals with profound prelingual deafness can access phonology in reading. Until recently however, little concern has been directed at the quality or the structure of the underlying representations that might support the use of phonological strategies in reading. Those studies that have examined awareness of phonological structure have largely focused on rhyme awareness in children or adults. In reviewing the literature, one study of deaf children's awareness of syllables and two studies dealing with phoneme awareness were found.

Syllable Awareness Studies

Sterne and Goswami (2000) examined sensitivity to the phonological structure of words in three separate experiments each focused on one level of linguistic complexity for different participant groups (mean age within groups was 11.9 years). This study is of particular interest because it is the only study that has attempted to compare deaf children's awareness of phonological units across levels of linguistic complexity. Still, a direct comparison of individual development across levels of structure is not possible as different groups of deaf children participated in each experimental task. Oral and MCE educated deaf children participated in each experiment and performance patterns were compared with groups of age-matched and reading-age matched (mean RA 7.8) hearing children. In the first experiment a picture-based word length judgment task was used to measure syllable awareness. The children were required to discriminate differences in word length on two different sets of word pairs consisting of 18 pairs of pictures each. The first word set was devised to be orthographically and phonologically incongruent. Some words contained the same number of letters but differed in syllable length (e.g., "cake - lion") while other words contained the same number of syllables but differed in the number of letters (e.g., "piano - elephant"). A second set of words were paired on syllabic length and orthographic length in two categories: short-short pairs (e.g., "dog – box") and long-short pairs (e.g., "butterfly – fork"). Phonological length judgments and reaction times were recorded. The results indicated that all three groups of children had similar patterns of performance on this task and made accurate phonological length judgments for most of the word pairs. The researchers concluded that the phonological representations of these deaf children had good segmental organization at the syllable level. Sterne & Goswami (2000) suggested that successful judgment of syllable length by both hearing and deaf students is influenced by the size of syllable discrepancy between word pairs. They reported that on this task, requiring participants to make a 'yes – no' judgment by discriminating that words like "shorts" and "tomato" are different lengths (one vs. three syllables) was much easier than determining that words like "cake" and "lion" (one vs. two syllables) were different lengths. However, on a task requiring a judgment between two words it is difficult to determine what source of knowledge was applied in order to discriminate differences in word length. That is, a successful response in discriminating differences in word length between two words may reflect an awareness of syllable (phonological) structure, as concluded by Sterne and Goswami. Arguably however, sensory evidence from kinaesthetic cues, or a kinaesthetic awareness of differences in movement/motor pattern between two words, could also account for the successful responses on this task.

Rhyme Awareness Studies

Sterne & Goswami (2000) tested the second level of phonological structure, rhyme awareness, using a picture judgment task. Children were presented with a prompt picture and asked to choose the item that rhymed with the prompt from two alternatives. Five categories of distracter items varying in orthographic or phonological similarity to the prompt item were used to investigate the strategies the deaf children used in this task. Results indicated that the younger reading-age controls were significantly more accurate in making rhyming judgments than the deaf group although the deaf children performed above chance. Orthographic similarity between the rhyming pairs enhanced the performance of the deaf children whereas the hearing children performed equally well on orthographically similar (O+, e.g., “sock - clock”) and orthographically different (O -, e.g., “fly - eye”) rhyme pairs. Analysis of error patterns revealed that the effect of distracter type was seen only with the deaf children. Specifically, distracter items with matching letter onsets (e.g., “bridge - bricks” or “witch - wall”) significantly reduced rhyme judgment accuracy. Overall, distracter items with similar lip-shapes to the cue were found to have little effect on rhyme judgment accuracy which the investigators acknowledged as surprising in light of reports from other research groups that lip-shape does affect deaf individuals’ ability to make rhyme judgments. However, a post hoc analysis revealed that distracter items classified by the investigators as ‘highly similar’ in lip-shape (e.g., “phone - van”) did have a significant adverse effect on accuracy judgments compared to those classified as ‘less similar’ in lip-shape (e.g. “book – man”). The authors concluded that these results provided evidence that deaf children use lip-read information to support identification of shared rhyme and that deaf children were able to make rhyme judgments in a simple matching-to sample task when the task demands were low. However, their results can be interpreted in other ways as well. The authors report a 73% overall accuracy rate on this task. This score, however, includes performance on both orthographically similar (O+) and orthographically different (O-) word sets. In relation to deaf students, reporting a combined score is problematic. Because similarity in sound often leads to similarity in orthography as is seen in O+ words, a correct judgment on a two response choice task does not necessarily require phonological abilities. That is, a correct response on the orthographically similar word sets could be made simply on the basis of a spelling pattern match between cue and target in comparison to the one distracter. Reporting on the number of successful responses on orthographically different word sets alone would provide a clearer indication of a deaf student's ability to recognize a phonological rhyme. Similarly, it is difficult to interpret data patterns from a task with two response choices as it is not possible to eliminate alternate sensory explanations for apparent 'phonological' effects. For example, while the conclusion that high similarity in lip-shapes provides evidence that lip-reading is a source of support in the identification of shared rhyme for deaf individuals may be accurate, the evidence reported could also easily be reconciled with the view that the distinguishing variable between the 'highly similar' and 'less similar' words categories was the degree of tactile overlap between cue and distracter items. It may have been that words in the 'highly similar' category also shared a matching tactile pattern whereas the words in the 'less similar' category shared only a similar visual lip-read pattern. On a two response choice task, the possibility is raised that a shared tactile/kinesthetic pattern between cue and target (when the additional distracter item does not share tactile overlap) may result in what looks like a successful 'phonological' rhyme judgment although arguably different sources of knowledge would be used to make the judgment. Of interest, Dyer, MacSweeney, Szczerbinski, Green, and Campbell (2003) adapted Sterne and Goswami's picture-rhyme matching task by collapsing the multiple distracter conditions into two conditions: distracters that shared speech similarity with the target (e.g., "house - owl") and distracters that shared no speech similarity with the target (e.g., "sock - tree"). They presented the 40 item task to a slightly older group of 49 deaf children whose mean age was 13 years with a mean reading age of 7.0 years. This deaf group had a mean combined (O+ and O-) accuracy score of 63% correct rhymes. Again, it is likely that the combined score over-estimates the deaf children's ability to make a 'phonological' rhyme judgment as at an individual level it was reported that 31 participant scores fell within chance range. The authors argue that performance within chance range does not necessarily indicate random guessing because error analyses indicated that the majority of errors were systematic and shared perceived speech characteristics with the target. As well, the pattern of correlations of rhyme accuracy with Reading Age was similar between chance-level rhymers (n = 31) and better than chance-level rhymers (n = 11). Still, the systematic error pattern reported suggests that for the majority of the participants, word representations were not sufficiently distinct to support phonological rhyme judgments. Of interest, 11 of the deaf students who had a natural language (i.e., British Sign Language) as a first language demonstrated a similar pattern of correlations as that of the hearing group but the matched group of deaf students without a natural sign language as a first language did not.

In one of the early studies to investigate phonological awareness in deaf readers, Dodd and Hermelin (1977) used a word reading task to determine if orally educated deaf boys (12-14 years old) were able to use rhyme to assist homophone matching. The children made significantly more errors in matching randomly associated word pairs (e.g., "than- train") than homophonic word pairs (e.g., "reign – rain"). In an additional experiment the same participants scored above chance level when asked to determine if pairs of lip-read nonsense words rhymed or not. Since the deaf children were able to judge words that look alike on the lips as rhyming pairs, Dodd and Hermelin concluded that although primarily dependent on visual input from lip-reading, deaf children were able to develop phonological awareness of rhyme. Reading ages, intelligence and hearing levels were not reported making interpretation of the findings difficult in terms of the nature of the skills contributing to the deaf children's performance. While the study demonstrates that deaf children are able to distinguish between pairs of words that look alike on the lips (as rhyming words always do) and pairs of words that do not, the authors did not include the necessary control condition consisting of non-rhyming words with similar lip-read representations (e.g., house – owl) in order to clearly assess whether deaf children could overcome lip-shape similarity. Including a visual control distracter would have provided clearer evidence that correct performance on the task was a reflection of these children's ability to recognize a phonological rhyme as opposed to recognizing a shared visual pattern.

Campbell and Wright (1988) reported evidence that orally educated deaf teenagers were able to judge rhyme on the basis of picture presentation in an odd-man-out task. To ensure that the teenagers understood the concept of rhyme the investigators conducted practice trials. The investigators reported that the deaf teenagers were able to match pictures that rhymed quite well in this task and showed a similar pattern of response to younger reading age-matched hearing controls on words that rhymed but had different spellings ("bear" and "snare") and words that did not rhyme but had similar spellings ("fear" and "wear"). Because both groups made some false positive errors on the latter word set, Campbell and Wright concluded that the deaf teenagers' performance reflected a secure notion of rhyme. They suggested that the ability to make these judgments "must have been derived by mapping the known spelling patterns onto the lip patterns that the words make" (p. 129). However, as with earlier tasks, their task required the participant to match two similar items from a set of three alternatives. Thus, it could be argued that successful matching could be accomplished simply by a process of elimination that matched two words that "look most alike" from a lip pattern trace in memory, or successful judgment could be made from matching the two words that "feel most alike" from a tactile pattern trace in memory – without positing a link to phonology for either trace. Distracter items that required participant discriminations between acoustic, visual, and tactile distracter items would be needed to clarify on what basis deaf children were making matching judgments.

In contrast to the results reporting that oral deaf teenagers appeared to have a grasp of the concept of rhyme in the odd man out trials, Campbell and Wright (1990) report that in another experiment when oral deaf teenagers were expected to use rhyme as a cue to remember words in a paired associate learning task, they did not do so. This is a rather consistent finding throughout the literature. That is, while several studies have reported evidence suggesting that oral deaf individuals may use phonology in memory tasks (Lichtenstein, 1998; MacSweeney, Campbell, & Donlan, 1996) the question that has troubled researchers is that there is little evidence to suggest that these deaf individuals actually use phonological cues in reading words (Waters & Doehring, 1990). For example, Waters and Doehring (1990) reported on orally trained deaf participants (ages 7 - 20 years) some of whom demonstrated phonological awareness task performance scores comparable to hearing readers. These participants were able to decode the orthography but were still not able to read new words to the extent that might be expected based on their level of phonological awareness. The authors note that the deaf subjects who did possess phonological awareness in matching degree to that possessed by the hearing readers still did not achieve normal reading levels. The authors suggested that use of phonological translation in word identification did not convey the same advantage for these deaf subjects as it did for hearing subjects.

Positive evidence of rhyme skills was reported by Hanson and McGarr (1989) in a group of profoundly deaf college students with a mean reading grade level of 10.1. Fifteen students were asked to generate rhymes in response to 50 target words (e.g., blue, shoe, late, eight). About 50% of the students' responses were correct rhymes. Of the correct responses, 70% could have been generated using an orthographic strategy (e.g., reporting a spelling rhyme *die* to the target word *pie*) indicating that the orthographic properties of words is a salient cue in supporting deaf participants generation of rhyme. However, the remaining 30% of correct responses generated were orthographically different from the target (e.g., response *two* to the target word *blue*). The authors noted "orthographically different responses represent the clearest case for rhyme generation because the participant cannot have generated this response based on the orthographic representation of the word" (p. 4). The authors report that overall task performance for the group was correlated with oral production skills but not to reading levels. Interestingly, the deaf students of deaf parents (native signers) demonstrated a slight advantage (34.4% and 28.1%) in being able to generate more orthographically distinct rhymes than students with hearing parents although they had less intelligible speech than the latter group. These mixed results suggest there is no clear relation between the quality of overt speech and awareness of rhyme structure for deaf learners. The authors concluded that deaf adults (including native signers) were able to generate rhymes that were not based on the orthographic properties of written words although, given the exceptional reading skills of their participant group, Hanson and McGarr cautioned against generalizing that 'rhyme ability is necessarily characteristic of deaf individuals' (p. 7). Still, the students' performance is seriously restricted in range in comparison to what would be expected from hearing college students with similar reading levels. An analysis of the error patterns for the incorrect responses revealed that over half of the responses reflected orthographic similarity to the target (e.g., bear - dear, eight - right). Additional errors were thought to originate in lip-read representations (e.g., red - ran) or in characteristics of their own productions (blue - balloon) as was similarly noted in Dodd and Hermelin (1977).

The influence of orthographic similarity between written words on deaf participants' judgement of rhyme was again clearly demonstrated in another study with deaf college students (Hanson & Fowler, 1987). Participants were asked to judge rhyme pairs in a lexical decision task utilizing orthographically similar rhyme pairs (e.g., dark - mark) and orthographically similar nonrhyme pairs (e.g., clown - flown). An analysis of the mean percentage of errors on both word pairs (28.1 % for the rhyming pairs and 70.8% for the nonrhyming pairs) suggested that the deaf group based their judgements on orthographic similarity. It is important to note that each of the stimulus word pairs shared a spelling pattern thus this task could not have provided direct evidence as to whether deaf students could make a rhyme judgement on a phonological basis. Clearer evidence of phonologically based rhyme judgments would be seen in correct responses to rhyming word sets that were orthographically different such as '*three – key*'. In a second task, Hanson and Fowler (1987) used a forced-choice rhyme task that was designed so that participants could not rely on orthographic similarity in making a judgment. In this task, participants were asked to judge which of two orthographically matched pairs of written words (e.g., save-wave vs. have-cave) rhymed. Orthographic information was thus made redundant while phonological similarity was manipulated. The performance of the deaf participants (64.1 % correct) was much less accurate than the hearing controls (99.6% correct) although the deaf students' performance was significantly better than chance. The authors indicated that the effect of rhyme was related to the deaf participants' speech abilities but was not related to their reading levels. That is, the good speech group demonstrated an advantage for the overall rhyme task however, the reading comprehension scores did not differ significantly between the good speech and poor speech deaf groups and there was no significant correlation between reading comprehension and a rhyme advantage. It is important to acknowledge that the participants in the college study were a select group of highly educated deaf adults with advanced reading skill and thus these results may not be representative of the majority of deaf individuals. Waters and Doehring (1990) were unable to replicate these results with a group of orally trained deaf children and adolescents.

Onset and Rime Awareness Studies

Harris and Beech (1998) were the first investigators to measure young deaf prereaders' awareness of phonological units. Harris and Beech (1998) measured awareness of phonological units at the onset and rime level in 5-year-old (age range 4.2 to 6.2 years) children with a severe to profound prelingual hearing loss. The children were attending school programs that had a spoken language focus: an exclusively oral program and a program using a MCE system. Harris and Beech used a picture-based adaptation of Bradley and Bryant's (1983) oddity task that was modified to a similarity task to make it more accessible to the deaf children. The children were shown a picture and were asked to identify a similar word from a set of pictures representing words sharing the same initial sound (e.g. *p*ink, *p*ig, fish), or medial and final sound (e.g., s*ock*, cl*ock*, black). Harris and Beech reported that the deaf group was able to correctly identify 60.5% of the items. However, they were much poorer at the task in comparison to an age matched control group of hearing children who identified 81.5% of the items correctly. The experimenters reported sounding out the words for the deaf children making it difficult to interpret the children's abilities to internally generate a response and segment on their own independent of externally provided lip-pattern cues. Analysis of individual error scores revealed sharp differences in performance between the deaf and hearing groups. The majority of the 56 hearing children made minimal errors with only two children making 8 or more errors. In contrast, 15 of the 24 deaf children made eight or more errors suggesting that even with external speechreading cues provided this proved a difficult task for this age group. The scores on the phonological awareness test were positively correlated with reading vocabulary after one year of instruction at school. Word reading results indicated that in comparison to hearing peers, the progress of deaf children was markedly slower. Harris and Beech commented that the majority of the deaf children had barely begun to read and could recognize about 10 words after one year of instruction. The children's high error rate on the phonological awareness task and slow progress in word reading suggests that many of the deaf children had difficulty in establishing an internal representation of printed words in memory. Of note, at a two-year follow-up, Harris and Beech conducted an analysis of the skills of the four best deaf readers whose reading gains placed them at a comparable word reading level to their hearing peers. Two contrasting profiles emerged from the analysis. Two children were non-signers who had good spoken English skills. Both children scored high on the phonological awareness task and on the British Ability Scales test of English language comprehension. The other two children were strong signers from deaf families. Both scored poorly on the phonological awareness task but had high scores on the English language comprehension test. These contrasting profiles suggest that rather than deafness per se, or the lack of spoken language skills, perhaps the more critical factor lies in the degree to which children have developed an internalized representation of language that supports their ability to analytically work on language irrespective of modality (see also Miller, 1997; Goldin-Meadow & Mayberry, 2001).

Phoneme Awareness Studies

There are few studies that have looked at awareness of phonological structure at the phoneme level. Sterne and Goswami (2000) used a nonsense word reading task that required phonological recoding to measure phoneme awareness. Children were shown a picture and asked to choose the correct homophone from a group of four written nonsense word alternatives that contained the homophone and three distracter items modified by a change in the initial letter, medial letter, or final letter. For example, children were shown a picture of two boys and required to choose the word that sounds like the picture from a choice of "boiz, roiz, beiz, or boin". The younger reading-age controls performed at ceiling on this task. The deaf children's performance was significantly worse though still above chance level (63%). This task, however, is more accurately a measure of decoding skill than it is a pure measure of awareness of phonological structure at the phoneme level. In addition, this task shares the methodological concern of the other tasks described so far - homophones all 'feel' the same in that they share a tactile pattern of articulatory contact.

Izzo (2002) used a picture based word-to-word matching tasks to investigate phoneme awareness in a young group of prelingual severely to profoundly deaf students (mean age 9) who used sign language as their primary mode of communication. Similar to Miller's (1997) task, participants were required to choose two (from a total of four) picture items that shared the same target sound (e.g., initial, medial or final sound or rhyme). Test items where the target sounds had graphically similar and dissimilar representations to the cue word were included. Izzo reported that as a group the participants failed to display basic competency in phoneme awareness. Mean accuracy was 5.55 on the 24 item test. There was no direct correlation between reading ability and phonemic awareness however; reading ability was significantly correlated with sign language ability as measured by videotaped analysis of participant interview language samples.

The established view articulated in the deafness literature argues that deaf children's acquisition of phonology is largely influenced by visual experiences (speechreading) and/or gestural experiences (speaking). There is intuitive appeal in this notion that awareness of phonological structure in deaf learners is fostered or enhanced by speech experience and good speech production skills as we see with hearing children. However, these previous studies that have examined the relationship between speech production skills and phonological awareness have been mixed. Some investigators have observed better performance on phonological awareness tasks by deaf individuals who used sign language and not speech (Hanson, 1986; Hanson &

Fowler, 1987; Hanson & McGarr, 1989). Other studies have found no relationship between speech skills and performance on phonological awareness tasks in profoundly deaf children for whom spoken language is the sole mode of communication and who have received the most intensive oral training (Leybaert, Alegria, Hage & Charlier, 1998; Waters & Doehring, 1990). While it is difficult to reconcile the disparate results of these studies, it is evident that neither speech experience nor the use of speech is a reliable predictor of awareness of phonological structure in profoundly deaf learners. Indeed, Miller (1997) in a comparison study of the effect of communication mode (oral or sign) on the development of phonemic awareness in profoundly deaf children found no difference in levels of phoneme awareness between oral and signing (deaf children of deaf parents) students in the fourth to ninth grade using a four choice picture word-to-word matching task. The deaf signing students, but not the oral students, demonstrated equivalent performance in accuracy and response latency to a hearing control group when orthographic processing of words was sufficient for correct item identification (O + words). Miller reported that hearing levels of the deaf students did not correlate significantly with task performance or with estimated reading levels. Response latency and reading comprehension correlated for the hearing controls and oral deaf participants. For the deaf signers, accuracy and response latency was unrelated to reading level.

This brief overview demonstrates that there is little consensus across studies on the phonological awareness abilities of deaf individuals. The one study (Sterne & Goswami, 2000) comparing awareness of segmental structure across levels of linguistic complexity used different task formats to assess each level of structure with different groups of children participating in each task. As well, only items that were within the spoken vocabulary of the deaf children (e.g., they could clearly articulate the name) were used. Children who were unable to articulate the spoken name of the test items were excluded from the experiment. In light of the evidence to date that suggests it is a very small minority of deaf children who develop adequate speech skills (see review in Marschark, 2001) the findings from this study cannot be considered representative of most deaf children.

In the studies outlined above, and as determined by non-reading tasks, there is little positive evidence for robust representational structure beyond the syllable level in elementary school aged children whose educational environment was structured to support the development of spoken English (oral and MCE communication modes). Some awareness of rhyme was reported in oral and MCE educated children and adolescents who have already developed reading skills although it appears that these phonological units are not easily or rapidly available. Evidence of rhyme awareness was also reported in select groups of highly educated college students (both native and non native users of sign language) who had attained exceptional reading levels. Deaf children and adult's performance patterns across studies suggest that spelling similarity and lip-read similarity were salient cues in supporting rhyme matching judgments across tasks. Some studies report a relation between oral production skills and better performance on rhyme tasks although no studies have found this ability to be related to reading level. Positive evidence of sensitivity to phonological structure at the phoneme level relied on a word decoding task.

Overall, no coherent picture of deaf individuals' awareness of phonological structure emerges from the data available. It is difficult to integrate findings from the studies available because the level of linguistic analysis for measuring phonological awareness varies across studies and has been restricted mainly to one level of phonological complexity (rhyme). In addition, many studies have primarily dealt with a restricted age group (adults or 13-14 year olds) and groups that are not representative of the larger population of severely and profoundly deaf learners (exceptional readers or intelligible speakers). As well, similarity in sound often leads to similarity in articulatory movement and in tactile stimulation. These are important methodological considerations when attempting to determine the nature of the skills that deaf children use in phonological judgments. Differences in the type of stimulus used (written words vs. pictures) and control of specific stimulus factors such as sensory similarity between cue, target and distracter items has varied between studies and may account for at least some of the variability in the results reported.

Summary of the Literature

This literature review highlights a number of important points. First, contrasting perspectives on the origin of the phoneme segment raise different questions and hypotheses as to the challenges and possibilities faced by deaf children in developing word recognition skills and in learning how to read. Advocates of an accessibility account have invoked the notion of 'developmental lag' or the need for 'maturation' to explain the differences in deaf children's acquisition of phonological structure (see review in Paul, 1998). These accounts argue that the significant characteristic separating deaf learners and hearing learners in reading development is that the rate of acquisition is much slower (Bochner, 1982; Hayes & Arnold, 1992; Paul, 1998). The potential for 'catch-up' is predicated upon developing English language ability based on intensive instruction in spoken language alone or spoken language supplemented by a manually coded English system. Underpinning these accounts is the notion that speech is initially perceived at a linguistic level and that non-auditory aspects of the input provide deaf learners with information about the phonological contrasts of spoken language. Therefore it is argued that for deaf learners, making English visible will support the establishment of an internal system of representation for English. English language development then will lead to metalinguistic awareness and metalinguistic awareness in turn will develop phonological awareness (Alegria, Leybaert, Charlier, & Hage, 1992; review in Leybaert, 1993). Campbell and Burden (1995) further suggest that "through intense efforts by therapists and carers to improve speech quality the young deaf child often develops metalinguistic, phonological awareness on an underdeveloped phonological system. When this makes contact with a systematic orthography there is potential for further refinement of phonological representations" (p. 120). Within an emergent framework, however, while language development leads to metalinguistic awareness, metalinguistic awareness does not lead directly to phonological awareness. Rather, phonological awareness emerges out of underlying phonological development. Thus, "phonemic awareness is not 'simply' a problem of accessing underlying units of speech representation, but also is limited by the very nature of these representations, which undergo substantial developmental change" (Metsala & Walley, 1998, p. 91). In reference to children with little or no residual access to acoustic speech information, the emergent account would predict that maturation alone may not be enough to 'fix' the representations.

Second, it is clear that the extent to which visually perceived speech input or articulatory motor patterning recruits phonological information for deaf individuals is far from resolved. There is little empirical support for the long standing arguments that the cues available to profoundly deaf individuals such as lip-reading and articulatory feedback are capable of supporting a non-auditory connection to *phonology* for profoundly deaf learners, as advocates of the 'qualitatively similar' perspective argue. Rather, the empirical evidence available suggests that, for profoundly deaf individuals, there may be fundamental flaws in these assumptions. In several past studies it was noted that although a correct response may 'look like' a phonological response – one can not be certain whether the participants' correct response was arrived at because the target word chosen was more similar to the cue in tactile or visual pattern than was the only additional foil. Consequently, what appears to be a 'phonological effect' may be due to uncontrolled differences in tactile or visual similarity between cue and the targets in which case, an unequivocal link to phonology can not be established. These limitations complicate the interpretation of phonological awareness studies and are sufficient to suggest reasonable doubt regarding the evidence for 'phonological effects' that have been previously noted in the literature. In relation to deaf learners, evidence for 'phonological effects' would be more convincing if experimenters used stimulus sets distinguished by whether or not they required discriminations based on tactile, visual and acoustic patterns.

Finally, there is limited data available to evaluate the claims that give rise to the hypothesis that the cognitive processes supporting word reading acquisition are similar in deaf and hearing individuals. Without such data, understanding of the processes and strategies that may be supportive of reading skill development for deaf learners will remain elusive. As with hearing children, it is knowledge of the cognitive precursor skills that are in place for the learner that guides teachers in establishing developmentally appropriate practice in reading instruction.

Statement of the Problem and Hypotheses

The ability to use phonological information plays an important role in hearing children's acquisition of word reading skills. Converging evidence suggests that phonological representations that have not reached a sufficient level of precision are not likely to support fast and accurate recoding of written units into phonological units as a word identification strategy (e.g., Goswami, 2002; Stanovich, 2000). Most reading instruction programs for deaf learners assume that deaf readers read words in a qualitatively similar manner as hearing readers. Yet, experimental evidence on the representation of phonological structure in deaf learners is scarce.

Paradigms used to assess phonological knowledge have, primarily, been concerned with the question of whether deaf children could or could not access phonological information. For the most part, these studies have yielded only categorical data which is insufficient in providing direct evidence regarding the quality of the underlying representations that could then support deaf children in the use of phonological reading strategies. Moreover, the central question of whether severely and profoundly deaf individuals do have access to phonological information remains unresolved as earlier studies often do not consider whether orthographic similarity, and/or tactile and kinaesthetic patterning could be a source of the effects noted. In addition, earlier studies have not tried to explain the extent to which apparent phonological skills in deaf learners might be influenced by age and/or reading skill development. These issues will be addressed in this study through assessing phonological awareness abilities at three levels of linguistic complexity across a range of ages, reading abilities, and through the careful choice of stimuli which may allow for a clearer picture of the extent to which deaf children's response patterns are likely to correspond to acoustic, tactile or orthographic units.

The present study examines awareness of phonological structure at the level of syllable, rhyme and phoneme in deaf children and adolescents who have severe to profound prelingual hearing losses and use sign language as their primary means of communication. Three parallel tasks requiring picture matching-to-sample judgments at each level of phonological structure are used to address the following questions:

1. To what extent do deaf children and adolescents have awareness of phonological structure across the three levels of linguistic complexity: syllable, rhyme, and phoneme?
2. Does the performance of deaf children and adolescents on the phonological awareness tasks vary as a function of stimulus similarity (acoustic, tactile, visual) of target words to distracter items?
3. Does the performance of deaf children and adolescents on the phonological awareness tasks vary as a function of age and/ or reading ability?

A comparison of the extent of phonological specification in word formation (segmental organization of phonological knowledge) across the range of phonological structures of English has not been addressed before with this population. However, several researchers have proposed a developmental continuum in sensitivity to phonological structure in hearing learners that moves from awareness of larger structures like syllable and rhyme to awareness of smaller phonological units like phonemes. If deaf learners follow a similar pattern in the development of phonological awareness, individual patterns of performance across tasks are expected to be delayed as predicted by an accessibility account, but will (a) reflect individual control moving from syllable to phoneme level awareness (larger to smaller) and (b) to vary as a function of age and/or reading ability. Alternatively, if as predicted by the emergent account, the acoustic signal is more centrally tied to the emergence of phonological awareness it is expected that severe to profoundly deaf individuals will show little evidence of phonological organization across levels of linguistic complexity.

Finally, there has been little evidence bearing on the extent that non-auditory cues actually link to phonology for profoundly deaf children and adolescents. While early studies suggest that speech skills, spelling patterns and speechreading are salient cues in supporting deaf learners in making phonological matching judgments, lack of control of stimulus factors makes it difficult to determine the exact nature of the code that was accessed in these tasks. The phonological awareness tasks used in this study are designed to clarify these issues and directly examine whether matching judgments of the deaf children and adolescents are influenced by the perceptual status (acoustic, visual, tactile) of distracter items. As outlined earlier, a successful matching judgment can be made on the basis of either orthographic or phonological information that is available in the stimuli for orthographically similar word pairs (O+, e.g., "night – fight"). While a clearer case of phonological judgment is seen in successful matching between cue and target on items where phonological similarity is not reflected at the items' grapheme level (O- , e.g., "blue – two"), for deaf children it can be argued that tactile information is still available in the stimuli to support an accurate judgment. Thus, an additional level of control where phonological similarity can not be determined solely on a tactile or visual basis is implemented for this study. Separation of sensory cues is accomplished by including an additional distracter item which allows for three response choice alternatives and by testing matching judgments under four distracter conditions (no pattern, visual pattern, tactile pattern, visual and tactile pattern). In this way, the extent to which deaf individuals' response patterns are likely to correspond to acoustic, tactile/kinesthetic or orthographic cues can be more directly compared. In turn, insight into the sources of knowledge deaf individuals use to complete phonological judgment tasks can be more clearly delineated.

At each level of phonological structure, the experimental hypothesis predicts a difference in the accuracy of syllable judgments, rhyme judgments, or phoneme judgments (dependent variables) as a function of manipulating the acoustic, tactile, or visual pattern distracters (independent variables). In line with the performance patterns of hearing children on similar picture matching tasks, it is expected that if deaf participants are using phonological information to make a matching judgment, orthographic similarity and perceptual similarity between cue/ target pairs and distracter items should not interfere significantly with performance accuracy. Poor performance when distracter items are included that share a spelling pattern with the cue and phonological target would suggest that deaf participants are using orthographic information to support matching judgments. Similarly, poor performance when distracter items share a tactile pattern with the cue and phonological target but are acoustically and orthographically distinct would suggest that deaf participants are using tactile information to support matching judgments. The clearest evidence for phonological judgment would be seen in accurate performance on test items requiring discrimination between acoustic, visual and tactile pattern distracters together in the same set.

CHAPTER 3: METHODS

The study utilized a within-subjects design to evaluate awareness of phonological structure at three levels of linguistic complexity - syllable, rhyme and phoneme - in deaf children and adolescents with a prelingual, severe to profound hearing loss. Three parallel picture matching-to-sample judgement tasks were used to investigate awareness of phonological structure. To clarify which sources of sensory evidence contribute to deaf children's and adolescent's performance on phonological tasks, the extent to which phonological matching judgments were influenced by the perceptual status (acoustic, tactile, visual) of distracter items was directly examined. For each task, the dependent variable was the number of correct phonological (syllable, rhyme or phoneme) judgments made by the participants.

Participants

Consent of the school districts, parents and students was required for participation in the study. Sampling requirements were: a prelingual severe to profound hearing loss (70 decibels or more), the use of sign language as a primary means of communication and no additional exceptionality. All students enrolled in two Provincial Schools for the Deaf in Western Canada who met these requirements were considered potential participants. Classroom teachers were asked to send home information letters, consent forms, and response envelopes with these students (see Appendix A). Sixty students were given permission to participate in the study. Of the 60 students, four students were excluded because they scored two standard deviations below the mean on a measure of nonverbal IQ. Background screening identified two participants whose degree of hearing loss did not meet sampling requirements (better ear average) and they were excluded from further analyses. The data on two additional students whose age of diagnosis was unreported were removed from the study because the prelingual criteria for onset could not be confirmed. The final sample consisted of 52 students (19 girls and 33 boys). The students ranged in age from 6 years 6 months to 18 years 10 months. The mean age of participants was 13 years 1 month. Forty-five students (86.5%) were born severely or profoundly deaf. Seven students (13.5%) were prelingually deafened with profound hearing losses diagnosed prior to 18 months of age. The better ear pure tone average (PTA) threshold for participants in this study ranged from 75dB to 120dB with a mean hearing loss of 101.6 dB. Seven students had families headed by Deaf parents, 45 students had families headed by hearing parents with 18 of these students having some family history of deafness. All participants had normal or corrected to normal vision. All participants used sign language as their primary mode of communication.

Measures

Background measures were obtained for each participant: a pure-tone audiogram from the school, a nonverbal (performance) IQ measure, an ASL language rating, and two reading comprehension measures. A family background questionnaire was also completed by the student's parent/guardian. The participant's awareness of the phonological structure of English was assessed using three experimental tasks: syllable matching, rhyme matching and phoneme matching.

Background Measures

Hearing Level. Pure tone average (PTA) measures the hearing of individual frequencies of sound. Because most of the speech sounds are in the mid-frequency range, hearing thresholds in that middle range provide an indication of hearing for speech. From the most recent audiological records provided by the schools each student's pure-tone average (PTA) for the frequencies of 500, 1K and 2K Hz for the better ear were computed. The higher the PTA the worse the hearing.

Nonverbal Intelligence. The Raven's Standard Progressive Matrices (Raven, Court, & Raven, 1986) were administered individually to participants to estimate nonverbal intelligence and to screen for possible cognitive problems. Minimal verbal directions are used in the administration of this measure making it particularly suited to deaf samples and a frequently used measure in research with deaf subjects. Participants were required to complete abstract patterns by choosing from an array of eight possible solutions. Problems increase in difficulty from simple perceptual matching to recognizing patterns that vary on several dimensions. The examiner recorded the participant's choice on a response sheet.

ASL Proficiency. The students' proficiency in ASL was rated by a Deaf ASL specialist who was familiar with the students. The students were rated from one to ten on their receptive and expressive use of ASL. The scores on the receptive and expressive components were averaged to provide an overall language proficiency score.

Background Questionnaire. A detailed questionnaire was completed by a parent or guardian of study participants (Appendix B). Information gathered from the questionnaire included: child's age, mother's and father's highest level of education and occupation, family hearing status, vision status, etiology, age of onset, age of diagnosis, amplification use, family communication practices, child's educational placement background, speech use, and speech comprehension.

Reading Comprehension: Scores from the paragraph-meaning subtest of the Stanford Achievement Test - Special Edition for Hearing-Impaired Students (SAT-HI, Harcourt Brace, 1996) were collected through school records when available. In addition, sentence comprehension skills were assessed using the 82 item reading comprehension subtest of the Peabody Individual Achievement Test - R (Markwardt, 1989). Standardized administration of the test was followed with the caveat that instructions were delivered in ASL rather than in spoken English. In this test, participants were required to read a sentence silently and point to one of four pictures that best illustrated the sentence that was just read. The examiner recorded the student's response on an answer form.

Phonological Awareness Measures

Three parallel picture matching-to-sample judgement tasks were created to provide an estimate of the participants' awareness of syllable units, rhyme units, and phoneme segments. For each task, a test item consisted of a four picture quadruplet made up of a cue, a phonological target response that matched the cue in phonological structure (syllable, rhyme or phoneme) and two additional distracters. Picture stimuli were presented by computer. The cue picture was outlined by a box with a red frame (6.01 cm x 6.01cm) and was centered on the computer screen. The three matched sized picture response choices were bounded by yellow frames and were aligned in a row directly underneath the cue picture. The four pictures appeared at the same time on the computer screen. Participants were required to point to the picture on the computer screen that matched the cue picture in target phonological structure (syllable length, rhyme or phoneme) from the three alternative pictures. The examiner recorded the participant's choice by pressing a number pad connected to the computer which allowed for accuracy and response choice data to be recorded. For each task, the dependent variable was the number of correct phonological matches made by the participants.

Item selection. To ensure appropriateness of the items for the participants, the word selection process was conducted carefully and with input from a consultative group made up of four members from the deaf adult signing community. It has been common practice to use print presentation of test items rather than speech presentation when testing phonological abilities with deaf students because of deaf children's reduced access to spoken language input. However, as Sterne and Goswami (2000) observed, when test items are presented orthographically and the visual word form is readily available, there may be little need for a deaf child to access phonological representations. Following Izzo (2002), Sterne and Goswami (2000), Miller (1997), and Campbell and Wright (1988), the current study used nameable pictures for test items. It has been repeatedly shown that for hearing children, nameable pictures are remembered in phonological rather than visual codes (Schiano & Watkins, 1981). Since there is no acoustic information in picture presentation, the phonological representations of picture names needs to be internally generated before they can be held in short term memory.

For signing deaf children, the potential for ASL phonological influence in word selection has not been accounted for in past studies. Controlling for this potential confound was deemed important in this study. The consultative group evaluated each of the words used in the three phonological awareness tasks along the following dimensions: signability, ASL phonological overlap, familiarity, and ease of representation in picture format.

Seidlecki, Vowtaw, Bonvillian, and Jordan (1990) suggest that words meet signability criteria when they have "a common one-sign translation equivalent in ASL as determined by a dictionary of signs" (p.189). Signability was determined by locating each word in the Canadian Dictionary of ASL (Bailey & Dolby, 2002). In addition, each word was further evaluated by the consultative group to control for possible provincial variations in signs. Similarly, each item was evaluated to ensure that there was no phonological overlap on ASL phonological parameters between each item in a quadruplet. Only words that would likely be in the vocabulary of the youngest children in the sample were chosen. This was determined by evaluating words on how familiar they would be to a deaf first grader. Following Sterne and Goswami (2000) word sets in the syllable task were differentiated by the size of syllable discrepancy between a cue and target word. Similar to Izzo (2002), Sterne and Goswami (2000) and Miller (1997), the present study used words at the rhyme and phoneme level of the task that had graphically similar and dissimilar representations to the cue word. As well, words at the rhyme and phoneme level of the task were one and two syllables in length to control for linguistic complexity (Stahl & Murray, 1998). Finally, only words that could be easily represented by nameable pictures were selected. Simple colour illustrations selected from a variety of Clip Art sources were used for the picture stimuli.

Syllable Matching Task. A syllable length judgment task was used to measure awareness of syllable structure. In a refinement of Sterne and Goswami's (2000) two picture (yes/no) pairs word length judgment task, additional distracter items were included to create a four picture matching-to-sample judgment task. The syllable task consisted of 25 test items. Each test item consisted of a four picture quadruplet made up of a cue, a phonological target response that matched the cue in syllable length, and two additional distracters. The 25 tests items were arranged in five sets of five items. The five sets increased in difficulty and were grouped as follows:

- *Congruent Sets (Set 1 and Set 2).* In the first two sets, the cue picture and the phonological target response choice agreed in both syllable length and orthographic (spelling) length. Thus, if the cue was a three syllable word with a long spelling pattern (e.g., crocodile), the target response choice was a three syllable word that also had a long spelling pattern (e.g., kangaroo). Similarly if the cue was a one syllable word with a short orthographic length (e.g., box), the target response choice was also a one syllable word with a short orthographic length (e.g., van). These sets were designated as Congruent (P = O) sets because word length judged on a phonological basis agreed with word length judged on an orthographic basis. For both sets, the two additional distracters in a quadruplet were orthographically and syllabically distinct from the target. Set 1 and Set 2 were differentiated by the size of syllable discrepancy between the target response and the additional distracters. Set 1 had a two syllable discrepancy between the target response and the two distracters (e.g., *helicopter* – gum, *caterpillar*, socks). Set 2 had a one syllable discrepancy between the target response and the two distracters (e.g., *moon* – teacher, mountain, *blue*).
- *Incongruent Sets (Set 3 and Set 4).* To control for orthographic bias (counting letters) in length judgements, two sets that were matched orthographically (O = O) across all words in a quadruplet were also included. In Set 3 and Set 4, the cue picture and the phonological target agreed in syllable length and in spelling

length. For both sets, the two additional distracters also agreed in spelling length but were distinct from the target in syllable length (e.g., *potato* – cheese, *eleven,* stairs). These sets were designated as Incongruent Sets (O = O). A two and one syllable discrepancy between target response and the two alternative response choices again differentiated Set 3 and Set 4 respectively.

- *Mixed Set (Set 5).* A fifth set was included where the cue picture and the phonological target agreed in syllable length but differed in orthographic length (e.g., *sandwich* – comb, *taxi,* helicopter). This set was designated as Mixed (P not continue with the task. No feedback was provided on test item trials. Cronbach's Alpha reliability for the Syllable Awareness task was .75.

Rhyme Matching Task. To measure the second level of phonological structure, rhyme awareness, a picture matching-to-sample judgement task consistent with the presentation format of the syllable task was developed. This task consisted of 40 test items. Each test item consisted of four pictures made up of a cue, a phonological rhyme target, and two additional distracters. An equal number of orthographically similar (e.g., O+, "k*ing* – r*ing*") and dissimilar (e.g., O-, "cr*y* – p*ie*") rhymes were used in the task. The 40 test items were arranged in four sets with 10 items in each set. The sets were grouped according to distracter type. The composition of the four sets was as follows:

- Set 1 (No Pattern) consisted of five O+ and five O- cue and rhyme targets. The two additional distracter items in this set shared no orthographic, acoustic, or tactile similarity with the cue and rhyme target. These distracters were designated as no pattern distracters (O-P-T-). Set 1 example: (O+) king – ring, blue, cheese; (O-) tree – key, star, girl.
- Set 2 (Visual Pattern) consisted of five O+ and five O- cue and rhyme targets. One distracter item was orthographically similar (spelled alike) but acoustically and tactilely distinct (sounded and felt different) from the cue (e.g., pour - sour). These distracters were designated as visual pattern distracters (O+P-T-). The second distracter was a no pattern distracter (O-P-T-). Set 2 example: (O+) four – pour, sour, hand; (O-) shoe-blue, toe, ring.
- Set 3 (Tactile Pattern) consisted of five O+ and five O- cue and rhyme targets. One distracter was similar to the cue word in articulatory/tactile contact but was

orthographically and acoustically distinct from the cue (e.g., kite – gun). These distracters were designated as tactile pattern distracters (O-P-T+). The second distracter was a no pattern distracter (O-P-T-). Set 3 example: (O+) night-fight, tent, blue; (O-) plate – wait, bleed, dog.

- Set 4 (Visual and Tactile Pattern) contained five O+ and five O- cue and rhyme targets. One distracter was a visual pattern distracter (O+P-T-) and the other was a tactile pattern distracter (O-P-T+). Successful performance on the O- set should provide the clearest case for awareness of the phonological structure of rhyme as an accurate response cannot be made based on the orthographic or tactile representation of the word. Set 4 example: (O+) kite-white, knit, gun; (O-) sour-flower, soup, zero.

The three response choices for each test item were spread randomly across all possible word positions. A list of the words and their order of presentation is included in Appendix D. Consistent with the presentation format of the syllable task, participants were required to point to the picture on the computer screen that matched the cue picture in target phonological structure (rhyme) from the three alternative pictures. The examiner recorded the participant's choice by pressing a number pad connected to the computer which allowed for accuracy and response choice data to be recorded. The dependent variable was the number of correct phonological rhyme choices made by the participants. Prior to beginning the test items, six practise items (three O+ rhymes and three O- rhymes) were presented on the computer. Feedback was provided on the practice items. No feedback was provided on test item trials. Cronbach's Alpha reliability was .88 for the Rhyme matching task.

Phoneme Matching Task. To measure the third level of phonological structure, phoneme awareness, a picture matching-to-sample judgment task consistent with the picture presentation format and administration of the syllable and rhyme tasks was created. This task consisted of 48 test items. Each test item consisted of four pictures made up of a cue, a phonological target that matched the cue in initial, medial or final sound, and two additional distracters. An equal number of graphically similar (e.g., O+, "*m*ilk - *m*oon") and dissimilar (e.g., O-, "*c*ar – *k*ey") items were used in the task. The 48 test items were arranged in three sets of 16 items. The sets were grouped according to phoneme position: initial, final, and medial. Within each set, and consistent with the rhyme task, distracter items varying in acoustic, orthographic or tactile similarity to the cue item were included. The composition and order of presentation of the three sets is outlined below.

- Set 1 (Initial phoneme matching) consisted of 16 test items: eight O+ and eight O- cue and initial phoneme targets. These 16 items were separated into four subsets according to distracter type as follows:
    - No Pattern distracter (O-P-T) subset consisted of two O+ and two O- cue and initial sound targets. The two additional distracter items in this set shared no orthographic, acoustic or tactile similarity with the cue and the initial sound target.
    - Visual Pattern distracter (O+P-T-) subset consisted of two O+ and two O- cue and initial sound targets. One distracter item was orthographically similar (same letter) but acoustically and tactilely distinct (sounded and felt different)

from the cue (e.g., *gym* - *gum*). The second distracter was a no pattern distracter (O-P-T)

- Tactile Pattern distracter (O- P- T+) subset consisted of two O+ and two O- cue and initial sound targets. One distracter was similar to the cue word in tactile contact but was orthographically and acoustically distinct from the cue (e.g., kite – gun). The second distracter was a no pattern distracter (O-P-T-).
- Visual and Tactile Pattern distracter subset consisted of two O+ and two O- cue and initial sound targets. One distracter was a visual pattern distracter (O+P-T-) and the other was a tactile pattern distracter (O-P-T+). Successful performance on the combined O- Visual and Tactile distracter subset should provide the clearest case for awareness of phonological structure at the phoneme level as an accurate response cannot be made based on the orthographic or tactile representation of the word.

- Set 2 (Final phoneme matching) consisted of 16 test items: eight O+ and eight O- cue and final phoneme targets. These 16 items were separated into four subsets according to distracter type as outlined for Set 1.
- Set 3 (Medial phoneme matching) consisted of 16 test items: eight O+ and eight O- cue and medial position phoneme targets. These 16 items were separated into four subsets according to distracter type as outlined for Set 1.

The three response choices for each test item were spread randomly across all possible word positions. A list of the words and their order of presentation is included in Appendix E. Consistent with the presentation format of the syllable and rhyme task, participants were required to point to the picture on the computer screen that matched the cue picture in target phonological structure (initial, medial or final phoneme) from three alternative pictures. The examiner recorded the participant's choice by pressing a number pad connected to the computer allowing for accuracy and response choice data to be recorded. The dependent variable was the number of correct phoneme matches made by the participants. Computer practice trials preceded test items at each of the three phoneme positions. There were four practice trials preceding Set 1 (initial position) test items. Two practice items were graphically similar (O+) and two practice items were graphically dissimilar (O-). Two practice items (one O+ and one O-) preceded Set 2 (final position) test items and two practice items (one O+ and one O-) marked the beginning of Set 3 (medial position) test items as well. Feedback was provided on practice items. No feedback was provided on test items. Cronbach's Alpha reliability was .87 for the phoneme matching task.

Procedures

Between February and April of the school year, all participants were administered a battery of reading and English and ASL language tasks as part of a larger study. The total test battery took approximately 120 minutes to administer spread over three or four sessions. The Syllable, Rhyme and Phoneme matching tasks used for this dissertation were completed in one session lasting approximately 30 to 40 minutes. All participants were tested individually in a private room free of visual distractions and noise in their respective schools during school hours. All testing was administered directly (not through an interpreter) and all instructions were given in ASL and print. The phonological awareness tasks were administered by the hearing researcher who is an experienced teacher of signing deaf students. Additional sign language vocabulary measures were administered on separate days by a research assistant who is a deaf native signer. A reading measure and a non verbal IQ measure were administered by the hearing researcher with the help of an assistant on some test occasions.

The picture stimuli for the Syllable, Rhyme and Phoneme tasks were presented on a Dell Latitude C840 laptop computer using Direct RT v2002 precision timing software (Empirisoft, 2002). Students sat facing the laptop's 15 inch SXGA viewable screen with the examiner sitting to the right of the student. The equipment and its functions were described and the experimental procedures for the task were outlined. Any questions the participant had were answered at this time.

Familiarity with the correct name of the picture stimuli was assured through pretesting using a task specific picture dictionary created for that purpose. Students were asked to think of the spoken name of the picture and to name each of the pictures for the examiner. Signed or spoken responses were accepted. Generally, the examiner was able to determine that the participant was using the correct label for a picture by careful observation of the mouth patterns that frequently accompany sign at the word level. In the few instances that the response did not correspond to the expected label, clarification of the correct label was provided by the examiner by signing and mouthing the word. The student repeated the label. These items were retested when the participant had completed naming all of the pictures in the dictionary. In each instance the student responded with the expected label. All of the participants, including the youngest, were familiar with the names of each picture and correctly identified all of the picture labels. Following Sterne and Goswami's (2002) administration procedures, explicit instruction and a practise session preceded phonological awareness testing where understanding of the concept of syllable, rhyme and phoneme was assured (a transcription of the practise session activities and instructions is described in Appendix F). The presentation format for the practice session was identical to that used in the experimental tasks except that pictures were presented on sheets of 8 ½ X 11 paper rather than on computer. No pictures from the experimental stimuli were used in the practice session and participants received feedback on the correctness of their response throughout the session. The practice session was reinforced through computer practise trials with feedback that preceded each phonological awareness experimental task. No feedback was provided on test items. Testing was discontinued if a child got the first 6 test items in a row incorrect.

CHAPTER 4: RESULTS

Presentation of the results begins with a description of student performance patterns on each of the English phonological awareness tasks: syllable, rhyme and phoneme separately. Descriptive statistics were conducted on all measures. The data displayed relatively normal distributions and all analyses were performed with raw scores. For each task, analysis began by determining if observed performance was above chance level (a) on the overall task, (b) across the different manipulated conditions of the task, and (c) on both orthographically similar (O+) and dissimilar (O-) word types. Next, to determine if performance on the phonological awareness tasks varied as a function of stimulus similarity (acoustic, tactile, visual) of target words to distracter items, performance accuracy was compared across conditions using repeated measures analysis of variance (ANOVA). An analysis of the response choice pattern of the students was also conducted to provide insight into the strategies deaf children were using to make syllable, rhyme and phoneme judgments. Finally, the effects of age and reading ability on the students' phonological awareness development at the levels of syllable, rhyme and phoneme were analyzed with analyses of variance. Presentation of the results of these analyses for each task is followed by a brief task specific summary. A general discussion of the study findings is presented in Chapter 5.

Syllable Awareness

The syllable awareness task was constructed to determine if deaf children have awareness of phonological structure at the syllable level. In order to perform the task participants viewed a cue picture and three response choice pictures. Their task was to choose the response choice picture whose name matched the name of the cue picture in syllable length. Syllable Awareness scores were based on a scale of 0 – 25. Accuracy scores ranged from 2 to 25 indicating that participants scored from very low to very high. The mean accuracy score on the syllable task was 13.79 (54.9 % accuracy) with a standard deviation of 3.91. The mean number of correct syllable judgments for each set is shown in Table 1.

A one-sample *t*-test was computed comparing the students' observed performance on the Syllable Awareness task to chance level performance. The analysis showed that overall task performance in selecting a correct syllable match was significantly above chance, $t\ (51) = 10.20, p < .001$. To investigate whether the deaf students performed above chance across the different conditions of the task, performance levels for each set were statistically compared to expected chance level performance using a one-sample *t*-test. The analysis showed that the students performed significantly above chance for the Congruent (P=O) sets, Set 1: $t\ (51) = 14.95, p < .001$; Set 2: $t\ (51) = 12.38, p < .001$, and Incongruent (O=O) Sets, Set 3: $t\ (51) = 6.06, p < .001$; Set 4: $t\ (51) = 2.56, p < .01$. On the final Mixed (P $\neq$ O) set, deaf students demonstrated below chance level performance, Set 5: $t\ (51) = -4.06, p < .001$.

Table 1

Mean (SD) Performance Scores for Congruent, Incongruent, and Mixed Sets (max.5/set)

Congruent (P = O)		Incongruent (O = O)		Mixed (P $\neq$ O)
Set 1	Set 2	Set 3	Set 4	Set 5
4.06 (1.16)	3.90 (1.32)	2.73 (1.29)	2.10 (1.26)	1.00 (1.16)

Note: P = phonological length; O = orthographic length

Analysis of Performance across Conditions. To examine whether the observed differences in mean accuracy across sets were significant, a one-way repeated measures analysis of variance was calculated with Condition (with five levels: Sets 1-5) as the within-subject factor. The sphericity assumption was not met so the Greenhouse-Geisser correction was applied. Results showed a significant main effect of Condition, F (3.07, 156.68) = 74.04, $p < .001$, $\eta^2 = .59$, indicating significant differences in participant performance across the five sets in the task. Post hoc comparisons among the five sets were performed at .05 significance level using the Bonferroni adjustment for multiple comparisons. The results indicated that mean performance accuracy for the two Congruent (P = O, Sets 1 and 2) sets was significantly better than mean performance accuracy on the Incongruent (O = O, Set 3 and 4) sets. The mean difference in performance on Set 1 and Set 2 (P=O) was not significant. Similarly, there was no significant difference between mean performance accuracy on Set 3 and Set 4 (O=O). Mean performance on the Mixed (P≠O, Set 5) set was significantly worse than mean performance on the other four sets. Table 1 indicates that the participants were better able to make a successful length judgment when a word's syllable length was congruent with its orthographic length (P=O). They had significantly more difficulty in making a successful length judgment when orthographic length cues were no longer available to support length discrimination (O=O) and were reduced to below chance performance when orthographic lengths cues were misleading (P≠O) .

Table 2

Set 5 (Mixed) Response Choice Analysis - Mean (SD) Performance Scores (max. 5)

	Phonological choice (number of syllables)	Orthographic choice (number of letters)	Random choice (no pattern)
Mean	1.0 (1.15)	2.52 (1.45)	1.29 (1.19)
Median	1.0	3.0	1.0
Mode	1.0	4.0	0

Set 5 (Mixed) Response Choice Analysis. To further investigate the strategies that the deaf students used in judging the syllable length of an item label, a response choice analysis was conducted on the mixed word set. Table 2 shows the mean (standard deviation in parenthesis) of the response choices made by the deaf students on the mixed word set. Inspection of the table shows that matching word pairs on orthographic length was the most frequent choice.

Analysis of the Effect Age and Reading Ability on Performance. The third question posed in this study asked whether performance on the syllable judgment task would vary as a function of the age and/or the reading ability of the participants. Age and reading ability were only mildly correlated, $r = .473, p < .01$ thus separate analyses were conducted in order to better discriminate the effect of age from the effect of reading ability. First, to determine if performance on the syllable task was differentially related to age, the participants were sorted into younger (8-13 years) and older (14-19 years) age categories consisting of 26 participants each. The students' performance on the syllable task was analyzed using a repeated measures analysis of variance with Age (two levels: younger and older) as the between-group factor and Condition (three levels: Congruent, Incongruent, Mixed) as the within-group factor. The sphericity assumption was not met so the Greenhouse-Geisser correction was applied. The analysis showed no significant main effect of Age, $F(1, 50) = .105, p = .748, \eta^2 = .002$, a significant main effect of Condition, $F(1.79, 89.52) = 132.39, p < .001, \eta^2 = .726$ and no interaction between Condition and Age, $F(1.8, 89.52) = .740, p = .466, \eta^2 = .015$, indicating that both younger and older participants demonstrated similar patterns of performance across sets of the syllable task.

Next, to determine if performance on the syllable task was differentially related to reading development, the participants were separated into two groups determined by reading age (RA), those reading above and below age nine level because nine years of age corresponds to the 3rd grade median level of reading achievement of the deaf school-aged population. There were 31 participants in the RA < 9 group and 21 participants in the RA > 9 group. The students' performance on the syllable task was analyzed with a repeated measures analysis of variance with Reading Ability (two levels: RA < 9, RA > 9) as the between group factor and Condition (three levels: Congruent, Incongruent, Mixed) as the within group factor. The sphericity assumption was not met so the Greenhouse-Geisser correction was applied. The analysis showed no significant main effect of Reading Ability, $F(1, 50) = 1.12, p = .296, \eta^2 = .022$, a significant main effect of Condition, $F(1.79, 89.55) = 125.29, p < .001, \eta^2 = .715$ and no interaction between Condition and Reading Ability, $F(1.8, 89.5) = .756, p = .459, \eta^2 = .015$, indicating that reading ability was not a significant factor in participant performance across the different syllable sets.

Syllable Awareness: Summary of Results. Awareness of phonological structure at the syllable level was examined by seeing whether deaf children can discriminate phonological differences in word lengths. It was predicted that if students had an awareness of the syllable as a phonological unit they would be more likely to choose word pairs with matched syllable length independent of the spelling length of the word. This was not the case. Similarly, it was predicted that if students were making length discriminations on an orthographic basis they would be more likely to choose word pairs with matched spelling lengths. The results of this study support this prediction. Performance accuracy was relatively high on the first two sets of the task (P=O) where use of either a syllable counting or a letter counting strategy was adequate to get a correct response. Thirty-six participants (69.3%) performed at over 80% accuracy (a conservative standard in comparative terms to the reported ceiling performance patterns by young hearing children) at this level of the task. However, when the number of letters was held constant across all words in a quadruplet (e.g., O=O, five-letter cue: *horse* – five-letter response choices: table, *green,* river) so that the participants could not rely on letter counting to get a correct response, only four participants (7.6 %) were able to make syllable judgements at or above 80% accuracy. Finally, when application of phonological knowledge was clearly essential for successful syllable discrimination as in matching words like "sandwich" – "taxi" in the Mixed word set (P≠O), only two participants (3.8%) were able to make syllable judgements at or above 80% accuracy. Forty-two participants (81%) performed below chance at this level of task difficulty suggesting that the syllable is not a well-represented phonological structure for the deaf students in this sample. Moreover, analysis of the response choice patterns for the

Mixed (P ≠ O) set showed that 37 participants (71%) chose an orthographic match on two or more items indicating use of a letter counting (orthographic) strategy to match word lengths.

For the syllable task used in the present study, the word sets were differentiated by the size of syllable discrepancy between cue/target items and the two distracter items. Although mean performance accuracy was slightly better on words in Set 1 (two syllable discrepancy) compared to words in Set 2 (one syllable discrepancy), and again on words in Set 3 (two syllable discrepancy) in comparison to words in Set 4 (one syllable discrepancy), the differences between mean performance on Set 1 vs. Set 2 and Set 3 vs. Set 4 were not statistically significant. Thus, while it is possible that a larger or more salient syllable discrepancy between a target and the distracter items may provide an additional cue allowing participants to make an accurate response, it seems unlikely that any support received was tied to an awareness of the 'phonological' structure of the name of a word. Rather, the findings from this task indicate that segmental organization of phonological knowledge is not well defined at the syllable level and a more likely explanation may be that any effect of syllable discrepancy is realized as a clearly longer (or shorter) articulation path/movement pattern for both cue and target in comparison to distracter items. Moreover, when faced with more than two response choices, it is clear that the sensory evidence that may have been provided through kinaesthetic cues was not sufficiently contrastive to support accurate discrimination of differences in word length suggesting that primary reliance on kinaesthetic cues would be an ineffective strategy in supporting deaf learners in syllabic parsing of words.

Overall, the results of this task show little evidence that judgements about the length of a word were made on a syllabic basis. Performance on the syllable awareness task decreased significantly as task difficulty increased across sets indicating that phonological specifications of words at the syllable level, irrespective of age and reading ability, were not sufficiently differentiated to support phonological word length judgments for the participants in this sample.

Rhyme Awareness

The rhyme awareness task was constructed to determine if deaf children have awareness of phonological structure at the rhyme level. The rhyme task consisted of 40 rhyme judgement trials separated into four different word sets. Each word set contained an equal number of graphically similar (O+, e.g., clock, sock) and graphically dissimilar (O-, e.g., fly, eye) cue and rhyme target pairs. In addition, each word set had a different category of distracter (no pattern, visual pattern, tactile pattern, and visual and tactile pattern). In order to perform the task, participants viewed a cue picture and three response choice pictures. Their task was to choose the response choice picture whose name rhymed with the cue picture.

Rhyme Awareness scores were based on a scale of 0 – 40. Scores ranged from 0 to 39. The mean accuracy score on the rhyme task was 22.13 (55%) with a standard deviation of 7.63. The mean number of correct rhyme judgments on each set is shown in Table 3. Inspection of the table indicates that the data is consistent with the prediction that students would perform better overall on the graphically similar (O+) rhyming pairs.

Table 3

Mean (SD) Performance Scores across Word Sets on the Rhyme judgment task

	Accuracy (max. 5/set)	
	O+	O-
Set 1 (No pattern)	4.37 (1.27)	3.23 (1.46)
Set 2 (Visual pattern)	3.37 (1.50)	1.96 (1.48)
Set 3 (Tactile pattern)	3.48 (1.38)	2.42 (1.94)
Set 4 (Visual & Tactile)	2.67 (1.26)	1.19 (1.19)
All Sets Total		
Raw Score	13.88 (4.39)	8.25 (3.96)
Percentage Correct	69 %	41 %

Note: O+: orthographically similar; O-: orthographically dissimilar

A one-sample *t*-test was computed comparing the students' observed performance on the rhyme awareness task to chance level performance. The analysis showed that overall task performance in selecting a correct rhyme match was significantly above chance, $t\,(51) = 8.44, p < .001$. To investigate whether the deaf students performed above chance across the different conditions of the task, performance levels for each set were statistically compared to expected chance level performance using a one-sample *t*-test. The analysis showed that there was a statistically significant difference between mean scores and chance level test values for both graphically similar (O+), and graphically dissimilar (O-) rhyme pairs for the following sets: Set 1 O+: $t\,(51)$ 15.44, $p < .001$; Set 1 O- : $t\,(51)$ 7.79, $p < .001$; Set 2 O+: $t\,(51)$ 8.27, $p < .001$; Set 3 O+: $t\,(51)$ 9. 57, $p < .001$; Set 3 O- : $t\,(51)$ 4.67, $p < .001$; Set 4 O+: $t\,(51)$ 5.84, $p < .001$. Mean performance accuracy on the graphically dissimilar (O-) words in Set 2 was not significantly different from chance, t (51) 1.52, p =.14 and mean performance accuracy on O- words in Set 4 was significantly below chance, t (51) = -2.78, p =. 008.

Analysis of the Effect of Distracter Type on Performance. To examine whether the observed differences in the means on the O+ and O- words were significant across different sets, repeated measures analysis of variance was calculated with Distracter Type (four levels: no pattern, visual pattern, tactile pattern, visual and tactile pattern) and Orthographic Similarity (two levels: O+ and O-) as the within-subject factors. The sphericity assumption was met. The analysis yielded a significant main effect of Distracter Type, F (3, 153) = 65.68, $p < .001$, $\eta^2 = .56$, and a significant main effect of Orthographic Similarity, F (1, 51) = 122.57, $p < .001$, $\eta^2 = .71$. The interaction between Distracter Type and Orthographic Similarity was not significant, F (3, 153) = 1.15, p = .332, $\eta^2 = .02$, indicating that the differences in accuracy due to orthographic similarity was fairly uniform across the different task conditions. Post hoc comparisons among the four conditions were performed at .05 significance level using the Bonferroni adjustment for multiple comparisons. The results indicated participants were significantly more successful in making an accurate rhyme judgment on Set 1 words where the distracter items shared no similarity to the cue and target than they were on all other sets. Performance means for Set 2 (visual pattern) and Set 3 (tactile pattern) were significantly different than performance means on each other set, however there was no significant difference in participants' mean performance between Set 2 and Set 3. Similarly, mean performance on Set 4 (visual and tactile pattern) was significantly worse than mean performance on the other three sets.

Set 4 (O-) Response Choice Analysis (Visual and Tactile pattern). The effect of distracter type was further examined on the Set 4 subset where acoustic, visual and tactile cues do not overlap in order to provide information on the strategies that the deaf students were using to attempt rhyme judgment. Table 4 shows the mean and standard deviation for student response choices on the O- words in Set 4. Inspection of the table shows that the visual (orthographic) pattern distracter was the most frequent choice as a rhyme match for the cue.

Analysis of the Effects of Age and Reading Ability on Performance. To investigate whether performance on the rhyme judgment task varied as a function of age and/or reading ability, the participants' performance on the rhyme task was analyzed in two steps. First, the participants' performance was analyzed with a repeated measures analysis of variance with Age (two levels: younger and older) as the between group factor and Orthographic Similarity (two levels: O+ and O-) as the within group factor. The results showed that participant performance did not vary significantly as a function of Age, $F\,(1, 50) = 3.10$, $p = .084$, $\eta^2 = .058$. The older participants had a mean accuracy of 11.98 and the younger participants had a mean accuracy of 10.15.

Table 4

Mean (SD) Response Choice Scores on Orthographically Dissimilar (O-) words in Set 4

	Phonological Pattern	Visual Pattern	Tactile Pattern
Mean	1.0 (1.19)	2.19 (1.43)	1.33 (1.20)
Median	1.0	2.0	1.0
Mode	1.0	3.0	1.0

There was a significant main effect of Orthographic Similarity, $F(1, 50) = 139.65$, $p < .001$, $\eta^2 = .736$, and no interaction between Orthographic Similarity and Age, $F(1, 50) = .080$, $p = .779$, $\eta^2 = .002$, indicating that both younger and older participants demonstrated a similar pattern of performance on both O+ and O- word types.

Next, to investigate the effect of reading ability on rhyme judgement the students' performance on the rhyme task was analyzed with a repeated measures analysis of variance with Reading Ability (two levels: RA < 9 and RA > 9) as the between group factor and Orthographic Similarity (two levels: O+ and O-) as the within group factor. The results showed that the effect of Reading Ability was approaching significance, $F(1, 50) = 3.78$, $p = .057$, $\eta^2 = .070$, with the RA > 9 readers performing with a mean accuracy of 12.27 and the RA < 9 readers performing with a mean accuracy of 10.24. There was a significant main effect of Orthographic Similarity, $F(1, 50) = 132.68$, $p < .001$, $\eta^2 = .726$. There was no significant interaction between performance on the orthographically similar and dissimilar word types and reading ability, $F(1, 50) = .271$, $p = .605$, $\eta^2 = .005$.

Rhyme Awareness: Summary of Results. The aim of this experiment was to investigate rhyme awareness in deaf children. The data from this task provides no clear evidence of awareness of phonological structure at the rhyme level. In line with past research, it was expected that overall task performance would be better on O+ word types where use of either a phonological (sound match) or an orthographic (spelling match) strategy was adequate to get a correct response. The data supports this prediction. Performance accuracy was significantly better on the graphically similar (O+) words in Set 1 where distracter items shared no phonological overlap or spelling pattern similarity with the target rhyme in comparison to performance accuracy on any other word sets. Similarly, although the addition of a visual pattern distracter (Set 2, O+) or a tactile pattern distracter (Set 3,O+) caused enough of a decrement in performance to suggest that these distracters were a significant source of interference, performance on these two sets was still significantly better than performance on the graphically dissimilar words across sets – with the exception of similar performance patterns to those for the O- words in Set 1, where distracter items shared no phonological overlap or spelling pattern similarity with the target rhyme. Of interest, on two sets of graphically dissimilar words (Set 1 O-, no pattern distracter and Set 3 O-, tactile pattern distracter) the participants' performance in making an accurate rhyme judgment was significantly above chance. Typically, successful performance on words with the same sounding name but different spellings (O-) has been reported as providing evidence that deaf students are capable of phonological segmentation at the rhyme level. However, separation of sensory cues (acoustic, tactile, visual) through distracter manipulations provided an additional level of control in this task and revealed that there may be several alternate explanations for successful performance on graphically dissimilar words. Specifically, a closer inspection of participant performance across the O- word sets indicated that additional finer-grained orthographic evidence (e.g., letter vowel-consonant distinctions and more orthographic overlap between cue and target than distracters) that was not controlled in the stimulus may have provided additional cues that allowed for what appeared to be a successful 'phonological' rhyme match. In addition, the pattern of performance across the manipulated conditions of the task suggests that successful performance on graphically dissimilar words is likely attributable to awareness of orthographic structure rather than to an awareness of phonological structure at the rhyme level. For example, using an orthographic strategy to support rhyme judgment on the graphically similar (O+) words in set 2 where the distracter item was phonologically distinct but shared a similar spelling pattern (visual pattern distracter) with the target rhyme picture (e.g., cue: **pour**, distracters: **four**, *sour*, hand) offered the participants a 50% chance of making an accurate rhyme match. However, using the same orthographic strategy on the O- words in this set (e.g., cue: **shoe**, distracters: **blue**, *toe*, ring) would be misleading and result in an incorrect match (e.g., toe) in every instance. Application of orthographic knowledge thus seems to provide a likely explanation for the chance level performance on this word set. Likewise, distracter items that shared a tactile pattern but were phonologically and orthographically distinct from the target rhyme (e.g., cue: **kite,** distracters: *gun*, moon, **night**) also interfered with rhyme judgment accuracy on both graphically similar and dissimilar word types. Finally, it was expected that an unequivocal case for phonological discrimination at the rhyme level would be seen in successful performance on the graphically dissimilar (O-) words in Set 4 which included both a visual pattern distracter and a tactile pattern distracter. On this set, the application of phonological knowledge is clearly essential to override any tactile or visual distracter interference. Significantly, at this level of task difficulty the decrement in performance was marked with 85% of the participants scoring at or below chance. This suggests that rhyme was not a well-represented phonological structure for the deaf students in this sample.

Overall, strong orthographic interference on the visual pattern word set for both orthographically similar and orthographically dissimilar rhyme pairs suggest that deaf students are most reliant on spelling patterns to make rhyme judgements. Similarly, interference from the tactile/kinaesthetic distracters suggests that tactile patterning (how words feel) may be an additional, although misleading, source of information that is tapped by deaf children in attempting to make rhyme judgements. For the majority of the participants, it is clear that rhyme judgments were not made on a phonological basis which suggests that rhyme is not a well-represented phonological structure for the deaf students in this sample. Rather, the results indicate that the application of orthographic knowledge provides a fairly robust explanation of the deaf students' performance in the rhyme judgement task.

Phoneme Awareness

The third phonological awareness task investigated whether deaf children have awareness of phonological structure at the phoneme level. Children were presented with a cue picture and asked to choose the item that matched the cue in initial, medial or final sound from three alternative pictures. There were 48 items used in the phoneme judgment task. At each of the three positions (initial, medial, final) eight target items were graphically similar (O+, e.g. *k*ey, *k*ite) to the cue. The remaining eight target items were graphically dissimilar (O-, e.g., *k*ey, *c*ar) to the cue. As in the rhyme task, three different categories of distracter items varying in phonologic/acoustic, orthographic or tactile similarity to the cue item were used to investigate the strategies the deaf children used in this task.

Phoneme Awareness scores were based on a scale of 0 – 48. Scores ranged from 0 to 37. The mean accuracy score on the phoneme level task was 22.17 (46.2 %) with a standard deviation of 7.94. The mean number of correct phoneme judgments on each word set is show in Table 5. Inspection of the table shows that students performed better across all positions on words that shared graphic similarity (O+).

A one-sample *t*-test analysis was computed comparing the students' observed performance on the phoneme awareness task to chance level performance. The analysis showed that overall task performance in selecting a correct phoneme match was significantly above chance, $t\ (51) = 5.75, p < .001$. To investigate whether the deaf students performed above chance across the three phoneme positions, performance levels for each set were statistically compared to expected chance level performance using a one sample *t*-test. The analysis showed that the student performed significantly above chance on orthographically similar (O+) words in initial, $t\ (51) = 8.72, p < .001$; medial $t\ (51) = 6.52, p < .001$; and final $t\ (51) = 7.51, p < .001$ positions. There was no significant difference between mean performance levels and chance level for the orthographically dissimilar (O-) words in initial , $t\ (51) = -1.35, p = .184$; medial $t\ (51) = .-450, p = .654$; and final $t\ (51) =.403, p =.688$ positions.

Table 5

Mean (SD) Performance Scores on the Phoneme Judgment Task: Initial, Medial and Final Positions (max.16/position)

Initial		Medial		Final	
O+	O-	O+	O-	O+	O-
5.10 (2.03)	2.37(1.47)	4.44 (1.99)	2.54(1.63)	5.00(2.28)	2.73(1.62)

Note: O+: orthographically similar; O-: orthographically dissimilar;

Analysis of Performance Between Phoneme Positions (Initial, Medial and Final). To examine whether the observed differences in mean performance levels on the O+ and O- words were significant across different phoneme positions, repeated measures ANOVA were conducted with Phoneme Position (three levels: initial, medial, final) and Orthographic Similarity (two levels: O+ and O-) as the within-subjects factors. The sphericity assumption was met. There was no significant effect of Phoneme Position, F (2, 102) 2.42, p =.094, $\eta^2 = .05$, but a significant effect of Orthographic Similarity, F (1, 51) = 126.84, $p < .001$, $\eta^2 = .71$ was found. There was no Phoneme Position by Orthographic Similarity interaction, F (2,102) =2.34, $p = .101$, $\eta^2 = .04$.

Analysis of the Effect of Distracter Type on Performance. To examine whether the observed differences in the means on the O+ and O- words were significant across different distracter types, the accuracy scores for each subset of distracters were pooled across positions and analyzed using a repeated measures ANOVA with Distracter Type (four levels: no pattern, visual pattern, tactile pattern, and visual and tactile pattern) and Orthographic Similarity (two levels: O+ and O-) as within-subjects factors. The sphericity assumption was met. The results revealed a significant main effect of Distracter Type, F (3, 153) = 71.14, $p < .001$, $\eta^2 = .58$, a significant main effect of Orthographic Similarity, F (1, 51) = 126.84, $p < .001$, $\eta^2 = .71$, and a significant interaction between Distracter type and Orthographic Similarity, F (3, 153) 4.69, p =.004, $\eta^2 = .08$. The Distracter Type by Orthographic Similarity interaction indicates that performance accuracy on orthographically similar and dissimilar words was differentially affected by the different distracter types. Post hoc comparisons among the eight subsets were performed at .05 significance level using the Bonferroni adjustment for multiple comparisons. The results indicated that the mean performance on words within the No pattern (O+) subset was significantly better than mean performance on words within any other subset. Performance on the Visual pattern (O+) word types was significantly different than on most other subsets with the exception that there was no significant difference in mean performance on words in the Visual pattern (O+) and the Tactile pattern (O+) subset nor between the Visual pattern (O+) and the No pattern (O-) subset. Differences in mean performance on words in the Visual and Tactile pattern (O+) subset were significant in comparison to the other subsets with the exception of the Tactile pattern (O-) subset. There was no significant difference between mean performance on words in these two subsets. Mean performance on words in the Visual pattern (O-) subset was not significantly different than mean performance on words in either the Tactile pattern (O-) or the Visual and Tactile pattern (O-) subset. Finally, mean performance accuracy on words within the Visual and Tactile pattern (O-) subset was significantly worse than mean performance on words in each of the other subsets with the exclusion of the Visual (O-) subset. As noted above, there was no significance difference between mean performances on these two subsets. Figure 1 displays the effect of stimulus similarity on phoneme judgment and indicates that when task demands were low (O+) and distracter items would not be a source of interference (No pattern) the participants were better able to make a successful matching judgment. However, the inclusion of distracter items that were orthographically distinct but overlapped the cue in tactile contact (O+, Tactile pattern) or were orthographically misleading (O+, Visual Pattern) interfered with accuracy and resulted in comparable

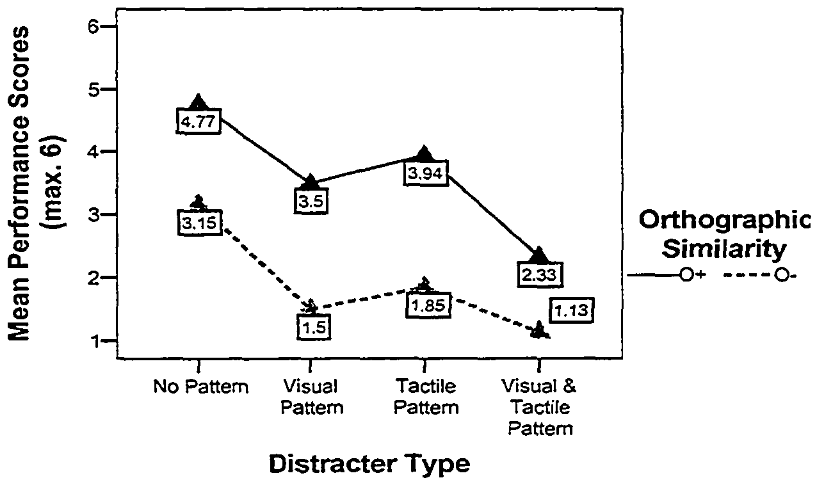

Figure 1. The Effect of Stimulus Similarity on Phoneme Judgment for Orthographically Similar (O+) and Orthographically Dissimilar (O-) Word Types.

performance between these O+ subsets and the easiest level of the O- subsets (O-, No Pattern). There was a significant decrement in performance when orthographic cues were not available to support matching judgments (O- words) and particularly on subsets where the orthographic cues in the distracter items were misleading (O- Visual Pattern, O- Visual and Tactile pattern).

Analysis of the Effect of Age and Reading Ability on Performance. To investigate whether performance on the phoneme judgment task varied as a function of age and/or reading ability of participants, performance on the phoneme task was analyzed with a repeated measures analysis of variance with Age (two levels: younger and older) as the between group factor and Orthographic Similarity (two levels: O+ and O-) as the within group factor. The results showed a significant main effect of Age, *F*

(1, 50) = .6.97, p =.011, η^2 = .122 with the older participants performing with a mean accuracy of 8.43 and the younger participants performing with a mean accuracy of 6.47. There was a significant main effect of Orthographic Similarity, F (1, 50) = 127.03, p < .001, η^2 = .718 but no significant Age by Orthographic Similarity interaction, F (1, 50) = 1.07, p =.305, η^2 = .021. Both younger and older students were more successful on the O+ word types than on the O- word types.

Next, to investigate the effect of reading ability on phoneme judgement, the students' performance on the phoneme task was analyzed with a repeated measures analysis of variance with Reading Ability (two levels: RA < 9 and RA > 9) as the between group factor and Orthographic Similarity (two levels: O+ and O-) as the within group factor. The results showed there was a significant main effect of reading ability on performance, F (1,50) = 15.42, p < .001, η^2 = .236 with the RA > 9 readers demonstrating a mean accuracy of 13.41 compared with a mean accuracy of 9.52 for the RA < 9 readers. There was a significant main effect of Orthographic Similarity, F (1, 50) = 134.07, p < .001, η^2 = .728 and no significant interaction between Orthographic Similarity and Reading Ability, F (1, 50) = 2.87, p =.097, η^2 = .054. It should be noted that the Orthographic Similarity by Reading Ability interaction was approaching significance suggesting that performance accuracy on the O+ and O- word types may be differentially affected by reading ability. Post hoc comparisons were performed at .05 significance level using the Bonferroni adjustment for multiple comparisons. The analysis revealed that the RA >9 readers did significantly better on both O+ (M= 17.48 vs. 12.55, p <.001) and O- (M= 9.33 vs. 6.48, p <.001) word types in comparison to the RA < 9 readers. Figure 2 shows that there is a larger difference in performance between the two groups on the O+ words than there is between the performance of the two groups on the O- words. In light of the earlier reported chance level performance on O- words for the group as a whole, mean O- accuracy scores for the more advanced readers was compared to expected chance level performance using a one-sample *t*-test. Performance for the RA > 9 readers on the O- words was not significantly different than chance, $t(20) = 1.35, p = .194$.

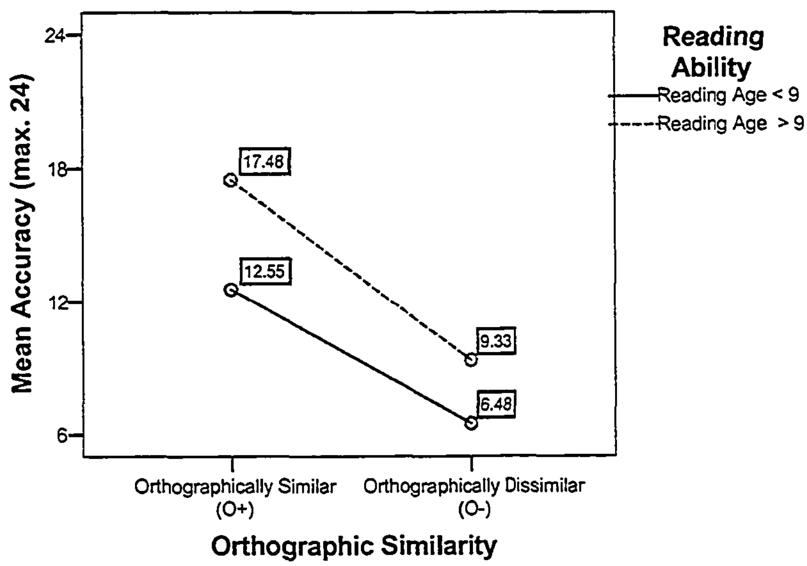

Figure 2. The Effect of Reading Ability (Reading Age > 9 and Reading Age < 9) on Phoneme Judgment Accuracy for Orthographically Similar (O+) and Orthographically Dissimilar (O-) Word types.

Phoneme Awareness: Summary of Results. The aim of this experiment was to investigate phoneme awareness in deaf children. The data from this task provides no evidence for awareness of phonological structure at the phoneme level. The results of the phoneme judgement task showed that the deaf students performed significantly above chance when cue and target shared the same letter(s) in initial, medial or final position. Stimulus similarity between phoneme target and distracter items significantly reduced performance accuracy on graphically similar (O+) word types. When graphic similarity could not be relied on to support phoneme judgment, as on O- word types, the deaf students' performance fell to chance level across all three phoneme positions indicating that this task was performed on the basis of letter matching rather than sound matching. Overall, the results suggest that the phoneme is not a well-represented phonological structure for the deaf students in this sample. Older participants did better on the task than the younger participants and more advanced readers did better on the task than less advanced readers. As the performance differences between the groups reflects mainly larger differences on the Orthographically similar (O+)words it may be that word analytic skills or an increased understanding of orthographic structure may improve with age and with reading ability. As with the syllable and rhyme data, the application of orthographic knowledge provides a fairly robust explanation of the deaf students' performance on the phoneme judgment task.

CHAPTER 5: DISCUSSION

Research has clearly demonstrated that establishing the phonological awareness skills needed to attend to and segment the sounds of language facilitates learning to read an alphabetic script for hearing children (Adams, 1990; Parrila, Kirby & McQuarrie, 2004). The ability to encode and analyze speech sounds is an important determinant in hearing children's ability to (a) store and retrieve word names in their oral language development and (b) learn letter sounds supporting efficient storage and retrieval of written word names (Ehri, 1998; Moats, 2004). For hearing children, spoken language phonological awareness provides the linguistic and cognitive underpinnings for successful early use of written language.

Research findings underscoring the importance of spoken language phonological awareness in literacy acquisition present the field of deaf education with somewhat of a conundrum when considering how best to support deaf learners in reading skills development. Children who have hearing losses in the severe to profound range are biologically precluded from auditory access to the speech stream. While it is clear that severe and profound hearing loss will limit the amount of sensory evidence available to the deaf child, it is widely speculated that other sensory processes can, to varying degrees, compensate or substitute for inaccessible acoustic evidence. It is argued that although deaf children cannot discriminate sound contrasts or 'hear the sound', nevertheless they can develop phonological skills through 'seeing the sound'. Exposure to visible English via speech reading and/or MCE systems is thus offered as a viable alternative for developing an internal representation of spoken English (Leybaert, 2000; Mayer & Wells, 1996). Instruction in reading is founded on the assumption that when speech is perceived visually (with or without manual sign or cue supplements) and supported by long-term intensive articulation training, deaf learners can develop phonological skills to support an orthographic-phonological connection. Despite these long held assertions, experimental evidence on the representation of phonological structure in deaf learners is scarce. The results of existing studies investigating phonological awareness skills in deaf learners have been inconsistent in their findings with some studies reporting 'phonological effects' while others have found no such evidence. For the most part, studies reporting negative findings come from investigations of PA in young deaf children, whereas studies reporting positive findings come from investigations of older, skilled deaf readers. Recent attention has thus focused on questions exploring the extent to which phonological skills that may develop in deaf learners are dependent on being taught to read.

To date, positive evidence of 'phonological effects' as outlined in the literature arise largely from tasks measuring one level of phonological structure (rhyme) and from paradigms requiring participants to make a phonological judgment between words presented in print or on picture tasks requiring a two-choice discrimination between word pairs. Conclusions that deaf individuals' successful performance on these tasks is necessarily tied to a phonological code are problematic on two fronts. First, there is the concern that words presented orthographically may change the nature of the task making 'positive' findings less generalizable to phonology. Second, current understandings of the multi-sensory nature of speech perception allow that alternate sensory accounts are equally capable of explaining deaf individuals' successful performance on these tasks. That is, an argument for 'phonological effects' on a two-choice task is weakened by the fact that this effect ignores the possibility that different sources of information may have been applied to the signal which produced what 'looks like' a correct response.

Such methodological concerns raise questions about the long-standing proposal of equivalence for both spoken and lip-read stimulus in providing deaf learners with access to spoken language phonology. Based on the empirical evidence available, the central question of whether deaf individuals have awareness of phonological structure remains unanswered. Consequently, and in relation to reading acquisition, conventional arguments that deaf children can similarly benefit from phonological reading strategies as hearing children are equally without an established empirical foundation. The evidence needed to substantiate any claims of equivalence in word reading acquisition processes between deaf and hearing readers is clearly dependent on the extent to which the sensory evidence in non-auditory cues can similarly support deaf learners in the segmental organization of phonological knowledge across all levels of linguistic structure.

The present study attempted to address the equivalence issue by investigating (a) awareness of phonological structure at three levels of linguistic complexity: syllable, rhyme and phoneme, in children and adolescents with a severe to profound, prelingual hearing loss, (b) the extent to which matching judgments across the phonological awareness tasks were influenced by the perceptual status (acoustic, tactile, visual) of distracter items, and (c) whether age and/or reading ability would differentially affect the performance of deaf children and adolescents on the phonological awareness tasks. Using a within subjects design encompassing the age range from 6 to 19 years, three phonological awareness tasks were administered to a representative sample of fifty-two children attending two provincial schools for the Deaf in Western Canada. Performance accuracy was analysed at each level of phonological structure and compared across stimulus conditions using repeated measures ANOVA. Insensitivity to phonological structure was observed at all three levels of linguistic structure in the presence of average IQ across all ages and within good and poor reader groups. Moreover, the data revealed that the ability to make syllable, rhyme and phoneme level judgements was not tied to phonological facilitation as it is with hearing learners. I will discuss each of these findings in turn.

First, it is important to reiterate that nameable pictures were used as the stimuli for each experimental task because the use of picture stimuli provides a cleaner measure of phonological awareness than print presentation allows. It has been repeatedly shown that nameable pictures are remembered in phonological rather than visual codes. However, because phonological information is not present in picture stimuli, a participant has to internally generate the phonological representation of the intended item label before the name of the picture can be held in short-term memory. The phonological tasks used in this study were not intended to tap the speed of word identification, but instead the process by which the identified item label activated by a picture stimulus was judged as being similar to a cue in the phonological unit tested. Thus the process being studied is the process of encoding the picture stimuli and the labels activated by the stimuli and then deciding which item label is a better fit with the cue within the phonological units of syllable, rhyme or phoneme. The use of perceptually similar distracters was intended to clarify the extent to which the resolution of phonological units may be differentially affected by an acoustic factor, a tactile factor, or an orthographic factor.

The first finding of interest across the experimental tasks was that a composite score reflecting overall task performance on both orthographically similar (O+) and dissimilar (O-) words was significantly above chance for the deaf participants studied. This finding is consistent with the reports of positive findings for phonological awareness from previous studies as outlined in Chapter 2. However, in the present study when the data was reanalyzed according to O+ and O- categories, there was a significant effect of orthographic similarity with performance accuracy seriously reduced across all O- categories. For example, on the final level of the syllable task, orthographic length between cue and target was mismatched (same number of syllables but different number of letters) to determine if phonological specifications for item labels were sufficiently distinct to overcome this kind of orthographic confusion. As well, the final level of the rhyme and phoneme tasks eliminated all targets that were orthographically similar to the cue item and included both visual and tactile pattern distracters to determine whether phonological specifications for item labels were sufficiently defined to overcome these kinds of orthographic and/or tactile confusions. At this level of task difficulty across all three tasks, the application of phonological knowledge was clearly essential in order to make a successful syllable, rhyme or phoneme match. Significantly, participant performance fell to below chance in every instance. These performance patterns lead to the first question raised at the outset of the study: do deaf children have awareness of phonological structure across the three levels of linguistic structure? The findings from this study indicate that, unlike hearing children of a much younger age for whom these phonological structures are well established, the syllable, rhyme and phoneme are not well represented phonological structures for the deaf children and adolescents. Consequently, careful scrutiny of the studies reviewed in Chapter 2 that report positive findings of awareness of phonology based on a composite score (O+ and O-) is needed.

The next finding of interest across all three tasks was that there was a significant 'stimulus similarity' interference effect induced by the perceptual overlap of distracter items to the cue stimulus. For example, reliable and fairly large differences in performance accuracy were obtained on the rhyme and phoneme task by stimuli that differ from the cue word in acoustic, tactile and orthographic representations. On the first level of each task in which the distracter items were neutral with respect to shared perceptual similarity with the cue and target, accuracy was better than on all other remaining sets. At this level of the task, successful performance could be made using either a phonological or an orthographic strategy. Across all other sets in each task, the error rate difference was bigger when the distracter items were orthographically related to the cue, but there was still a significant interference effect with tactile pattern distracters - especially when there was no orthographic (spelling) similarity between the cue and the target phonological response (e.g., O- cue: kite, response choices: night, gun, moon). Response choice analyses revealing that tactile patterning for the deaf students studied rendered the phonetic realization of a word such as "kite" as a companion rhyme to a word like "gun" suggests that the internally generated code (the code activated) may not include information about phonemic (i.e., meaning bearing) contrasts between one word and another. More significant perhaps, on O+ word sets (e.g., O+ cue: "boat", response choices: "coat, jump, pool") where a successful match could have been made on an orthographic basis by matching spelling patterns, the internally generated code often failed to distinguish between words that have different orthographic representations resulting in responses that, for example "pool" was the companion rhyme to the cue "boat". Importantly, these types of errors are thought to denote the state of the internal representation. Clearly, if a visual/tactile code were able to compensate or substitute as a 'phonological' representation for deaf learners such confusions should not be evident. Typically hearing children rarely, if ever make mistakes of this type.

Past studies involving phonological awareness testing of deaf participants have produced inconsistent results. In contrast, the results from this study using tasks requiring phonological disambiguation between sensory cues were quite straightforward. When deaf children made decisions requiring syllable, rhyme or phoneme discrimination, matching judgements were not tied to phonological facilitation as they are with hearing learners. On these tasks, while it is clear that some sort of pattern code was computed which activated a lexical item, there is little evidence to suggest that there was anything fundamentally 'phonological' in the code that was generated. As discussed in Chapter 2, phonological awareness tasks requiring a simple matching judgement measure what Stanovich (2000) refers to as the basic or surface level of phonological awareness. At a surface level, the participants in this study were not able to reliably exploit the phonological/ meaning bearing contrasts that normally enhance discrimination across syllable, rhyme and phoneme boundaries. While these findings suggest that both visual (lip-read) and tactile information may be integral parts of the input signal for deaf learners, they similarly suggest that deaf individuals may use the sensory motor system with little or no integrative activity. As such, they underscore the important role played by auditory information in coding and the limitations of visual/tactile information alone in establishing meaningful linkages between sensory cues. Although it may be argued that visual/tactile cues are a part of the 'phonological' evidence in the input signal, it is clear that for these deaf learners it is not the 'right kind' of sensory evidence that supports awareness of similarities and contrasts in the sounds of words. It is proposed then, that use of the term 'phonological' to account for deaf learners' performance patterns on phonological tasks may be misleading - at least to the extent that conventional use of the term carries with it an underlying assumption of 'meaningful' integration of sensory cues.

As noted in Chapter 2, it has been suggested that phonological awareness develops hierarchically as a function of age with mastery of syllable awareness preceding the development of other phonological skills (Blachman, 1994, Caravolas, 1993, see overview in Goswami, 2002). If deaf learners were developing phonological competence along similar lines as hearing children we would expect to see awareness of larger structures (syllables) precede awareness of smaller structures (phonemes). Of interest, an examination of individual performance profiles of the deaf children in this study revealed several different patterns in performance across the syllable, rhyme and phoneme tasks. For example, while 28% of the participants demonstrated typical patterns of development (e.g., Syllable > Rhyme > Phoneme), 29% of the participants demonstrated a Rhyme > Syllable > Phoneme pattern of performance, 18% demonstrated a Rhyme > Phoneme > Syllable pattern of performance and 16%

demonstrated a Syllable > Phoneme >Rhyme pattern of performance. Importantly, a range of ages and reading abilities (good to poor) were reflected in each of the profile categories.

Recently, it has been suggested that deaf learners may follow an idiosyncratic path in their phonological development demonstrating rather limited awareness of the pre-reading phonological structures that are most strongly cued by visible speech (e.g., onsets) while showing reading-level appropriate representation of phoneme structure (Sterne & Goswami, 2000). Theoretically, it might be possible that children with some residual hearing could display such atypical patterns. Still, atypical progressions in development would be surprising given the solid evidence that for hearing children early phonological skills (e.g., syllable awareness) seem to be necessary precursors to the establishment of more refined phonological skills (e.g., phoneme awareness). However, for the children in this study whose hearing loss precludes access to auditory information, it is unlikely that the variable performance profiles reflect idiosyncratic phonological development because there is little evidence of a phonological foundation from which to base such conclusions. A more plausible explanation for the variable individual profiles noted in this study is that the knowledge based tapped in performance of each task was not in the conventional sense 'phonological'. Rather, as suggested by the data from the response choice analyses, it is likely that accuracy in syllable, rhyme, and phoneme judgment was supported primarily by knowledge of orthographic patterns.

Lending support to the arguments above, the third finding of interest in the present investigation was that the younger deaf children studied (6 -13 years) did not show less sensitivity to phonological structure relative to the older children (14-19 years). While the older students were slightly more accurate in their ability to make matching judgements across all three tasks, the difference in performance accuracy between groups was not significant. Similarly, the reading data indicated that reading abilities ranged from poor to skilled despite similar insensitivity to phonological structure across all participants. This would argue that for these learners, awareness of phonological structure was not refined by increased exposure to or experience with print. These findings then are in direct contrast to typical patterns reported with hearing individuals and are inconsistent with traditional proposals in the deafness literature that awareness of phonological structure is a developing skill that improves with age and/or reading ability. Instead, it may be that ongoing sign vocabulary development along with growing awareness of orthographic structure might better account for the small increase in accuracy noted for the older group in comparison to the younger group of signing children participating in this study.

There is one loose end related to the reading data however that is somewhat puzzling. Debates related to reading development and deaf children derive from the available cognitive theories and models of reading acquisition that are premised on the centrality of a phonological code. Underpinning most models of reading is the understanding that graphemic representations are associated with phonological representations. In fact, Perfetti (1992) proposes that the grapheme is recognized as a unit central to reading on the condition that the child has the opportunity to discover that sequences of letters are associated with phonological units. Yet, the use of graphemes as functional reading units does not appear to be dependent on previous development in the representation of spoken language phonological structure for the children studied in the present investigation. Moreover, it appears that substantial, even average reading achievement is possible in the absence of spoken language phonological awareness. The tempting conclusion from such results might be that phonological awareness does not underlie reading achievement for deaf learners because the alternative would be to argue that deficits in phonological awareness contributed to the difficulty with reading for the poor deaf readers but that the good deaf readers reached high levels of reading achievement without any phonological support. It seems unlikely that similar deficits in phonological awareness differentially affected both groups. Thus, if the grapheme is not tied to spoken language phonological coding for deaf readers, the question is raised as to what is the nature of the processing unit for this group? Is orthographic coding independent from phonological coding for deaf readers? Such conjecture would be consistent with the suggestion that these two sources of knowledge contribute differentially to reading difficulties. However, that the grapheme may serve as a functional reading unit for deaf learners independent of any phonology is extremely difficult to argue in light of substantial research evidence linking phonological awareness to reading skill development and in face of the overwhelming evidence of the persistence of deaf children's English language learning and reading difficulties. If orthographic input alone could mediate access to meaning for deaf learners then certainly more deaf children should have succeeded with reading than historically, or presently, is the case.

There is, however, another alternative that could explain the performance of the deaf children in this study. These deaf children communicate via natural sign language and thus have complete access to the sublexical (sign phonemes) structure of a natural language. It may be then that those readers who do succeed do so because they have another phonological system at their disposal. As Ehri (1992) suggests for hearing children, it is access to the sublexical structure of a natural language that is critical to supporting reading acquisition as it is the learned patterns of association at the sublexical level that serves to glue words in memory. Full access to the phonological structure of natural sign language(s) enables signing children to discover more predictable and consistent patterns in the input than is possible through the spoken language input they receive. Signing thus provides an alternate means of coding words and establishing fully specified phonological representations of words as they are learned. It is possible then that good signing deaf readers were able to exploit the phonological patterning in Sign Language and discover on their own more predictable patterns of association between their conversational language and the language of print. Needless to say, this suggestion is speculative. That little evidence exists in support of this hypothesis is not surprising given that deaf learners have not been taught to read using a code other than spoken phonology. For all readers, efficiency in accessing the lexicon is a learned process. The acquired sets of relations (e.g., grapheme-phoneme links) demonstrated by successful hearing readers are cultivated. If young deaf children were afforded the same explicit instruction – and taught how to exploit the phonological patterns underlying their own robust internal sign representational system – it is possible that sign language phonological awareness could provide the linguistic *and* cognitive underpinnings for successful use of written language for deaf learners. In such case, the hypothesis would be that the grapheme is not independent of phonological coding at all but rather, is directly tied to an alternative phonological representation. Such a proposal then does not necessarily contradict the predictions from conventional models of reading. It does however raise new questions that deserve further experimental scrutiny.

The results of the present study regarding deaf children's awareness of phonological structure may be summarized as follows:

1. Insensitivity to phonological structure was observed across all three levels of linguistic structure suggesting that the syllable, rhyme and phoneme are not well represented phonological structures for children with severe to profound, prelingual hearing loss.
2. Sensitivity to phonological structure across all three linguistic levels did not vary as a function of age suggesting that segmental organization of phonological knowledge (representation of phonological structure) is not a 'developing skill' for these children with severe to profound, prelingual hearing loss.
3. Sensitivity to phonological structure across all three levels of linguistic structure did not vary as a function of reading ability suggesting that segmental organization of phonological knowledge (representation of phonological structure) is not developed or refined through print exposure for these children with severe to profound, prelingual hearing loss. Arguably however, slightly better performance of the more skilled readers on the orthographically similar words may indicate that word-analytic abilities may be developed through increased exposure to print.

4. Difficulty in differentiating between phonetically similar (and confusing) but phonologically contrastive words was evidenced across all three tasks suggesting that the underlying phonological representation for the students in this study may not be informationally rich enough to support accurate discriminations.

It is important to note that while the use of phonology predicts above chance level performance on tasks of phonological awareness, performance above chance does not in itself indicate the use of a phonological strategy. Demonstration of insensitivity to phonological structure in young deaf children and older adolescents, and in good and poor readers strongly suggests that difficulties with sound-based phonological awareness are not outgrown, do not represent a developmental lag and are persistent and pervasive throughout at least adolescence despite intensive and long term interventions. Thus, the conjecture that deaf children's phonological development is qualitatively similar though quantitatively delayed in comparison to hearing children is not supported. Similarly, conceptions of phonological awareness as an emergent, developmental skill may only be applicable for individuals who have complete access to the phonology of a natural language.

Implications for Educational Practice

The results presented here have two-fold implications in the education of children with severe to profound hearing loss relating first to language development in general and second to reading acquisition in particular.

Spoken word recognition. "Knowing word meanings and differentiating confusable words depends on accurate perception of the phonological structure of words. Children must be aware of subtle contrasts in similar-sounding words, such as "shark" and "shock"; "fill", "fell", and "fail"; "fresh" and "flesh"; and "irrelevant" and "irreverent" in order to learn their meanings" (Moats, 2004, p. 274). Speech perception requires an input signal, an integrative mechanism and a motor output. For individuals with all sensory systems intact, the evidence available in the input signal consists of mutually contrastive patterns, contrastive in both the articulatory and auditory sense. As outlined by several researchers, the coupling or link between the representations of auditory (sound) parameters and articulatory (motor) parameters is learned and develops in an experience-dependent way. Several researchers propose that through a process of lexical restructuring, both perceptual and motor representations are altered and refined. Ongoing refinement of word percepts in turn helps disambiguate the input signal and leads to automaticity amongst all multisensory (acoustic, tactile/kinaesthetic, visual) cues. However, in the case of deaf individuals, the spoken language signal is analyzed according to how it is perceived visually (lip-read patterns) and produced tactily (tactile/kinaesthetic motor patterns) – both sources of sensory evidence that, as outlined earlier, are not on their own mutually contrastive. The consequences of an ambiguous signal would be incomplete and inaccurate coding. Moreover, an inability to establish fully specified phonological representations, well coded in both auditory and articulatory detail, appears to prevent deaf learners from differentiating between phonetically similar (and confusing) but phonologically contrastive words. It is not a far stretch then to imagine the processing penalty that might be imposed on individuals who are biologically precluded from perceiving acoustic structure (both the temporal and spectral information in the speech signal) if multiple letters (e.g., t, d, l, n) and multiple words (e.g., 'kite, gun, kid, gut, cut, kit, cut, kin....etc.') can be encoded as the same perceptuo-motor representation. Simply, a significant cost in terms of the speed and ease with which lexical forms are consolidated and learnt must result. As Stanovich (2000) outlines for hearing children, it is reasonable to assume that difficulty in establishing segmented representations may impede the deaf child's ability to establish lexical forms and represent them in such a way as to provide for efficient storage and retrieval processes. The effects of lack of exposure to a language's explicit phonological patterns in a comprehensible form may offer a partial explanation for the pervasive vocabulary difficulties reported for deaf and hard of hearing learners such as restricted vocabulary size (Marschark et al., 2002), a narrow range of meaning for words (Paul, 1998) and deficiencies in establishing word categories (McEvoy, Marschark, & Nelson, 1999). Access to the continuous phonemic stream of a natural language may be a necessary condition for establishing a robust internal representational system that will support lexical acquisition and, in turn, the acquisition of linguistic representations associated with later stages of linguistic development.

Written word recognition. The foundation for instruction in early reading development for hearing learners is phoneme identity and differentiation. As with spoken word recognition, several researchers suggest that automaticity in written word recognition is also closely linked to the quality of initial coding of word percepts (e.g., Goswami, 2000; Mody, 2003; Stanovich, 2000). For early readers, it is argued that phoneme to grapheme knowledge functions in part as a mnemonic tool enabling hearing children to retain letter-specific information about individual words in memory (Ehri, 1992). That is, the linking of sounds and letters allows for more efficient storage and retrieval of written words in memory. Ehri (1992) proposes that a skilled, fluent word reader is able to read words accurately and quickly because all of the letters have been secured in memory whereas difficulty in word reading is likely when only some letters in a word are loosely connected to a phonological representation in memory. Latency data from word identification tasks further indicates that faster response latencies are based on how typical an example a stimulus is of its category. Thus, the closer the signal is to the ideal signal the faster individuals make their classification (Miller, 2001). One can well imagine the enormity of the task for the deaf child who is attempting to make corresponding linkages between ambiguous visual percepts and letters or between ambiguous tactile percepts and letters. The consequences for learning may be that written words remain poorly connected in memory. Without predictability and consistency in the input signal from which these children can discern regularity, it is likely that automaticity or fast and accurate word identification may be sacrificed. Moreover, for hearing readers, different spelling patterns activate a distinct phonological representation that then activates all the associated meanings of a word. However, in the case of deaf individuals, written word processing may be much different. If the spellings of multiple words activate a common visual/tactile representation (e.g., kit, gun, get, kite, kill, gill…etc.) the result would be multiple words competing for attention. Thus, there would be ambiguity in the system at two levels, the visual/tactile (phonetic) level prior to meaning activation and again at the level of meaning. The activation of multiple written word candidates may then result in a substantial processing time cost to the reader. Thus, deaf learners may read words less accurately and more slowly and may misread similarly spelled words such as "short and shirt" and even differently spelled words such as "kite and gun" or "time, name and dime" because many of the same letters could be connected to a common perceptuo-motor representation in memory. Although contextual support may assist readers in resolving some of the ambiguity that may arise at the level of meaning, as Paul (2001) suggests, the demonstrated difficulties with English syntax alongside reductions in breadth and depth of vocabulary knowledge for most deaf learners would make it difficult to infer the meaning of words using sufficient context clues.

Success in reading continues to be the exception rather than the rule for deaf children. Like all children, difficulties in reading for deaf learners may result from any one of multiple causes, namely, total inability to use a strategy, ineffective use of a strategy, or use of an ineffective strategy. A valid developmental theory of reading acquisition is premised on the understanding that early competencies must be in place before later ones are attempted. Successful use of any phonological word reading strategies implies that the child has the cognitive abilities and representational knowledge structures that underlie use of each strategy. For any learners, we can conclude that phonological prompts will be ineffective as retrieval cues if lexical representations are not organized into segments that correspond to the cues that are provided. For children with severe to profound hearing loss, such phonological strategies are unlikely to succeed simply because they are premised on skill sets that the learner does not have and will not acquire.

The current investigation provides support for the notion that the well-documented difficulties that deaf children encounter in learning to read might arise from underlying deficits in the accuracy and the segmental organization of the phonological representations of words in their mental lexicons. For the students in this study, the visual (lip-read) and tactile evidence in the input signal did not appear to be sufficiently informative to provide these students with the means by which to shape and refine phonological information. By extension, a validation of the traditional 'qualitatively similar' equivalence claims require that approaches to reading instruction that are focused on making sound-based phonology 'visible' to deaf students be evaluated against their potential to develop a robust and reliable internal system of representation of spoken language phonological structure for deaf learners. If lacking such potential, difficulties in securing written words in memory, as well as with accuracy and speed of word recognition would be predicted.

Limitations of study

The findings of this study indicate that there may be skills other than sound-based phonological abilities that play critical roles in the reading achievement of signing deaf individuals. In the design of the tasks used in this study attention was focused on control of global or surface level orthographic patterns in the stimuli like those seen in full spelling pattern matches. The response choice analyses clearly indicated that there was still finer-grained orthographic evidence available in the stimuli that could support the appearance of a correct response such as more letters in common between cue and target than between cue and distracter and shared final letters between cue and target. Further attention at the individual letter level would have eliminated this problem. As well, in the design of the tasks, cue and target items were monitored to ensure that they did not overlap in ASL phonological parameters to control for the possibility that this source of knowledge might contribute to a 'looks like' successful judgment. Further study with signing students should also consider the inclusion of an ASL phonology distracter item. ASL phonological awareness was not addressed in the present study. Finally, it is unclear how far the results of this study may be generalized. Certainly, further study is necessary to determine the extent to which sensitivity to phonological structure may be impacted by more mild to moderate hearing losses. Thus, no conclusions are forwarded that move interpretation of the results beyond the specific age range and characteristics of the population examined in this investigation.

Future Directions

Several questions arise from the findings of this study which lead in three clear directions. First, refinement of the phonological awareness tasks themselves should be explored. Because the tasks used in this study are accessible to both deaf and hearing individuals, they may be suitable for future comparative research between hearing and deaf readers. While this study focused on children with severe to profound, prelingual hearing losses, future research should also include children with less severe hearing losses as well as children with cochlear implants. Such investigations would be important in order to determine the extent to which perception of the sensory evidence available in the input signal is sufficiently informative to provide these learners with the means by which to integrate phonological information and to refine and shape phonological representations. As well, 'phonological' representations are not, for hearing individuals, exclusively auditory in nature (see discussion in Skipper, Nusbaum, & Small, 2005). As Hayes et al. (2003) note, recent neuroimaging studies indicate that difficulty in representing and/or integrating multisensory information is a factor in reading deficits of learning disabled subjects. As the tasks used in this study are designed to separate acoustic, tactile, and visual cues they may have some future diagnostic application for hearing individuals experiencing reading difficulty. That is, they may offer support in more clearly delineating a locus of difficulty in attention to stimulus parameters.

Second, the findings of insensitivity to phonological structure acquired from a comparatively large sample of children spanning a broad age range across childhood provides tentative developmental evidence of the persistence of sound-based deficits in phonological awareness up to adolescents for children with severe to profound prelingual hearing loss. It would be interesting to investigate whether these performance patterns would be replicated in an older group of severe to profoundly deaf adults who also are skilled readers. If profoundly deaf adults demonstrate the same level of phonological insensitivity as the younger participants in this study confirmation that sound-based phonological deficits are not 'remediable' and persist across the lifespan for this population would be obtained. In addition, if similar performance patterns were observed in a group of highly skilled deaf signing readers this would suggest that reading difficulties of poor deaf readers who sign may be symptomatic of other differences but that spoken language phonological awareness, in and of itself, does not underlie reading achievement for the signing population.

Third, best practice in reading instruction for all learners underscores the importance of developing analytic strategies for word identification and the limitations of simply relying on a memory-based approach. It seems both pragmatic and practical to research alternate strategies for reading instruction with signing deaf learners–strategies that will capitalize on developing analytic links to orthography from the sign language phonological base from which the child is working. In this way, instructional paradigms for deaf learners will better parallel best practice paradigms for hearing learners that focus teaching on how to accomplish the integration of print language with the child's mental representation of language. A longitudinal intervention study incorporating explicit ASL phonological awareness training in preschool and kindergarten would be a first step.

Conclusions

In summary, this study examined the extent to which deaf learners have awareness of phonological structure across three levels of linguistic complexity. The results of this study represent a replication of previous findings of insensitivity to phonological structure at the rhyme and phoneme level in children with severe to profound prelingual hearing losses and extend those findings to a wider age range and to all three levels of linguistic structure. These findings also offer an account for the inconsistent findings reported in the literature with respect to deaf learners phonological awareness skills. That is, it is possible to account for the 'phonological awareness' reported in previous studies without necessarily positing a link to phonology. Further study is necessary to clearly explicate the properties or the nature of the code that is represented and generated by deaf individuals before conclusions of 'phonological effects' can be validated.

The current investigation provides support for the notion that reduced input specificity of seen (speechread) as compared to heard speech is not likely to support deaf children in developing a spoken language phonological system with accurately specified or segmentally organized internal representational structure. The findings of this study then are in line with a growing body of data that suggest that difficulty in establishing phonological structure may influence the ability for segmental processing in recognition which appears to have predictable effects on acquisition, access and retrieval of lexical representations. Consequently, reading instruction premised on developing a speech-mediated link to orthography that is established through a degraded phonological trace is unlikely to support prelingual, severe to profoundly deaf children in literacy development beyond the most rudimentary levels. The results suggest that more global or holistic representational structure may underlie deaf children's difficulty in speed of word recognition. Moreover, ambiguity in the visual and tactile signal may similarly affect the accuracy and speed of deaf children's word recognition.

The struggle with reading is a well documented fact in the lives of most deaf children. Oakhill, Cain and Bryant (2003) suggest that "skilled comprehenders build better-integrated and informationally richer text representations" (p. 444). Similarly, in relation to word recognition it appears that skilled word readers build better-integrated and informationally richer word representations. As Phillips (2002) asserts, the ability to read well depends on how readers employ the evidence available to them. Perhaps the more general debate about the use of spoken language or the use of sign language in the education of deaf children is not as important as turning our research attention to a more detailed investigation of what critical evidence must be available in the input signal to support deaf learners in the process of lexical restructuring and in turn, the construction of rich and robust word representations. Such research may further our understanding of reading and its development for deaf learners and may help to clarify what works, for whom and under what conditions. Importantly for deaf children who use a natural sign language it appears that the available evidence in the input signal does not need to be 'spoken'. Like all children however, the available evidence may need to be "phonological".

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Appendix A Cover Letter, Letter of Information and Consent Form

Cover Letter

Date

Dear Parent/Guardian,

I would like to ask for your participation and your child's participation in a research study examining reading in signing deaf children and adolescents. Please find attached a letter of information describing the nature of the study in more detail. You will also find a consent form, a background questionnaire, and a response envelope. I would greatly appreciate if you could fill out the Consent Form and send it back to the school with your child. A second copy is included for your records. If you agree to participate, I would ask that you fill out the background questionnaire, enclose it in the response envelope and also send it back to school with your child. An envelope has been provided for the questionnaire to ensure confidentiality of your responses.

Please read the attached letter of information carefully. If you have any questions at all that you need answered before making your decision, please contact me by phone at (780) 492-1146 (Voice and TTY) or email . Thank you very much for considering this request.

Sincerely,

Lynn McQuarrie
Doctoral Candidate
Department of Educational Psychology
University of Alberta

Letter of Information

Dear Parent or Guardian,

I am writing to ask for your help in carrying out a research project about signing deaf children's reading skills. The study is intended to obtain more information about the language learning strategies that deaf children who use visual language as their primary receptive channel of communication bring to the task of learning to read. I am an Assistant Professor of Education at the University of Alberta who is completing a doctoral study titled *Reading and Signing Deaf Learners: Investigating the contributions of Sign Language Phonology (ASL) and Spoken Language Phonology (English).* This project is supported, in part, by a doctoral fellowship from the Social Sciences and Humanities Research Council of Canada and a research grant from the David Peikoff Chair of Studies in Deafness, University of Alberta. The project has been reviewed and approved by the Faculties of Education and Extension Research Ethics Board at the University of Alberta. I am asking you to allow your child to participate in the study. Please read the information below. If you agree, please sign the attached sheet ("Consent Form") and return it to your child's classroom teacher in the self-addressed envelope provided.

Some background

Reading is important for success in school and in later life. Yet, in spite of the best efforts of parents and teachers, a majority of deaf learners continue to leave high school reading at or below a 4th grade reading level. Research is widely available outlining the factors that contribute to successful reading acquisition for hearing readers. For example, an understanding that spoken words are made up of component parts (phonological knowledge) is one factor that has been implicated in the development of a reading vocabulary for children who use spoken language for communication. By contrast, we know very little about the specific language factors that contribute to the development of a reading vocabulary for children who use sign language for communication. Interestingly, recent research has demonstrated that signs can be broken down into parts in a systematic manner, much like words in spoken languages can be broken down. However, how this knowledge might support signing deaf children in reading skills development has not been investigated. The purpose of this research is to examine deaf children's reading strategies in relation to the linguistic structures of their sign language.

Current reading instructional methods for deaf students are based on information gained from research on readers who are users of spoken languages. The goals in this study are to provide additional information specific to users of signed languages. It is hoped that this research will provide new insight into the language learning strategies that signing deaf children bring to the task of learning to read. These insights will support the ongoing efforts of teachers in their application of best practice principles in reading education to the learning needs of their students who are visual language users.

About the study

This study provides a first step in investigating the role of visual phonology (phonological knowledge in sign language) in reading skill development for signing deaf learners. The main objective of this study is to investigate the contributions of phonological knowledge of Sign language (ASL) and phonological knowledge of Spoken Language (English) to reading abilities in signing deaf children and adolescents. A secondary objective is to examine the extent to which orthographic (spelling) knowledge supports deaf children in word reading. To do this, we need to select a broad sample of signing deaf children across a range of ages and grade levels and ask them to perform a variety of reading, sign language, and spelling activities. Knowledge of the reading strategies of students of varying ages and reading abilities increases our ability to design reading programs and interventions that optimally support reading skill development for signing learners.

How your child would be involved

If you and your child agree to participate, I will arrange with your child's teacher convenient times when I can visit the school. I would ask your child to come to a room that is free of distractions to do some reading, spelling and sign language activities. A hearing researcher and a deaf research assistant both fluent in American Sign Language will be present throughout the testing. All testing will be administered directly (not through an interpreter) by a fluent signer so that communication is never problematic for your child. The first set of activities will take about 30 minutes. We will return to the school on 2 separate days to do some further language, reading and spelling activities, most of which will be performed on a computer. It is anticipated that the total amount of time for your child will be approximately 90 minutes spread over 3 sessions. I will do my best to ensure that your child enjoys the activities. If he or she loses interest, I will end the session and continue another day. The activities are like everyday school activities, though most are shown on a portable computer and some on a TV screen. I will record the answers your child gives on videotape, and in some cases, record the time an answer takes.

How you would be involved

I will also ask the parents or guardians to complete a brief questionnaire to gather background information on your child (e.g., degree of loss, age of onset, languages used in the home, educational history). This information is important for determining the effect of different characteristics, if any, on the assessment results. With your permission, I will also access student records at school to obtain relevant information regarding the reading process (e.g., current audiological records and SAT-HI achievement scores).

Protection of Confidentiality

It is important to me to protect the privacy of people who participate in this project. Here is what I promise:

- Participation is voluntary, and you may withdraw your child from the study at any time without consequence.
- No names will be used in the data or in any published work. All data collected from you or your child will be assigned a number in lieu of a name and only this number will appear on the tapes, response sheets and computer files. All research personnel will sign a confidentiality agreement.
- Videotapes and written records will be kept in a locked office at the University of Alberta to which only I will have access. Videotaped data will be destroyed upon completion of the study.
- You are not obliged to answer any questions you find objectionable or which makes you feel uncomfortable.
- There are no known risks or discomfort involved in any of these activities.

I will publish my results in academic and professional journals, and give presentation to interested parent and teacher groups. In every case, results will be combined across many participants, so no individual will be identifiable. You can obtain copies of the documentations resulting from this research by contacting Lynn McQuarrie.

Thank you very much for considering this request. If you have any questions at all about the project, please contact me by phone (780-492-1146 voice or TTY) or email (lynn.mcquarrie@ualberta.ca). For questions regarding participant rights and ethical conduct of research, please contact the Chair of the Research Ethics Board at (780) 492-3751.

If you consent to have your child participate, please indicate so in the attached Consent Letter and return it to your child's classroom teacher. Please enclose the questionnaire in the envelope provided and also return it to the teacher who will then deliver the envelope to me.

Sincerely,

Lynn McQuarrie
Ph.D. Candidate
Department of Educational Psychology
University of Alberta

Consent Form

Project Title: *Reading and Signing Deaf Learners: Investigating the contributions of Sign Language Phonology (ASL) and Spoken Language Phonology (English).*

I understand that I am being asked to participate in and to allow my child to participate in the research project entitled *Reading and Signing Deaf Learners: Investigating the contributions of Sign Language Phonology (ASL) and Spoken Language Phonology (English).* I understand that the purposes of the study are: a) to investigate the contribution of phonological knowledge of Sign Language (ASL) and phonological knowledge of Spoken Language (English) to word recognition and reading comprehension in signing deaf children and adolescents and b) to examine the extent to which orthographic knowledge (spelling) supports deaf children in word reading. I have read and understood the Letter of Information, and I have had any questions answered to my satisfaction.

I understand that my participation in this study will take about 15 minutes to complete a questionnaire. My child's participation will take approximately 90 minutes spread over 3 sessions. My child will be asked to complete a variety of sign language, reading and spelling activities. My child's answers will be recorded on paper, videotape or by a computer.

I understand that all data will be kept confidential, that I can withdraw my child and myself from the study at any time, and that I am not obliged to answer any questions I find objectionable or which make me uncomfortable. I understand that there are no known risks, discomforts or inconveniences involved in the study.

I understand that my child and I will not be identifiable in any documents resulting from this research. I also understand that the results of this research will only be used for research dissertation, scientific publications, and presentations to professionals and educators, and that following the completion of the study, any information identifying my child or me will be destroyed. I am aware that I may obtain copies of the documentations resulting from this research by contacting Lynn McQuarrie (lynn.mcquarrie@ualberta.ca). I am also aware that I can contact Lynn McQuarrie at (780) 492-1146 (voice and TTY) or her supervisor, Dr. Rauno Parrila at (780) 492-3696, with any questions or concerns that I may have.

I am aware that this study has been reviewed and approved by the Faculties of Education and Extension Research Ethics Board (EE REB) at the University of Alberta. For questions regarding participant rights and ethical conduct of research, I can contact the Chair of the Research Ethics Board at (780) 492-3751.

Please complete the following and return it your child's classroom teacher in the self-addressed envelope provided.

Name of Child (please print): ______________________________

Grade and School: ______________________________

Name of Parent or Guardian (please print): ______________________

_______ YES, I give permission for my child to participate in this study

_______ NO, I do NOT give permission for my child to participate in this study

Signature: ______________________________

Date: ______________________________

Appendix B Background Questionnaire

FAMILY INFORMATION QUESTIONNAIRE (please print)
Please answer the following questions. Your answers will remain strictly confidential. If, however, there are any questions you would prefer not to answer, just leave them blank.

Name of parent or guardian: ______________________________

Name of child: __________________________________ Male___ Female ___

Birthdate of child (MMDDYYYY) _________________________________

Present School ____

General Family Background:

1. Place an X beside the highest level of education attained by the child's ***father***.
   _____ Grades 1-8
   _____ High School
   _____ Community college
   _____ University
   _____ Graduate or professional studies

2. Father's occupation: ____

3. Place an X beside the highest level of education attained by the child's ***mother***.
   _____ Grades 1-8
   _____ High School
   _____ Community college
   _____ University
   _____ Graduate or professional studies

4. Mother's occupation:____

5. Please identify any other children in the family.
   Siblings:

Age	Sex (M/F)	Deaf/ Hearing
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______

6. Are any other family members/ relatives deaf? ______ If yes, please circle all that apply from the following list:
   Mother/ Father/ Grandfather/ Grandmother/ Aunt/ Uncle/ Cousin/

PLEASE ANSWER THE FOLLOWING QUESTIONS ABOUT YOUR CHILD.

B. Child's visual information:

7. What is the status of your child's vision (normal, myopia, other (specify)?
   ____

8. Does your child wear glasses? YES ____ NO ____
   If yes, do the glasses correct the vision problem? YES ____ NO ____

C. **Child's audiological information:**

9. What was the age of onset of your child's hearing loss?
____ birth
____ Prelingual (prior to age 2)
____ Postlingual (age 3 or older)

10. Do you know the cause of your child's deafness? If yes, please specify

____

11. How old was your child when his/her hearing loss was formally diagnosed?

____

12. What is the extent of your child's hearing loss (unaided in the better ear)?
_____ Profound (91dB +)
_____ Severe (71-90 dB)
_____ Moderately Severe (56-70 dB)
_____ Moderate (41-55 dB)
_____ Mild (27 – 40 dB)

Hearing aid use:
13. Is a hearing aid prescribed for your child? YES ____ NO ____

14. At what age was your child aided? (if applicable)______

15. Does your child currently wear his/her hearing aids?
_____ all the time
_____ most of the time
_____ sometimes
_____ rarely
_____ never or hardly ever
_____ other (specify)

16. Does your child use any of the following assistive listening devices at school?
_____ hearing aids
_____ F.M. system
_____ other (please specify)

D. **Educational Background:**
17. What was your child's first formal educational experience/special training?
(Ageand type of training)______________________________

18. What other educational placements has your child had? Please indicate:
a) the type of educational program (provincial school for the deaf, neighbourhood school - self contained classroom; neighbourhood school - integrated classroom)
b) the language of instruction (e.g., Spoken English (oral); Spoken English with Sign Supports (one of the manually coded English systems); Spoken English with Cued Speech, or ASL)
c) how old he/she was in each program (age)
d) the amount of time your child spent in each program (tenure)

Type of Program	Communication Method	Age/Tenure in Program
__________	__________	__________
__________	__________	__________
__________	__________	__________
__________	__________	__________
__________	__________	__________

E. Communication:

19. What do you consider to be the primary (most often used) language of the home:
ENGLISH______ ASL______ Other (please specify) ______

20. What language do you consider to be your child's primary (most often used) language:
ENGLISH______ ASL______ Other (please specify) ______

21. Is this your child's first language? YES ____ NO ____ If no, please specify
____

22. How do you communicate at home with your child? [Code: 3= always, 2= sometimes, 1=never 8= not sure]

	Mother	Father	Siblings: 1	2	3
ASL	______	______	______	______	______
MCE (with speech)	______	______	______	______	______
Spoken English	___ ___	______	______	______	______
Fingerspelling	______	______	______	______	______
Cued speech	______	______	______	______	______

Comments:____

23. Please indicate the length of time individuals in the family have been using American Sign Language and the amount of training they have had :
Code: [VG=very good; G= good; A=average; P=poor; VP= very poor]

	Mother	Father	Siblings: 1	2	3
Length Of Use	______	______	______	______	______
Amount Of Training	______	______	______	______	______
Fluency	______	______	______	______	______

Comments: ____

24. At what age did your child begin exposure to signing? __________

25. At what age did your child begin speech therapy? __________

26. Does your child use speech? YES ____ NO ____

27. If yes, are you able to understand your child's speech? YES ____ NO ____

28. Could a stranger understand your child's speech without any help from you or a familiar listener? YES ____ NO ____

29. Do you read or share books with your child? YES ____ NO ____
If yes, how often?
_____ Daily
_____ Several times a week
_____ Once a week
_____ Other

30. The number that best describes how *you think* your child feels about reading is:

1	2	3	4	5
(I hate it)	(I don't like it much)	(It's o.k.)	(I like it)	(I love it)

Appendix C SYLLABLE AWARENESS TASK

Cue	Type	Response	Choice	Choice	Choice
car	practice		strawberry	fox	-
door	practice		boat	watermelon	-
snowman	practice		box	rainbow	-
pumpkin	practice		sixteen	bus	-
pen	practice		pizza	dog	button
bus	practice		volcano	fly	rainbow
bird	practice		sixty	carrot	tree
crocodile	practice		chicken	kangaroo	rabbit
monkey	practice		pear	purple	seventeen
shoes	practice		train	lemon	seven
1. umbrella	C – 2syll	P=O	hamburger	van	pear
2. helicopter	C – 2syll		gum	caterpillar	socks
3. butterfly	C – 2syll		fork	dinosaur	glue
4. clown	C – 2syll		spoon	seventeen	computer
5. bug	C – 2syll		cereal	eraser	van
6. dog	C – 1syll		river	box	letter
7. star	C – 1syll		coat	twenty	finger
8. moon	C – 1syll		teacher	mountain	blue
9. yellow	C – 1syll		window	grass	rain
10. zero	C – 1syll		lion	whale	cheese
11. tomato	I – 2syll	O=O	banana	shorts	gloves
12. potato	I – 2syll		cheese	stairs	eleven
13. video	I – 2syll		bread	fruit	radio
14. swing	I – 2syll		mouse	piano	radio
15. street	I – 2syll		friend	family	Indian
16. hospital	I – 1syll		thirteen	elephant	football
17. bridge	I – 1syll		pencil	tongue	coffee
18. horse	I – 1syll		river	green	table
19. open	I – 1syll		body	fish	door
20. hair	I – 1syll		walk	baby	copy
21. school	I	P/O	family	sun	money
22. sandwich	I		comb	taxi	helicopter
23. flag	I		pencil	tongue	lion
24. library	I		piano	ruler	fifteen
25. green	I		letter	dog	river

Appendix D RHYME AWARENESS TASK

Cue		Type	Response	Choice	Choice	Choice
fat		practice		bed	cat	stop
run		practice		sign	ball	sun
hose		practice		nose	wash	ring
shy		practice		tie	zoo	write
hole		practice		blow	roll	phone
hot		practice		more	bat	what
1.	king	No [O+]		blue	cheese	ring
2.	pear	No [O+]		rain	glove	bear
3.	car	No [O+]		tree	star	boy
4.	clown	No [O+]		brown	bear	snake
5.	sock	No [O+]		clock	girl	bed
6.	cry	No [O-]		bed	pie	dog
7.	plane	No [O-]		rain	key	shoe
8.	blue	No [O-]		hand	star	two
9.	four	No [O-]		door	king	milk
10.	tree	No [O-]		star	girl	key
11.	hand	V [O+]		blue	sand	wand
12.	glove	V [O+]		bear	love	move
13.	phone	V [O+]		milk	bone	one
14.	cave	V [O+]		moon	shave	leave
15.	pour	V [O+]		four	sour	hand
16.	roll	V [O-]		king	doll	bowl
17.	bear	V [O-]		tear	hair	foot
18.	boot	V [O-]		cave	fruit	foot
19.	head	V [O-]		read	bed	tail
20.	shoe	V [O-]		ring	toe	blue
21.	boat	T [O+]		jump	coat	pool
22.	talk	T [O+]		dog	walk	car
23.	bed	T [O+]		key	wet	red
24.	night	T [O+]		fight	blue	tent
25.	head	T [O+]		bread	four	yell
26.	plate	T [O-]		bleed	wait	dog
27.	box	T [O-]		pigs	leaf	socks
28.	ghost	T [O-]		cold	plane	toast
29.	bed	T [O-]		pet	head	green
30.	kite	T [O-]		moon	gun	night
31.	read	v and t [O+]		wait	head	bead
32.	cave	v and t [O+]		cough	leave	shave
33.	tail	v and t [O+]		jail	night	tall
34.	kite	v and t [O+]		white	gun	knit
35.	blind	v and t [O+]		find	wind	plant
36.	sour	v and t [O-]		zero	flower	soup
37.	snow	v and t [O-]		cow	toe	store
38.	wait	v and t [O-]		eight	read	walk
39.	chair	v and t [O-]		chain	square	shy
40.	dead	v and t [O-]		tent	read	bed

Appendix E PHONEME AWARENESS TASK

Cue	Type	Response	Choice	Choice	Choice
INITIAL a. strawberry	practice		tiger	think	sour
b. dream	practice		flower	dog	zoo
c. phone	practice		fat	elevator	bat
d. knife	practice		show	you	nose
1. swing	No [O+]		flower	pie	snake
2. milk	No [O+]		bear	key	moon
3. car	No [O-]		key	apple	plane
4. giraffe	No [O-]		rain	jump	purple
5. bed	V [O+]		red	cat	ball
6. foot	V [O+]		fish	milk	boot
7. gym	V [O-]		gum	jam	pie
8. cereal	V [O-]		carrot	star	boat
9. foot	T [O+]		van	farm	pie
10. time	T [O+]		two	name	brown
11. kite	T [O-]		cake	gun	milk
12. gym	T [O-]		apple	chip	jump
13. knee	v and t[O+]		tea	kiss	knit
14. walk	v and t[O+]		write	rug	one
15. kite	v and t[O-]		car	knife	gun
16. red	v and t[O-]		wet	bed	write
FINAL a. coffee	practice		sign	bee	pot
b. bus	practice		face	you	good
17. hat	No [O+]		apple	snake	coat
18. balloon	No [O+]		tree	clown	girl
19. grass	No [O-]		dance	key	bed
20. hockey	No [O-]		cookie	apple	giraffe
21. key	V [O+]		sky	snow	candy
22. moon	V [O+]		tree	train	move
23. movie	V [O-]		rain	baby	pie
24. book	V [O-]		giraffe	boot	magic
25. gun	T [O+]		kite	train	dog
26. walk	T [O+]		milk	car	rug
27. knife	T [O-]		cough	dive	plane
28. plane	T [O-]		bleed	grass	clown
29. pig	v and t[O+]		dog	pin	back
30. cat	v and t[O+]		boat	car	gun
31. snow	v and t[O-]		toe	store	cow
32. box	v and t[O-]		socks	pigs	boy
MEDIAL a. van	practice		bat	mouse	hot
b. gate	practice		test	robot	paint
33. plane	No [O+]		face	bed	dog
34. clown	No [O+]		eye	apple	flower
35. rain	No [O-]		horse	cat	whale
36. coat	No [O-]		ball	rope	eye
37. tail	V [O+]		boat	rain	hair
38. girl	V [O+]		soap	bird	fire
39. soup	V [O-]		mouse	juice	cow
40. bowl	V [O-]		soap	dog	clown
41. foot	T [O+]		phone	tree	book
42. boat	T [O+]		soap	four	moon
43. rain	T [O-]		white	face	moon
44. girl	T [O-]		church	corn	pig
45. moon	v and t[O+]		boat	food	mouse
46. bead	v and t[O+]		leaf	pen	head
47. read	v and t[O-]		dead	wait	cheese
48. pour	v and t[O-]		sour	door	boy

Appendix F PHONOLOGICAL AWARENESS TASK INSTRUCTIONS

SYLLABLE MATCHING TASK

Practices Session Instructions: (English Gloss/ Translation of Instructions)

English Gloss*: I am going to ask you to think about how words sound and how we say words. Spoken words can be long (use examples of familiar words i.e. classmates names that are long – Jonathon, Jeffrey- tapping syllables as the name is said) or short (i.e. Joe, Jill, Mom tapping syllables at the name is said)- . When I say the word 'dog', is that a short word or a long word? What about the word 'cat'? My name is Lynn. Watch when I say my name –it is a short word.. What about your name? ________ (child's name). Is that a short word or a long word? Tap out the syllables of the child's name and your name. Are they the same or different? When you say your name (i.e. Cole) and my name (i.e. Lynn) they [match/don't match,] they are the [same/different] length .Look at this picture. It is a cow. Is that a long or short word? Look at this picture – it is an astronaut. Is that a long or short word? Good – I want you to think about words this way as we play this game.* When the student understood the explanation of short and long words, a practice session was conducted using picture cards.

<u>Syllable practice:</u>

English Gloss: *We are going to play a game with words. I will show you pictures to help you remember the words. I want you to think about whether the words are long or short.*

1. Identifying long and short words:

Four sets of picture pairs [porcupine – man; calendar – dress; egg – alphabet; thumb – holiday] Picture cards were laid out in pairs. The student was asked to point to the picture of the long word or short word. They identified 2 long words and 2 short words. Feedback was given after each response.

2. *Matching long –long and short –short*

Three sets of picture pairs were presented in pairs [cow – rat; calendar – porcupine; witch – dragon; egg- astronaut]. This time the question asked of the child was *"are these words the same length?"* The student indicated yes or no through Sign. Feedback was given after each response. One set of picture triplets was laid out [watermelon, dad, elevator]. The student was asked to find the word that matched the cue picture in word length. English Gloss: *.Look at these three pictures (watermelon, dad, elevator) Think about the word "watermelon"? Is that a long word or a short one? Think about the word "dad' and the word 'elevator'. Is "dad" a long word or a short word? What about the word "elevator"? Which word - 'dad or elevator'- is the same length as the word watermelon?* The student identified the correct match by pointing to the correct picture. Feedback was given after each response. If the student was incorrect*: The word watermelon has 4 parts/syllables to it. Watch me say the word. Tap out the syllables of the word while saying it. Try it with me. Watermelon (tap and say). The word "dad" is a short word –dad only has one syllable. Tap out the syllable of the word dad' while saying it. Try "elevator" with me and let's count how many syllables it has.* Tap out the syllables of the word 'elevator' with the student. *Watermelon is a long word – it has 4 taps, dad is a short word it has 1 tap, elevator is a long word, it has 4 taps. So Elevator (4) is the same length as Watermelon (4).* If correct: *Good. I want you to think about words in this way when we do it on the computer.*

RHYME MATCHING TASK

Practices Session Instructions: (English Gloss/ Translation of Instructions)
English Gloss: *Do you know what the word "rhyme" means? This is when two words sound the same at the end. Look at these two pictures. This is 'bat' and this is 'rat'. Bat and rat are rhyming words – they sound the same at the end. Watch my mouth. What do you notice when I say the words? Yes... 'bat' and 'rat' look the same-they have the same mouth shape at the end. Rhyming words are words that sound the same at the end and that means they look the same (mouth shape) at the end too. Now look at these two pictures. This is a 'cat' and this is '3'. Do these words rhyme? No, they do not sound the same at the end. Watch me say 'cat' and 'three'. Do they look the same at the end? No. (point out difference) So- Cat and Three do not rhyme.*

Show pictures of 'bat' and 'rat' again. Print the words bat and rat. *What do you notice about how these two words are printed? That's right, they have the same letters at the end. Sometimes rhyming words that sound and look the same at the end will have the same letters at the end like "bat' and "rat". Look what happens when I change the "b" to a "c"...we get cat. Can you think of any other words that end like cat, bat and rat? Sometimes rhyme words are spelled the same at the end. But – you need to be careful. Lots of rhyme words are not spelled the same at the end. Look at these two pictures. This is "fox" and this is "rocks". Fox and rocks sound the same at the end. Watch my mouth. What do you notice when I say the words? Yes – these words look the same at the end. But look at how they are spelled (print words for student). They do not have the same letters at the end. Fox and rocks are rhyming words – they sound and look the same at the end but they do not end with the same letters. Can you think of another word that rhymes with fox and rocks? Now look at these two pictures. This is 'fork' and this is 'truck'. Are fork and truck rhyming words? Watch me say the words. Do they look the same? No, they do not look the same. They have the same final sound at the end but they do not rhyme. Look at how they are printed (print words for student). Both words end with the same letter and have the same final sound /k/ but they do not rhyme. This will make it a little bit harder, so think carefully about your choice.* When the children understood the explanation of rhyme, a practice session was conducted using picture pair cards.6 pairs of picture were shown individually.

<u>Rhyming Practise:</u>
English Gloss: *We are going to play a rhyming game. I will show you pictures to help you remember the words. I want you to think about rhymes and how the words sound the same at the end.* Pictures were presented in pairs. The question asked of the student was *"Do these words rhyme?* The student indicated yes or no through Sign. Two of the rhyme pairs had similar orthography (leg-egg; lock-rock), two of the rhyme pairs did not (thumb – Mom; stair - where) and 2 of the pairs did not rhyme (dress- fish; bird-frog]. Feedback was given after each response. If the student was incorrect: *That is not the right choice.* Example: *dress and fish do not sound the same at the end. They do not rhyme. Watch me say the words. Do these words look the same at the end? Try it with me.* Print the words. *Can you tell me what the end sound is for each word? That's right, "dress" has a /ess/ sound like the word mess or less. and fish has a /ish/ sound like dish or wish. Try to think about the end sounds of the words.* If correct: *Good. I want you to think about words in this way when we do it on the computer.*

PHONEME MATCHING TASK (INITIAL, FINAL, MEDIAL POSITIONS)

Practices Session Instructions: (English Gloss/ Translation of Instructions)

Part 1: Initial Sounds

English Gloss: *This time I want you to think about the sounds words make at the beginning and at the end and in the middle. Let's try thinking about beginning sounds.*

. I will show you pictures to help you remember the words .This is a picture of a 'light'. Light starts with the /l/ sound. Now look at these two pictures. Point to the pictures and say, "This is "fish", this is "lemon". This one is 'light'. The word light starts with the /l/ sound. Which of these words starts with the /l/ sound like light: fish or lemon?

If the student is correct: *"that's right, light and lemon start with the same sound, /l/. Lets' try the next one".* If incorrect: *"that's not quite right. The answer is lemon, because light and lemon (emphasize the first sound) start with the same sound, /l/. Can you think of some other words that start like light and lemon? (i.e. laugh, Lynn, love) Let's try another one.* Two additional practice items were presented using the same phrases as above and substituting the new words.

Practice items:

1. bird, banana, frog
2. peach, cow, paper

Part 2: Final Sound

Now let's think about the final sounds – the very last sound in a word. Look at the first picture. This is 'bird'. Now look at these 2 pictures: 'frog' and 'Dad' (point to pictures and name them). The word bird ends with the /d / sound. Which of these picture words ends with the /d / sound like bird – Frog or Dad?

If the student is correct: *that's right, bird and Dad end with the same sound, /d /. Lets' try the next one.* If the student is incorrect: *That's not quite right. The answer is Dad, because bird and Dad (emphasize the last sound) end with the same sound, /d/. Let's try another one.* Two practice items were presented using the same phrases as above and substituting the new words.

Practice items:

3. carrot, snowman, rabbit
4. bus, dog, dress

Part 3: Middle Sound

Let's think about the middle sounds this time. Look at the first picture. This is a 'Man'. Now look at these 2 pictures: 'rat and fish' (point to pictures and name them). The word Man has an /a/ sound in the middle. Which of these words has an /a/ sound in the middle like man - rat or fish? Point to the pictures as you say the names. If the student is correct: *that's right, man and rat have the same /a/ sound in the middle. Lets' try the next one.* If incorrect: *That's not quite right. The answer is rat, because man and rat (emphasize the middle sound) have the same middle sound, /a /. Let's try another one.*

Two practice items were presented using the same phrases as above and substituting the new words. Three practice items were presented using the same phrases as above and substituting the new words.

Practice items:

5. train, frog, nail
6. thumb, boat, Mom