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Investigating the Role of Phonological Awareness on Phonological Recoding During Reading in Deaf Children

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Investigating the Role of Phonological Awareness on Phonological Recoding During Reading in Deaf Children

by

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Abstract

Investigating the Role of Phonological Awareness on Phonological Recoding During Reading in Deaf Children

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This study uses eye-tracking to investigate the role of phonological awareness on phonological recoding during reading in deaf and hard-of-hearing (DHH) children who predominantly use sign language as compared to typically hearing children. Phonological recoding is one of the earliest strategies employed in reading, in which the reader maps each grapheme directly to the corresponding speech sound of the language (Jared, Levy, Ashby, and Agauas, 2015). Many DHH children struggle with reading, and the severity of the delays in some children increase with age. Although there are a few studies examining the eye-patterns during reading in DHH adults, there are considerably fewer studies examining phonological recoding and the role of phonological awareness during reading in DHH children (Belanger, Baum, and Mayberry 2011; Belanger, Rayner, and Mayberry, 2013). This study will be testing influence of the visual language signal on reading in deaf children.

I compare phonological awareness skills of English, ASL, and mouthing gestures to reading fluency, measured via eye-movement patterns when reading a sequence of sentences an eye-tracker. Sentences are manipulated to target phonological recoding during reading by altering target words embedded in the sentence in three experimental conditions: no change, homophone foil, and spelling control (Jared et al. 2015). Preliminary results indicate that deaf signers are proficient readers and seemingly rely on ASL skills to read. In addition, I suggest that deaf signers do not participate in phonological recoding.

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1. INTRODUCTION

Nationally, deaf adults on average achieve a 4th grade reading level, in contrast to the 9th grade average for hearing adults (Trybus & Karchmer 1977; Wolk & Allen 1984; Dew 1999; Easterbrooks & Beal-Alvarez 2012). Nonetheless, some deaf children become successful readers with little or no access to sound (Miller 2001). Instead, young deaf readers seemingly take advantage of multiple visual cues in their environment during literacy development. For deaf children in the U.S., these visual language experiences typically include American Sign Language (ASL), fingerspelling, written English, and English mouthing gestures. Various researchers contend that English speech-sound phonology plays a key role in reading development in deaf children (Harris & Beech 1998; MacSweeney, Waters, Brammer, Woll, & Goswami 2008; Paul 1998), although this view is countered by others (Allen, Clark, del Giudice, Koo, Lieberman, Mayberry, & Miller 2009; Mayberry, del Guidice, & Lieberman 2011; Petitto, Langdon, Stone, Andriola, Kartheiser, & Cochran 2016; McQuarrie & Parrila 2014). Indeed, some evidence suggests speechreading skills are most predictive of successful reading in deaf children (Harris & Beech 1998). Scholars have suggested that native ASL fluency predicts greater proficient reading (Pettito et al. 2016), and many studies have demonstrated a correlation between ASL fluency and reading skill (Mayberry et al. 2011; Stone, Kartheiser, Hauser, Petitto, &

Allen 2015). Currently, we lack studies that address the contribution of various aspects of the visual signal to deaf children's reading. Without such work, we fail to consider critical parts of a deaf child's daily communication.

Some scholars suggest that DHH children struggle with literacy acquisition due to a lack of phonological awareness of spoken English, and that learning to speechread and speak will provide sufficient English phonology for successful literacy acquisition (Burden & Campbell 1994; Leybaert & Alegria 1995). Indeed, multiple researchers suggest that DHH children with greater speech and speechreading skills are also the most fluent and skilled readers (Wang, Trezek, Luckner, & Paul 2008, Harris & Beech 2006; Alegria, Charlier, & Mattys 1999). Meanwhile, other authors suggest that claims about reliance on spoken English phonology are overstated even in the literature on typically hearing children (Camilli, Wolfe, & Smith, 2006; Hammill & Swanson, 2006; Share, 2008; Allen et al. 2009). Various reports in fact indicate that deaf readers process written words as efficiently as hearing readers (Miller 2001; Miller 2009; Wauters, von Bon, & Telling 2006) with only modest correlations between English PA and reading skill for Deaf readers (Mayberry, del Giudice, & Lieberman 2011; Chamberlain, 2002; Harris & Beech, 1998). Similarly, native signing deaf children with poor speechreading skills have comparable literacy outcomes to the strongest speechreaders (Allen et al. 2009; Hoffmeister 2000; Strong & Prinz 1997).

There are a multitude of approaches for educating deaf children in this country, especially regarding language choice in the classroom. There is a growing tendency towards bimodal bilingual education in which subject matter, including reading and writing, are taught in ASL (Andrews, Byrne, & Clark 2015). In contrast, many educators and researchers argue that the aural/oral method of instruction, which prioritizes speaking and reliance on residual hearing, helps DHH children acquire spoken a foundation of English phonology. Scholars suggest that English knowledge foundation provided by lip reading and speaking benefits later literacy acquisition (Wang et al. 2008). This method of instruction has been thought to benefit later learning of written English. It is worth noting that, in contrast to typical acquisition of spoken English or ASL, speechreading provides only partial visual access to spoken phonology, with the best speechreaders missing at least one third of the linguistic stream (Leybaert 2000); this may not allow for robust development of spoken language phonology for DHH students (Mayberry & Lock 2003).

Phonological awareness skills, the metalinguistic awareness of basic units of speech and the ability to consciously manipulate the linguistic units within words and sentences (Liberman & Shankweiler 1985; Wagner & Torgesen 1987; Castles & Coltheart 2004), have been shown to be a strong predictor of reading skill in typically-developing hearing children (Goswami & Bryant 1990). However, our understanding of the processes by which deaf and hard of hearing children learn to read is vague at best. Though some investigations have shown a positive association between reading and spoken language phonological awareness in deaf children (Campbell & Wright 1988; Dyer, MacSweeney, Szczerbinski, Green & Campbell 2003), others have failed to find such a correlation (Izzo 2002; Kyle & Harris 2006; Leybaert & Alegria 1993; Miller 1997).

The current paper discusses a specific investigation into the role of visual language processing skills and phonological awareness on phonological recoding during reading in deaf and hard of hearing children. I investigate the route of word activation in deaf signers and oral/aural deaf during early reading. There have been two proposed routes for word meaning activation during reading: the phonological/indirect route and the whole-word/direct route (Jared, Ashby, Augauas, & Levy 2015). This model of meaning activation was originally referred to as the Dual Access model (Glushko 1979), and later as the Developmental Bypass Theory (Pennington, Lefly, Van Orden, Bookman, & Smith 1987). Evidence of phonological recoding is suggestive of the indirect phonological route of meaning activation (i.e *cat* activates the phonological representation /kæt/), which in turn activates the meaning (i.e. *small, four-legged, furry animal that chases mice*). Phonological recoding is the process of directly mapping individual graphemes in written English to the corresponding speech sound. Most empirical evidence has suggested that typically hearing children begin reading via phonological recoding, which is later replaced by an automatic process of meaning activation (Share 1995, 2008).

The direct, whole-word route of activation bypasses the level of phonology and the written word directly activates the word meaning (i.e. *cat* activates *small, four-legged, furry animal that chases mice*). In typical literacy acquisition, the indirect phonological route of activation will eventually be replaced by the automatic word activation of the direct route (Pennington et al. 1987; Jared, Levy, & Rayner 1999; Jared et al. 2015). Fluent adult readers typically employ the direct route of activation, though unfamiliar or low-frequency words may require some phonological recoding (Glushko 1979; Adams, 1990; Share 1995, 2008).

A recent model of reading proposed by researchers at Gallaudet University suggests that deaf children should find success in learning to read with proper language input, independent of modality of the language input. This model expands the necessity of phonological skill required for reading fluency to include visual signed phonology (VSP). VSP is the "multidimensional development of the abstract level of language organization called phonology, here, in the visual modality" (Petitto et al. 2016; 2). VSP is proposed to be comprised of the silent segmental units of the variety of aspects of visual language acquired by deaf children, such as fingerspelling, speechreading gestures, and sub-lexical ASL and English skills (Petitto et al. 2016). The authors argue that the crucial link for successful early reading is not between letters and speech sounds, but between the written word and the abstract level of language organization called phonology. This project aims to test the phonological deaf skills provided by the various aspects of visual language streams experienced by deaf children, to better understand which language experiences provide the basis for literacy acquisition. The current study is part of a larger investigation of factors available in the visual language signal that contributie to literacy acquisition in deaf students. For the current project, I investigate the role of phonological awareness of English, English speechreading gestures, and ASL, on literacy acquisition. I intend to gain a better understanding of which aspects of the visual language signal provide the foundation and segmentation skills required for fluent and competent reading.

I aim to further our understanding of the link between the visual phonological skills acquired by the uniquely visual linguistic signal and the ability to read. Further, I hope to provide a better explanation of the phonological processes employed during reading in deaf children. To do so, I use eye-tracking technology to investigate the reading fluency of early-reading deaf native signers and orally-trained deaf students, as compared to hearing controls. I compare patterns of eye-movements to various measures of phonological awareness of English, ASL, and English speechreading gestures to measure the contribution of each language on reading fluency and understand which aspect of language best predicts reading fluency.

To target route of meaning activation during reading, I employ eye-tracking technology to investigate the degree of disfluency during reading across three experimental conditions. Eye-tracking is a useful tool for understanding the cognitive processes underlying many behaviors including reading (Rayner 2009). Many studies investigate reading patterns in typically hearing children and provided great insight into the cognitive processes underlying reading by measuring eye-movement patterns (Jared, Levy, & Rayner 1999; Rayner, Chace, Slattery, & Ashby 2006; Rayner 2009). To date, the few studies that do use eye-tracking to investigate eye-movement patterns in deaf children involve investigations of the visual processes underlying ASL comprehension (Thompson, Emmorey, & Kluender 2006) and real-world visual attention (Szarkowska, Krejtz, Klyszejko, & Wieczorek 2011). Studies with deaf adults have indicated that skilled deaf readers make greater use of parafoveal information when reading, increasing their words per minute reading rate over skilled hearing readers (Belanger & Rayner 2015) and that reading difficulties in deaf adults are not due to underrepresentation of phonological codes (Belanger, Baum, & Mayberry 2012). To date, however, no published studies utilize eye-tracking to investigate reading patterns in deaf children. This project will leverage eye-tracking technology and combine the resultant data with independent measures of PA for ASL and English.

For the purposes of this paper, I begin by framing the theoretical background of this project. I first discuss early reading in typically hearing children, followed by a description of two of the main perspectives regarding literacy acquisition in deaf children. One such group of theories suggests that phonological awareness, specific phonics instruction of English, and speechreading skills are required for literacy in deaf children (Wang et al. 2008; Harris & Beech 1998; Mohammed, Campbell, Macsweeney, Barry, & Coleman 2009). The other perspective suggests that phonological awareness is involved in the process of learning to read, though it is neither essential nor is a lack of spoken English phonological awareness detrimental to the process of learning to read (Allen et al. 2008; Petitto et al. 2016; McQuarrie & Parrila 2014). In this section I also address the model of literacy acquisition proposed by Pettito and colleagues (2016) which suggests that phonological awareness can be fueled by visual language. Following this, I briefly discuss the literature pertaining to literacy and eye-tracking. I go on to discuss the background of the study at hand, development of stimuli and methods, and early results. Lastly, I discuss the preliminary results and future directions of the project.

1.2 Early reading in typically-developing hearing children

Before any discussions of the specifics of reading, I must first discuss two proposed routes of reading, stemming from The Developmental Bypass Theory. This theory, in part based on the Dual Access model first proposed by Glushko (1979) suggests that reading acquisition begins with phonological recoding, but is later replaced by faster, direct activation of word meaning from print (Pennington et al. 1987). Phonological recoding is an early reading strategy employed by readers in which each written letter is recoded into the corresponding speech sound. Early reading employs the indirect route, which relies heavily on phonological recoding. According to this model, the reader sees the visual representation of the word, which activates the phonological representation of the word (e.g. the written word *cat* activates the phonological representation /kæt/). The phonological representation in turn activates the word meaning (e.g. /kæt/ activates *small, four-legged, furry creature that chases mice*). The direct route, however, bypasses the level of phonology, and the written word directly activates the word meaning (e.g. the written word *cat* activates *small, four-legged, furry creature that chases mice*; Pennington et al. 1987; Jared et al. 1999; Jared et al. 2015).

Early reading in typically hearing children appears to be marked by phonological recoding and relies on the alphabetic principle. The alphabetic principle is the knowledge that words are comprised of letters, and that letters correspond to speech sounds (Liberman, Shankweiler, & Liberman 1989; Wang et al. 2008). It has been shown that beginner readers do partake in phonological recoding (Grainger et al. 2012; Share 1995), which is a slow, effortful process of phonological recoding of individual graphemes to speech sounds. This process becomes automatized as exposure increases. It has been shown that the time it takes to read an individual word decreases with each exposure to that word (Share 1995). This automatic process has been proposed to be minor to phonological recoding, as experienced readers will employ phonological recoding when encountering unfamiliar or low-frequency words (Jared et al. 2015; Glushko 1979). Further, early reports showed that pre-reading phonological awareness skills were the greatest predictor of reading fluency outcomes (Lundburg, Olofsson, & Walls 1980). More recently, investigations have shown that children with poor pre-reading phonological skills become less skilled readers later in life (Bowey 2005; Stanovich & Siegel 1994; Goswami & Bryant 1990; Goswami 2000).

Some scholars suggest that the process of learning to read is impossible without the child first developing complete control of the oral language and complete knowledge of the phonological system of that language (Muter, Hulme, Snowling, & Stevenson 2004). Early phonological skills are often shown to be the greatest predictor of future reading outcomes, and many believe that the only way to become a fluent, adult-like reader is to have complete development of an auditory phonological system (Castles & Coltheart 2004; Lundburg, Olofsson, & Walls 1980; Elbro 1996). Due to this, current practices of early reading instruction rely heavily on letter-to-sound correspondences, in which children are taught explicitly that the written letters *b* + *a* + *t* create the spoken word "*bat*" (National Reading Panel, 2000).

There are, however, myriad reasons why this method of instruction may be inadequate or indeed inappropriate for some early readers regardless of hearing status. Most importantly, letter-to-sound correspondence does not sufficiently target how the language sounds, particularly in English. One study demonstrated that the strongest predictor of later reading outcomes is awareness of onset-rime units in the language, not the individual speech sounds of a language (Goswami & Bryant 1990; Goswami 2000). Onset-rime awareness is the ability to understand and distinguish the first unit of sound of a word (i.e. *c* in *cat* or *str* in *string*) and the final vowel-consonant cluster (i.e. *at* in *cat* and *ing* in *string*). In an early meta-analysis study, Goswami and Bryant (1990) were able to show that children with superior onset-rime knowledge were able to generalize their knowledge to read unknown words. So, if a child is able to read the words *cat* and *mouse*, they will be able to generalize the rime of *cat* and the onset of *mouse* to read the unfamiliar word *mat* (Goswami & Bryant 1990). This study was a major deviation from the previously-held standard of letter-to-sound correspondence knowledge as the strongest predictor of reading success.

In addition, phonological recoding and reading based on the alphabetic principle cannot be the gold standard of all early reading. Consider the various writing systems of the world that are not alphabetic. Many systems are character-based, such as Chinese, in which there is minimal correspondence between the written character and the phonological representation of the word. Acquiring literacy skills of a logographic system appears to require orthographic awareness, not necessarily phonological awareness (Tan, Spinks, Eden, Perfetti, & Siok 2005; Dye, Hauser, & Bavelier 2008). Studies have investigated the role of phonological recoding in early Chinese readers based on the fact that Chinese children learning Mandarin in school transition from whole-word reading of characters to phonological recoding of the alphabetic system pinyin (Siok & Fletcher 2001). Children learning to read the Chinese character system are able to find notable success despite beginning to read without phonological recoding. This suggests that phonological recoding does not necessarily need to be taught prior to the ability to employ whole-word reading.

Further, visual processing skills have been shown to correlate highly with reading fluency in children learning to read logographic/character systems. One study compared phonological and visual processing skills in 3rd graders from Britain, Hong Kong, and Taiwan. Results showed that visual processing skills correlated highly with reading fluency in children from Hong Kong and Taiwan, but not in children from Britain (Huang & Hanley 1995). In fact, brain areas recruited during reading logographic systems are quite dissimilar to those of alphabetic systems. Tan and colleagues (2001) demonstrated that right hemisphere activation is significantly stronger for native speakers and readers of Chinese as compared to native speakers and readers of English. The authors suggest that this is due to specific analysis of spatial characteristics of logographic systems. This may be quite similar to the spatial analysis of ASL, considering the enhanced visual-spatial skills acquired via sign language fluency (Belanger & Rayner 2015).

Similarly, many alphabetic systems vary in the degree to which letters correspond to speech sounds of the language. As outlined by Bar-Kochva and Breznitz (2014), there have been a few studies investigating the difference in reading shallow and deep orthographies. Deep orthography refers to a writing system in which sounds do not correspond exactly to the written letter. Shallow orthographies, however, have almost 1-to-1 mapping of sound to letter. Compared to other alphabetic systems, English has a deep orthography with inconsistent mappings of speech sounds to letters (eg. 'gh' in 'through', ‘ghost’, and ‘enough’; ‘p’ in ‘parrot’, ‘pterodactyl’, and ‘phantom’) compared to shallow alphabetic languages in which each letter corresponds to a single speech sound, such as Italian. In brain imaging studies, it has been shown that reading deep orthographies shows stronger activation in areas associated with irregular word reading and whole word retrieval (left posterior inferior temporal gyrus and anterior inferior frontal gyrus). However, when reading the shallow orthography of Italian, the areas of the brain associated with phoneme processing were active (left superior temporal regions; Bar-Kochva et al. 2014). While these studies did not target the process of learning to read, these findings suggest that reading of English does not necessarily require or even fully involve phonetic processing but instead whole word processing. Similar conclusions were drawn based on a study of event-related potentials (ERPs) in French monolinguals and French-Arabic bilinguals. When reading French, both groups had activation in the area of the brain associated with spelling-to-sound conversion. However, the bilingual participants no longer showed the same activation when reading dialectal Arabic, which has a far deeper orthography than French, as Arabic writing systems often do not include vowels (Bar-Kochva & Breznitz 2014).

1.3 Early reading in deaf populations

Within the literature, there are many debated theories surrounding literacy acquisition in deaf students. With regards to this paper, I will discuss the two major perspectives regarding deaf education, referred to as Perspective1 and Perspective 2. Perspective 1 considers phonological awareness and phonic skill to be essential to literacy acquisition. These scholars suggest that optimal reading fluency is gained from visual phonics instruction and adherence to the National Reading Panel guidelines of instructing speech sound to letter correspondence for all students regardless of hearing status (see Wang et al. 2008 for a review of the theories). Perspective 2 in contrast suggests that phonological awareness is not essential for deaf (or hearing) children to learn to read and that there is little evidence of phonological coding in deaf readers (see Allen et al. 2008 for a review of the theories).

1.3.1 Perspective 1: Reliance on phonological coding in deaf readers

Central to this school of thought is the Qualitative Similarity Hypothesis. This hypothesis suggests that deaf students learning to read should follow a process that is qualitatively similar to that of hearing peers, though quantitatively delayed (Paul 2001; Paul 2008). This hypothesis has been supported by a plethora of data indicating that deaf children follow the same sequence of language skill development with similar method of instruction as hearing peers (King & Quigley 1985; Leybaert 1993; Mayer 2007; Paul 1998, 2003; Schirmer & McGough 2005; Williams 2004). Following the qualitative similarity hypothesis and the conclusions drawn by previous studies, researchers in Perspective 1 suggest that the best practice for teaching deaf children to read should follow the National Reading Panel, considering that the process of literacy acquisition is qualitatively similar for deaf children. The NRP advocates for phonics instruction and heavy reliance on 1-to-1 correspondence of letter to sound to instruct reading for all students. The NRP further suggests that there are certain fundamentals of literacy that apply to all children learning to read. Thus, the foundations of reading instruction will be qualitatively the same, though perhaps slightly delayed in deaf populations.

In a summary article published in 2008, Wang and colleagues discuss a meta-analysis of various studies investigating phonemic skill and phonological awareness in early deaf readers. This article suggests that the most successful deaf readers are those with greater phonological awareness of spoken English, and that specific instruction of English phonics is ideal for literacy outcomes. Central to their theories is the reliance on phonics for literacy acquisition, following the suggestions of the NRP. A lack of fundamental phonics instruction has been implicated as the cause of life-long reading difficulties for all children (Narr 2008; Trezek & Malmgren 2005; Trezek & Wang 2006; Trezek, Wang, Woods, Gampp, & Paul 2008). However, some investigations suggest that visual phonics instruction can provide sufficient phonics knowledge for deaf children to find success in reading.

See the Sound (STS) and Visual Phonics (VP) are multisensory systems of hand cues and corresponding written symbols that represent aspects of the phonemes of a language and grapheme-phoneme relationship, devised as an abstract, modality-independent method of conveying phonemic units so that deaf students are able to better conceptualize spoken phonics (Narr 2008; Trezek & Wang 2006; Trezek et al. 2007). These systems were developed as a method of manually representing English phonemes and syllable structures with the hands and face. Central to these systems is the suggestion that multisensory feedback from tactile (articulatory), visual (speechreading), and kinesthetic (hand motion) information can sufficiently bypass the lack of auditory information and supply phonics awareness in a way that is more appropriate for deaf students (Cornett 1967).

According to scholars supporting Perspective 1, the majority of struggles during literacy acquisition in deaf students is a direct result of a lack access to spoken English phonology (Leybaert 1993, 2005). Some studies have shown that only deaf students with better speech skills showed orthographic regularity effects in reading (Hanson 1986) and deaf students with intelligible speech skills are more sensitive to regularity effects in reading (Leybaert & Alegria 1995).

One visual source of phonological information is speechreading. Many scholars have suggested that the information derived during speechreading may provide the basis for input for a phonological code of English in deaf children (Burden & Campbell 1994; Dodd 1980; Leybaert & Alegria 1995), and that speechreading may act as a proxy for phonological awareness or the distinctness of the phonological representation. Indeed, many studies have demonstrated that higher speechreading skills predicts greater reading fluency (Arnold & Kopsel 1996; Campbell & Wright 1988; Geers & Moog 1989; Kyle & Harris 2006) and deaf adults (Mohammed, Campbell, MacSweeney, Barry, & Coleman

2006). Further, recent investigations have shown that phonological awareness and speechreading skills are correlated in deaf children, and that there is a strong relationship between speechreading and phonetic spelling errors in both good and poor deaf readers (Kyle & Harris 2006).

It is important to distinguish between epi-phonological awareness and meta-phonological awareness attained by speechreading. It has been suggested that investigating English phonic knowledge at the epi-phonological level, i.e. sensitivity and implicit knowledge of linguistic units, as opposed to the meta-phonological level, i.e. the ability to explicitly identify and manipulate phonological units, is a more appropriate measure of phonological awareness of English in deaf readers (Harris & Beech 1998). It has been demonstrated that deaf readers are able to make correct rhyming judgements in written English words, as well as generate correct English rhymes regardless of orthographic structure (Charlier & Leybaert 2000; Hanson & McGarr 1989).

However, some very poor speechreaders are excellent readers, and some excellent speechreaders are poor readers (Kyle & Harris 2006). It is clear that speechreading benefits some deaf readers but may be insufficient for all deaf children. Speechreading conveys only a partial coding of a language and is insufficient for deaf children to extract regularities of English word forms and phonological representation (Leybaert 2000). For example, it is almost impossible to distinguish between the words *bat*, *pad*, and *mat* while speechreading because the onset of each word has the same place of articulation, which is the most visually salient component of speaking (i.e. bilabial for /b/, /p/, and /m/), and the same place of articulation for the rime (i.e. identical vowel shape /æ/ and alveolar final consonant). Further, while demonstrating that speechreading is correlated with phonological awareness, Kyle and Harris (2006) showed that speechreading alone is predictive of reading skill, not phonological awareness. Due to this, many researchers consider the adherence to phonological awareness as a predictor of reading in deaf children (and hearing children as well) to be overstated (Allen et al. 2009; Camilli, Wolfe, & Smith 2006; Hammill & Swanson 2007; Share 2008).

1.3.2 Perspective 2: deviation from phonological awareness in deaf literacy

The second school of thought behind theoretical issues in deaf literacy considers reliance on phonological awareness for children to learn to read to be overstated in the literature for deaf and hearing readers (Allen et al. 2009). Indeed, many reports demonstrate little or no evidence of phonological coding in deaf readers (Campbell & Wright 1988; Chamberlain 2002; Harris & Beech 1998; Izzo, 2002; Leybaert & Alegria 1993; Miller, 2007a). Further, it may be the case that literacy struggles in deaf populations have been overstated as well. Many reports in fact indicate that deaf readers process written words with hearing-comparable efficiency (Miller 2001, 2009; Wauters, von Bon, & Telling 2006) and that native signing deaf children with poor speechreading skills have comparable literacy outcomes to the strongest speechreaders (Allen et al. 2009; Hoffmeister 2000; Padden & Ramsey 1998; Strong & Prinz 1997; McQuarrie & Perrila 2014).

In a meta-analysis done by Allen and colleagues (2009), general language ability emerged as the strongest pre-reading predictor of reading fluency. A later meta-analysis demonstrated that English phonological awareness and sound phonological decoding skills do not strongly predict reading proficiency in deaf individuals (Mayberry, del Giudice, & Lieberman 2011). These meta-analyses have shown phonological coding predicted reading fluency no better than speech intelligibility, age, IQ, and memory span. All of these are contributing factors to literacy but are not as strong a predictor of reading as general linguistic skill. Similarly, early reading strategies employed by native signing deaf children allow for effective processing of written words at the lexical level, even in poor deaf readers (Miller, 2006c). It may be that lexical processing is central to literacy, considering phonological awareness and decoding impact reading comprehension by enhancing lexical processing of written words (Vellutino, Fletcher, Snowling, & Scanlon 2004).

According to Allen and colleagues (2009), the most essential contribution to literacy acquisition in deaf children stems from an effective communication system at home. General language comprehension skills are strongly associated with signing skills, not oral skills, in deaf children (Harris & Beech 1998). Signed Exact English (SEE) and ASL signers have less language skill variation than oral/aural deaf. Considering these observations, it has been suggested that the language skills acquired by one language (i.e. ASL or SEE) can bypass the performance form, signed or spoken, of the target second language and result in fluency. Essentially, deaf children are theoretically able to use their knowledge of a signed language to benefit acquisition of written English (Luckner & Handley 2008; Luckner, Sebald, Cooney, Young, & Muir 2005, 2006; Moores 2008;

Schirmer & McGough 2005). Together, theories and findings provided by camp 2 suggest that native sign language input results in the most efficient and complete general language skills, considering that literacy outcomes and general language outcomes are more homogenous.

Surprisingly, the correlation between ASL phonological awareness and reading skill in deaf students has not been thoroughly established in the literature. It has been theorized repeatedly that native access to ASL results in optimal literacy acquisition (Petitto et al. 2016; Conrad 1979) and that ASL provides the necessary first-language foundation upon which a second language (i.e. written English) can be built (Mayberry & Lock 2003), though few empirical studies have been conducted in support of this theory. There has, however, been a recent push in the field to further our understanding of the influence of early exposure to ASL, and a fully developed phonological system, on reading. Only within the last 15 years have studies begun to analyze the correlation between reading skills and ASL fluency.

1.4 Visual Sign Phonology

In a recent meta-analysis of reading in deaf children, researchers at Gallaudet proposed a modified model of reading specifically addressing the issue of phonology in deaf readers. This was a major push towards further understanding the role of visual language input (including ASL fluency) in the development of reading skills in deaf children. Researchers initially began theorizing this model following data showing that deaf and hearing individuals tend to create a homologous level of phonological organization in the brain, despite the fact that deaf individuals have little or no access to speech sounds. In this model, Petitto et al. (2016) propose a distinction between auditory-specific phonology and visual phonology, suggesting that the component of phonology in the original Harm and Seidenberg model (figure 1) can be supplied by universal phonology (see figure 2).

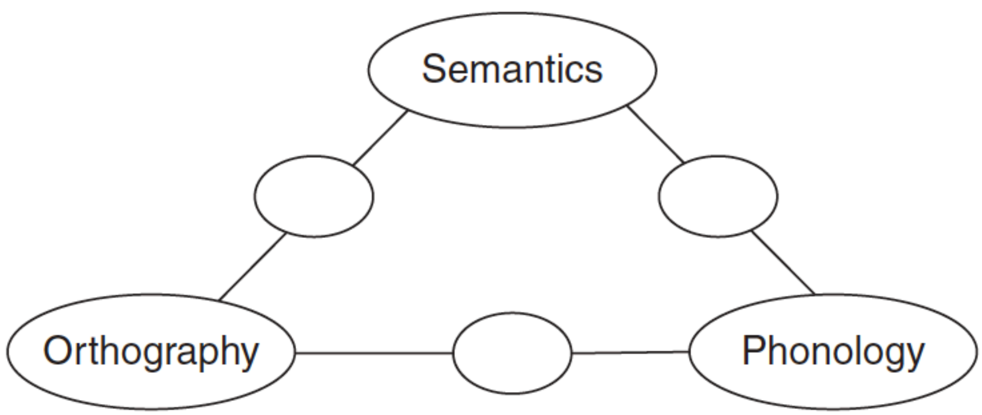

Figure 1: Harm and Seidenberg (2004) model of reading

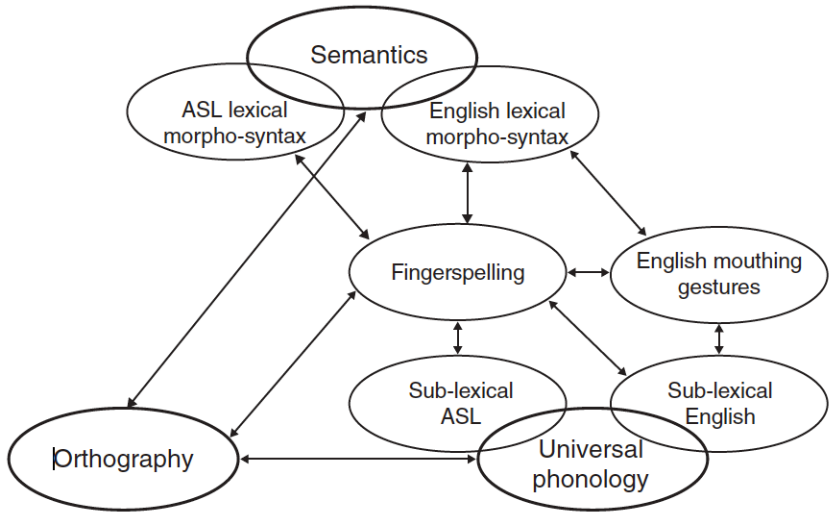

Figure 2: Petitto et al. (2016) model of reading

This model is an expansion of an earlier model of reading suggesting an equal amount of reliance on semantics, orthography, and phonology (Harm & Seidenberg 2004). The present model incorporates components of linguistic skill and knowledge provided by the visual language signal. Petitto and colleagues suggest that phonological awareness does not have to be sound-specific per se for fluent reading skill. Instead, deaf children develop visual sign phonology, or VSP, which provides the basis of phonological segmentation skill necessary for adult-like reading.

Fingerspelling in ASL, which is a system of hand configurations representing the 26 letters of the English orthography, is often used to teach reading to deaf children in bilingual education settings (Stone et al. 2015). Though ASL has a large vocabulary of signs, some English words (eg. proper nouns, specific jargon in medical or legal fields, etc.) have no sign counterpart in ASL and instead must be fingerspelled. Some signs are initialized as well, meaning the handshape of the sign corresponds to the handshape of the letter with which the word begins. Fingerspelling can be a significant aid for deaf children learning to read because they already have some concept of the alphabetic system of the spoken language (Stone et al 2015). During natural sign production, fingerspelled words tend to be processed as entire movement patterns with coarticulated letters and handshapes as opposed to the citation form of the fingerspelled word, in which individual letters are distinct from one another within each word (Ramsey & Padden 1998; Schwarz 2000; Geer & Keane, 2017). This process of natural fingerspelling reception mirrors that of whole-word, direct activation in reading in that the overall pattern of the word is perceived, not each individual signed letter (Padden, 1998; Schwarz, 2000; Geer & Keane 2017). Investigations have indicated that fingerspelling contributes to literacy acquisition in deaf children (Stone et al. 2015). In fact, Padden and Hanson (2000) suggest that fingerspelling is the “missing link” between signing skill and reading fluency, and a medium-effect size was shown between fingerspelling ability and reading score (Emmorey & Petrich 2012). For the purposes of this project, we will not discuss fingerspelling in greater detail, though later expansions of the current project will involve a specific investigation into the role of fingerspelling on literacy acquisition.

The role of English phonological awareness on reading in deaf children is potentially difficult to study in deaf populations. As mentioned earlier, pre-reading phonological knowledge at school entry is the greatest indication of reading success in hearing and deaf populations (Lundberg et al. 1980; Harris & Beech 1998). However, deaf children may find difficulty in conceptualizing tasks of phonological awareness of English. Many of methods used to investigate phonological awareness that may be intuitive hearing children may not be as obvious to signing deaf children. The two methods of investigation English phonological awareness that are of particular importance to this study are rhyme awareness and syllable awareness. By the age of 10, most hearing children either know the general definition of both syllable and rhyme or have an intuitive understanding of both and can be easily instructed to successfully perform judgement tasks. Most hearing children at that age have experience with and knowledge of syllable length and rhymes from nursery rhymes and other English language games typically played in early life. Though there are many language games in ASL, such games and songs do not include the same syllabic and rhyme structures of spoken English games. Thus, deaf children may need in depth definitions of each and detailed instructions regarding how to perform judgement tasks, particularly in the case of syllables, as there is no easy parallel in sign (Sterne & Goswami 2000). Prior to completing any tasks testing syllable or rhyme knowledge, it is imperative that deaf children are taught the exact meaning of syllables and rhymes in a visual manner so that they fully grasp the task at hand, or results will be invalid.

One study examined English phonological awareness in deaf signers of British Sign Language (BSL). Investigators focused particularly on rhyme awareness, syllable awareness, and phoneme awareness. Syllables are thought to be the primary linguistic processing unit in English, followed by onset and rime (Sterne & Goswami 2000). In fact, syllable awareness has been shown to come online in typically hearing children as early as 3-4, prior to any reading skill, and thus is a well-represented phonological structure upon learning to read (Liberman et al. 1974). In particular, investigators sought to understand if deaf children struggle to read for the same reasons as reading-impaired children with dyslexia and other language disorders. Further, they hoped to understand if deaf children have implicit phonological awareness of English prior to learning to read, considering that onset-rime skills are most important predictors of reading, while phonemic skill is not, in typically hearing children (Goswami & Bryant 1990; Sterne & Goswami 2000). Typically hearing children with reading impairments have been shown to have unspecified phonological representations and lack segmental organization (Sterne & Goswami 2000; Goswami 2000).

In order to ensure phonological segmentation was targeted specifically without any influence from orthographic segmentation, investigators used pictures instead of written words for all of their task stimuli. Word lists were developed for syllable and rhyme judgement tasks. Syllable judgement stimuli were all 1, 2, or 3 syllable words, controlled for frequency and varied in orthographic length (i.e. congruous, 'boat' vs. 'leaf', and incongruous, 'cat' vs. 'leaf'). Rhyme judgement stimuli were controlled for frequency and varied in orthographic regularity (i.e. 'cat' vs 'bat' and 'socks' vs. 'box'), and distractor items were paired by 1.) totally dissimilar- e.g. 'bed' vs. 'sock'; 2.) similar lip shape- e.g. 'rope' vs. 'comb'; 3.) shared initial consonant- e.g. 'witch' vs. 'wall'; 4.) shared initial consonant cluster- e.g. 'snowman' vs. 'snake'; and 5.) shared initial onset-vowel- e.g. 'bricks' vs. 'bridge'. Each presentation consists of a target picture above two other pictures, the distractor item and the rhyme item. Subjects are instructed to pick the picture from the two choices that rhymes with the target word. Rhyme pairs are either orthographic (e.g. target "clock" and rhyme "sock") or nonorthographic (e.g. target "eye" and rhyme "fly"). Distractor items were varied in phonological and orthographic similarity to the target or have similar lip shapes when spoken. Similar lip shape distractors were included to understand if deaf children make generalizations from speechreading gestures during rhyme detection tasks (Sterne and Goswami 2000). Prior to completing the judgement tasks, participants completed a word-learning test with all picture stimuli to ensure valid results. Further, in-depth definitions of 'rhyme' and 'syllable' were given to the deaf participants in particular, and instructions on how to complete a judgement task were given. For the syllable task, participants were instructed to look at two pictures, think of the English word for both pictures, and judge whether the word lengths (based on syllables) were "similar" or "different". For the rhyme task, participants were instructed to look at a target picture above two other pictures (distractor and rhyme), think of the English word for all three pictures, and choose which picture rhymes with the target. Accuracy and reaction times were recorded.

Results indicated that deaf children do indeed have syllable awareness and can make length judgements based on syllable length for English words. Moreover, deaf children are able to do so at a similar accuracy and speed as hearing controls. Orthographic length did mediate judgement, as reaction times increased in length for orthographically incongruent pairs, but it did so equally across both groups of participants. However, while deaf children were able to make rhyme judgements above chance for both orthographic and non-orthographic rhyme pairs, the deaf group showed a performance difference between orthographic and non-orthographic rhyme pairs and were significantly faster when judging orthographic rhyme pairs (Sterne & Goswami 2000). Syllable and rhyme judgement tasks from Sterne and Goswami (2000) were replicated for the current study (see methodology).

1.5 Eye-tracking and reading

One relatively easy and efficient way to investigate the cognitive processes underlying reading is eye-tracking. Eye-tracking is an excellent behavioral measuring technique, providing on-line, real-time insight into the cognitive processes that the brain performs while performing a variety of tasks, including reading (Rayner et al. 2006). To do so, most eye-trackers utilize infrared technology, which sends undetectable light to refract off the retina and cornea of the participant. The light refracted off the eye is calibrated to and recorded by the computer, allowing for detailed representations of the patterns that eyes perform while reading.

In a summary article regarding eye-tracking methods for researching reading patterns, Rayner and colleagues (2006) discuss how measuring eye movements can reflect the comprehension process of reading. Similar groups of readers (i.e. adult readers, new readers, second language readers, etc.) have many eye-movement patterns in common. In typical, adult-like reading, the eyes do not make smooth movements across all letters of each word. Instead, the eyes jump from character to character, in movements called saccades, and rely on peripheral vision to see read and predict the length of the next saccade. Further, people tend to perform regressive-saccades when reading, in which the eyes will regress back to words and characters that had been jumped over in previous saccadic movements (Rayner et al. 2006).

Patterns of eye-movements during reading can indicate disfluent or typical reading. The average skilled adult-like reader will jump 7-9 letter spaces per saccade for average reading difficulty material, with 10-15% regressive saccades. Children early in the process of learning to read will make longer fixations on each resting point between saccades (>350 ms per fixation), will have 2-3 fixations per word, and 30% of saccades are regressions. Disfluent reading is characterized by more child-like reading. As reading difficulty increases or individual reading skill decreases, fixation length increases, more regressive saccades will be made proportionally to forward saccades, and forward saccades are shortened (Ranyer et al. 2006).

Of particular relevance to the current study, eye-tracking has been employed to investigate the role of phonological activation of word meaning in early readers. In their 2015 article, Jared and colleagues used eye-tracking to investigate the role of phonology in the activation of word meanings in grade 5 readers. In their multi-experiment article, they discuss the homophone foil paradigm of investigating phonological activation during reading and the developmental bypass theory. For their studies, sentence lists were developed, each containing a target word. Target words are either high frequency (HFT) or low frequency (LFT). Non-target words are also controlled for high frequency (HFD) and low frequency (LFD). Each target word (e.g. 'sea') was paired with a homophone (e.g. 'see') and a spelling control (e.g. 'set'). Theoretically, if an individual is reading via the indirect route, 'sea' activates the phonological representation, /si/, which activates word meanings for both ‘sea’ and ‘see’. Thus, homophone foils would not cause disfluent reading when in the proper context. Direct route readers should demonstrate disfluent reading homophone conditions, because ‘see’ cannot directly activate the word meaning of the target ‘sea’, which would cause disfluency due to sentence context. Spelling controls, however, should cause disfluent reading patterns for direct and indirect route readers, because neither the visual representation ‘set’ nor the phonological representation /sɛt/ activates the correct word meaning. Individuals reading via the direct route would demonstrate similar degrees of disfluent reading for both homophone foil and spelling control conditions due to incorrect meaning activation. However, indirect route readers would demonstrate significantly more disfluent reading for the spelling control conditions as compared to the no change and homophone foil conditions, with similar patterns in the no change and homophone foil conditions, due to correct meaning activation in both conditions. See table 1 for sample sentences by condition.

Target word	No-change condition	Homophone foil	Spelling control
which (HFT, LFD)	The team captains decided **which** players they wanted.	The team captains decided **witch** players they wanted.	The team captains decided **whirl** players they wanted.
	David didn't know **which** chocolate bar he wanted.	David didn't know **witch** chocolate bar he wanted.	David didn't know **whirl** chocolate bar he wanted.
	The janitor showed us **which** recycling box is for paper.	The janitor showed us **witch** recycling box is for paper.	The janitor showed us **whirl** recycling box is for paper.
hear (HFT, HFD)	Sandra asked to **hear** her favorite song.	Sandra asked to **here** her favorite song.	Sandra asked to **hair** her favorite song.
	The crowd wanted to **hear** the president speak.	The crowd wanted to **here** the president speak.	The crowd wanted to **hair** the president speak.
	It is hard to **hear** the words of the song.	It is hard to **hair** the words of the song.	It is hard to **here** the words of the song.

Table 1: example sentences from Jared, Ashby, Agauas, & Levy (2015)

Each sentence is read in one condition, but each child reads all conditions for each target word. Participants were all average readers, fluent monolingual speakers of English, and all typically developing. After calibration on the eye-tracker, participants are instructed to read each sentence as quickly and accurately as possible. This is a passive reading task, without any judgements made by the participants. Gaze duration and saccade length and direction were recorded.

Results indicated that spelling controls caused disfluent reading in all participants regardless of frequency. Homophone errors were far less noticeable than spelling controls for all frequencies across groups, as gaze duration was significantly shorter on homophone errors than spelling controls. These results indicate that phonology does play an important role in the activation of word meanings in typically hearing 5th grade readers

Though the paradigm of homophone foils has yet to be used in deaf populations on an eye-tracker, one study did investigate the role of phonological activation via homophone foil in lexical decision tasks. Researchers investigated the nature of phonological processing during online word recognition in deaf adults in English homophones vs. pseudohomophones, and non-homophonous pseudowords. Participants were instructed to judge if a word was a real word in English or not. Hearing readers were shown to respond more slowly to homophones than control words in real and non-word contexts. Deaf readers, however, responded more slowly to homophones than controls in the pseudohomophone condition, but not non-homophonous pseudowords. While this many indicate that phonological representations are not clear or distinct in the deaf participants, this does provide evidence that deaf readers are able to perform homophone foil tasks and that they are able to activate phonological representations during read (Sterne & Goswami 2000).

1.6 Conceptualization of current project

The specific aim for this study is to investigate the role of phonological awareness and phonological recoding during reading in deaf signers and oral/aural deaf children, as compared to typically hearing children, ages 10-13. We will compare phonological skills gained from English, ASL, and speechreading to reading fluency in all participants to ultimately develop a model of reading predicting fluency and route of meaning activation based on language skills. Currently in my analysis, I have 9 deaf signers, 8 hearing controls, and 3 oral/aural deaf participants. Due to low numbers, I will only be discussing data from deaf signers and typically hearing controls for the purposes of this thesis, due to larger and matched participant numbers. Data from oral/aural deaf children will be included to provide a pattern of early trends, but no generalizations or conclusions will be made and statistical significance will not be discussed.

I predict that the deaf native signers will show less competence in the sublexical English and speechreading tasks and a higher degree of fluency in sublexical ASL skills. For deaf native signers, higher ASL phonological awareness will correlate with greater reading fluency. While I predict deaf native signers to be competent and fluent readers, I do not expect to find evidence of phonological recoding during the homophone foil paradigm and instead expect to see a greater degree of whole-word reading in deaf signers as compared to oral/aural deaf. Typically hearing children should demonstrate highest sublexical English skills, with lower scores in ASL and speechreading tasks, and should demonstrate very fluent reading without much evidence of phonological recoding.

2. METHODS

2.1 Materials

Each participant completes 6 measures of phonological awareness, one silent reading fluency task, and the eye-tracking paradigm. For all tasks, instructions are given in the appropriate language for each child. Each participant has a checklist with spaces for research assistants or me to write notes regarding the participant and any relevant information to the data (i.e. behavior on the eye-tracker, how distracted they are during the behavioral tasks, any important information they may share with you, etc.) There is also an area for the child to write their responses to the ASL-PA.

2.1.1 Measures of Phonological Awareness

One measure of ASL phonological awareness had been previously developed and tested in deaf children, and one was developed by the Booth lab at UT and compiled by me. Each participant first completed the ASL Phonological Awareness task (Corina et al. 2014). This test is a video-based test administered on a computer designed to examine phonological awareness of ASL signs. Participants are presented with video clips of two pseudosign forms and three real signs. Participants are encouraged to watch each video clip as many times as they need to examine the two nonsign forms and evaluate the three potential answers. Based on the two pseudosign forms, they are asked to isolate handshape, movement, and location properties of the two pseudosigns and recombine them in a fashion that yields an existing ASL sign. Participants determine which of the three real signs can be made from combining two pseudosigns that vary in hand shape, location and movement. The test consists of 20 distinct sign trials (Corina, Hafer & Welch 2014). For this particular experiment, the participants write down the video they picked to be correct (L for the video on the left, M for the video in the middle, and R for the video on the right) on the participant check-list.

Following the ASL PA, participants complete an ASL rhyme judgement task, which was developed by the sign language lab at UT Austin (UT SLLab). This is a computer-based task designed as a measure of ASL phonological awareness. For this task, one Deaf male native signer and one Deaf female native signer were recorded signing individual signs. Signs are paired as similar, i.e. the two signs contain two of three phonological components in common (eg. SUMMER and DRY), or different, i.e., no phonological components in common (eg. CAT and TOGETHER). There is a total of 72 pairs, broken into 4 separate blocks (18 each). Each participant sees all four blocks separately, and order of presentation of blocks was randomized by subject. Participants are asked to judge if the pair of signs are similar (based on phonological components; two in common) or different (no phonological components in common). The task was scripted in PsychoPy, which records reaction time and accuracy.

Similar to ASL phonological awareness tasks, one measure of speechreading was previously developed and used in deaf populations, and the other was developed at UT. The Test of Child Speechreading (ToCS; Kyle et al. 2013; 2014) is an online portal-based task, designed to be used with deaf and hearing children ages 5-14. Items were initially chosen based on word frequency and for early age of acquisition (i.e. all words are typically acquired by developing children by around 26 months). For this task, participants watch a silent video of a person saying a word and pick the picture that corresponds to the speech-read word. This task contains three subtests to measure speechreading skills at different levels: word level (15 items), sentence level (15 items), and short story (5 stores followed by two questions):

In the words subtest, participants watch a silent video of a talker (male or female; varied) saying the target word along with an array of 4 pictures. Participants are instructed to click on the picture that best matches the silent word, based on the mouthing gestures of the talker. Target word items consist of 30 different phonemes and 11 different visemes, or visually confusable phonemes that have very similar mouthing gestures (e.g. /p/ and /b/ or /d/ and /t/). Distractor photos are related to the target word in terms of visemic properties, sharing either the same initial or final viseme or the same vowel sound (e.g. *duck, fork,* and *dog*).

The sentence subtest is quite similar. Each of the 15 sentences in the sentence subtest contain one of the target words from the words subtest. Participants watch silent videos of a talker (male or female; varied) and then click on the corresponding picture (of an array of 4). The distractor photos were developed from erroneous interpretations of each silent video by deaf and hearing adults and children after being asked what was said by the talker. The rest of the distractors share features similar to the target, as in the words subtest (Kyle et al. 2014).

Following the ToCS, participants complete the speechreading rhyme judgement task developed by the Booth lab at UT. This is a computer-based task designed as a measure of phonological awareness of English mouthing gestures at the rhyme level. For this task, one male talker and one female talker were recorded saying individual words. Target words are CVC and were chosen for frequency and similarity of visemes (defined above). Word pairs are either "similar" condition, in which words share two visemes, either CV (e.g. *cat* and *cab*) or VC (e.g. *cat* and *bat*), or "dissimilar" condition, in which words share no visemes (e.g. *cat* and *pic*). There is a total of 68 pairs, broken into 4 separate blocks (17 each). Each participant completes all four blocks and is randomized to the order of presentation. Participants are asked to judge if the pair of words are similar (based on viseme criteria; at least one viseme in common) or different (no visemes in common). Stimuli are presented in PsychoPy, which records accuracy and reaction time of the participants.

Measures of English phonological awareness proved much more difficult to design, due to the mixed literature discussing methods of testing of English phonological awareness in deaf populations. As mentioned in the above section, it is imperative that deaf children are properly instructed and given language-appropriate descriptions of each component being measured. Stimuli and general design was borrowed from Sterne and Goswami (2000). In this particular study, the authors chose picture-based stimuli, as opposed to written stimuli, to ensure that phonological segmentation skills were specifically targeted, not orthographic segmentation skills.

A few modifications were made to the original study. First, the authors designed this task for British English. Some word pairs from the original study were changed to better fit American English words (i.e. the original pair *saw* and *four* was changed to *saw* and *paw* to match American English). Second, only the measures of syllable awareness and rhyme awareness were adapted and used for the present study. Lastly, visually accessible definitions and descriptions of syllables and rhymes were designed to better fit the needs of deaf children.

As previously discussed, most typically hearing American children arrive at school with an intuitive understanding of syllables and rhymes, due to experience with English language games and nursery rhymes. Though deaf parents often play ASL or visual language games and read to their children, deaf children do not have the same experience with spoken English games, therefore requiring much more in-depth definitions. For syllable definition, we developed a PowerPoint presentation with examples of monosyllabic, disyllabic, and tri-syllabic words with a ball that bounces on top of each syllable to give a visual representation of the way words can be segmented. For rhyme definition, we associate mouthing gestures with example target words, to focus the children's attention on how the words sound in English. Both PowerPoints also give visual descriptions of the task, with stick figure people looking at pictures and thinking of the English word for the picture.

The rhyme judgement task requires a similarity judgement of three simultaneously presented pictures, presented on a computer screen. Prior to the task, subjects took a pre-test to ensure each child knows the correct label for each picture and the detailed, visual definition of a “rhyme” in the language and depth appropriate for each child’s hearing status. Each presentation consisted of a target picture above two other pictures, the distracter item and the rhyme item. Subjects were instructed to then pick the picture from the two choices below that rhymes with the cue word based on the English word and given definition of a rhyme. As outlined specifically in Sterne and Goswami (2000), rhyme pairs are either orthographic (ie. target “clock” and rhyme “sock”) or nonorthographic (ie. target “eye” and rhyme “fly”), and one of five conditions: dissimilar distracter item (ie. target “sock” vs. distracter “bed”), similar lip-shape distracter (ie. “boat” vs. “moon”), similar initial consonant distracter (ie. “wall” vs. “witch”), similar initial consonant cluster (ie. “snake” vs. “snowman”), and similar onset-vowel distracter (ie. “clown” vs. “clock”). This task was scripted and is presented in PsychoPy, which records accuracy and reaction time for each trial.

The syllable judgement task requires a similarity judgement of two simultaneously presented pictures, presented on a computer screen. As in the rhyme task, participants were instructed to consider the English word for the two pictures presented. Each child was instructed to choose SAME or DIFFERENT on the computer based on the syllabic length of the word. Word pairs were either orthographically congruent with same number of written letters (ie. SAME judgement of “bird” and “tree”, DIFFERENT judgement of “cake” and “baby”) or orthographically incongruent with different number of written letters (ie. SAME judgement of “switch” and “cake” or DIFFERENT judgement of “switch” and “potato”). Distractor items consist of orthographically congruent or incongruent stimuli in opposition to the target stimulus. This task was scripted and is presented in PsychoPy, which records accuracy and reaction time for each trial.

2.1.2 Measures of reading fluency

Participants complete the Woodcock-Johnson Test of Academic Achievement, Third Edition (WJ-III; Woodcock, McGrew, & Mather, 2001): Silent Reading Fluency as a supplemental measure of reading skill. This measure tests the reading speed and fluency of the test-taker. Participants are handed the test (a sheet of paper) and a pencil and instructed to silently read as quickly and accurately as possible for 3 minutes. There is a total of 98 possible sentences. At the end of each sentence, participants indicate whether the sentence was true by marking "yes" or "no". The sentences are ordered from primer to adult. The purpose of this task is to investigate the speed of reading of each child (measured via how many sentences the child is able to read in 3 minutes) and accuracy of reading (measured via how many correct responses are given). This measure is standardized, allowing for generalizable conclusions to be drawn, and is included as an independent measure of reading fluency.

All participants complete an eye-tracking paradigm as well, measuring the degree of phonological recoding completed by young readers. For this task, participants are familiarized with the set-up of a table-mounted eye-tracker and shown how to place their chin comfortably on the chin rest and calibrated by the eye-tracker. Prior to calibration, the participants are shown their eye gaze and what it looks like when their eyes move around, to give them an understanding of the task at hand. Calibration consists of looking at dots on a grey computer screen. Sentences (borrowed from Jared et al. 2015) contain target words in one of three experimental conditions: no change, homophone foil, and spelling control (see table 1 for example sentences). All children read the same sentences, but there are three possible conditions for each sentence (i.e. no change, homophone foil, and spelling control). Each child reads a total of 108 experimental sentences, broken down into 3 blocks of 36 sentences, randomized to each condition with filler control sentences throughout. Following calibration, the child is instructed to read each sentence as quickly and carefully as possible. This is a passive reading task, so no action needs to be taken by the participants during the task. The eye-tracker will record eye-movements while encountering the three experimental conditions. Following each of the 3 blocks, participants were given an opportunity to take a break, get up and walk around, or continue without a break. Calibration reoccurs after each experimental block.

2.2 Participants

Prior to recruitment of the target population of the project, 5 ASL majors or minors at the University of Texas at Austin participated in the project as pilot participants. The data from these participants was not analyzed. The purpose of the pilot portion of this project was to ensure that all of the in-house experimental measures were scripted and designed correctly and that the eye-tracker produced the desired data.

Participant groups include deaf native signers, oral/aural deaf children without exposure to ASL, and typically hearing children, ages 10-13. This age range was chosen because, though phonology and phonological recoding should still play a large role in reading at this age (Jared et al. 2015), most children begin the more automatic, direct route reading at this age as well (Share 2008; Pennington et al. 1987).

Participants for this project are recruited by a variety of means. Applications for student participant recruitment were sent to a variety of Austin area schools, including the ASL-English bilingual school in the area Texas School for the Deaf. Hearing and oral/aural participants are recruited from public school systems including Austin and Round Rock and existing participant database from collaborating labs. In addition, information about the project was posted in the UT Austin daily events calendar, urging parents of children within the target age-range to email the researchers for more information about the project. Lastly, video blogs describing the project in ASL were posted and distributed on a variety of social media sites for deaf parents of deaf children to see and understand.

This project is still in the active recruitment phase. Currently in our analysis, we have 9 deaf native signers, 2 oral/aural deaf, and 8 hearing controls. Due to such low numbers I am reluctant to make generalizations based on the analyses thus far. However, I will report the trends and comparison statistics between the signing group and the typically hearing group. Oral/aural deaf participants will be included for the purposes of comparison and general trends only. By the end of the project, I aim to have 20 participants in each group.

2.3 Procedure

Depending on the availability of the participant and their families, subjects are either seen in individual 2-hour sessions with one researcher, in small sessions with sibling participants, or in larger "research days" with other participants.

In individual or small-group sessions, participants and their parent(s)/guardian(s) are first given a thorough description of the project and consent forms in the appropriate language by the researcher. Upon written consent from the parent and verbal assent from the subject, parents are given a questionnaire to fill out. This questionnaire requests specific information about their child's vision and hearing and language experience. For deaf and hard of hearing children, specific questions about the type and degree of hearing loss, use of hearing aids or cochlear implants, and use of language are requested to properly group the deaf subjects into predominantly signing and predominantly oral/aural groups.

During individual or small sessions, the order in which tasks are completed is flexible, and often left up to the child. After a description of all tasks, children decide if they would prefer to complete the behavioral tasks or eye-tracking tasks first.

Behavioral language measures: As an independent measure of reading fluency, all children complete the Woodcock-Johnson III Test of Silent Reading Fluency. Participants also complete each of the language tasks, typically beginning with English, moving on to speechreading, and ultimately completing the ASL tasks.

Prior to completing the English measures, all participants complete the picture learning PowerPoint to ensure stimuli pictures are associated with the correct target word. In addition, deaf participants are given a thorough, visual description of "syllable" and "rhyme". Participants then complete the Syllable Judgement and Rhyme Judgement Tasks. Speechreading awareness tasks are also completed, typically beginning with the speechreading rhyme task originally designed by the Booth lab and scripted by sign language lab at UT Austin followed by the Test of Child Speechreading (Kyle et al. 2008) . In addition, all participants complete the tests of ASL phonological awareness, typically starting with the ASL rhyme judgement task and ending with the ASL Phonological Awareness test (MacSweeney et al. 2008). All of the measures of phonological awareness are completed on the researcher's laptop or research laptops belonging to the UT Signed Language Lab, with the researcher or research assistant taking notes and guiding the child through each task. All children are given the option to take breaks between each task or continue through the protocol.

The eye-tracking paradigm is completed flexibly throughout the session. Some participants prefer to complete the eye-tracking first, opting to end with the language games, while others find it easier to sit and read sentences when already tired from the behavioral tasks. For participants with marked difficulty with the eye-tracker, whether due to boredom, discomfort, or difficulty calibrating, completion of eye-tracking paradigm can take up to an hour. Participants who calibrate easily and who tend to sit still can complete the eye-tracking task in less than 30 minutes.

Prior to calibration, participants are given a thorough description of the task and instructed to sit as still as possible and read each sentence as quickly and carefully as possible. Each child is fitted on the head mount and given an opportunity to see their eyes as they are recorded by the eye-tracker as well as what it looks like when the move around too much. This is to help the child understand why it is important to sit still when they are reading the sentences on the eye-tracker.

Once familiarized and comfortable, children are calibrated by the eye-tracker. Calibration is repeated as needed throughout each of the three eye-tracking scripts to ensure a proper track was occurring or if the gaze contingent display stopped working. Participants complete 1-3 eye-tracking scripts of 85-95 sentences in each script. Calibration is repeated as often as necessary to ensure a proper tracking of eye-movements throughout the eye-tracking portion, particularly for participants with lower attention spans who fidget or chat with the experimenter during the task. Some participants are unable to complete more than 1 eye-tracking script (95 sentences) due to fatigue, boredom, or difficulty with calibration. Some of the sentences (about 20%) are followed by a very simple yes or no question, to ensure the participants pay attention to the sentences. Though responses to the questions may indicate the degree to which the children are attending to the sentences, responses to these questions are not analyzed for the purposes of this paper.

At the end of the individual session, participants are brought back to their parents and given the $20 participation reimbursement ($10 for the child, $10 for gas reimbursement for the parent).

Some of the participants take part in research days in the lab instead of individual sessions. We hold 4-5-hour days of activities, experimental tasks, games, and snacks. Prior to beginning the day, all parents and children are given a thorough description of the project and individually run through the consent form. Upon completion, each child is given a "passport", with a list of all possible activities and experimental tasks. During the research day, children receive a sticker next to that measure on their passport upon completion of each individual task. Children are instructed that once they have received stickers for all of the experimental task, they will be given their $10 prize to incentivize their participation in all experimental measures. All children and parents receive reimbursement at the end of participation regardless of completion of each task. For the larger research days, multiple researchers are present to guide subjects through their tasks.

3 RESULTS

Currently in our analysis, we have data from 9 native signers and 8 typically hearing controls, though we ultimately aim to have 20 in each group. All participants are from the Austin area. Typically hearing participants (1 girl, 7 boys) range in age from 10 years, 0 months to 11 years, 11 months (M= 10.9, *SD*= 0.7 years). Eligibility requirements include monolingual English speakers without detectable hearing loss and with no exposure to ASL. All deaf signers (8 girls, 1 boy) attend a local bimodal bilingual school for the deaf, ranging in age from 10 to 13 (M=11.7, *SD* = 1.2 years). The deaf signers all have deaf signing parents and have hearing losses ranging from moderately severe (55-70 dB loss) to profound (70+ dB loss).

The current participant pool is skewed for a few reasons. Most importantly, we have only 1 girl and 7 boys in the hearing group, and the opposite pattern in the deaf signing group with 1 boy and 8 girls. In addition, hearing participants come from higher socio-economic status families, with all parents reporting annual household income above $100,000 yearly. In contrast, all but one of the parents of deaf participants reported annual household income between $20,000 and $50,000 yearly. One deaf participant was reported to live in a household with an annual income between $100,000 and $150,000 yearly. No participants have any reported history of language impairment or learning disability.

I will report and discuss the results from the deaf signing and hearing control groups. Results presented for the purposes of this paper will discuss differences in average scores on language tasks, as well as differences in average first pass time, proportion of regressions, and total reading time on each condition between groups of participants. The preliminary analyses reported here utilize t-tests for comparing performance within- and across-groups. After completion of the data collection, we anticipate using generalized linear mixed models to predict reading patterns by language task scores and relevant demographic variables (i.e. SES, amount of language intervention, etc.). In the current paper, data obtained from the two oral/aural deaf participants will be shown in language charts for comparison purposes only. Due to such low numbers and minimal statistical power, and we feel that no preliminary conclusions can be drawn from the oral deaf group.

As expected, our hearing controls have the highest scores on the English subtests, with an average score (representing proportion of correct scores) of 0.82 (*SD*=0.14) on the syllable test and an average of m=0.97 (*SD*=0.02) on the rhyme awareness task. Deaf signers have the lowest English syllable and rhyme awareness scores, as predicted, though they are far above chance in both the syllable (m=0.7, *SD*=0.17) and rhyme tasks (m=0.77, *SD*=0.2). An analysis of the score means on measures of English Rhyme task indicates that the difference between deaf signers and typically hearing controls' scores is significant (t = -2.94, p = 0.018); the difference between groups on the Syllable task approaches significance (t= 1.89, p = 0.08).

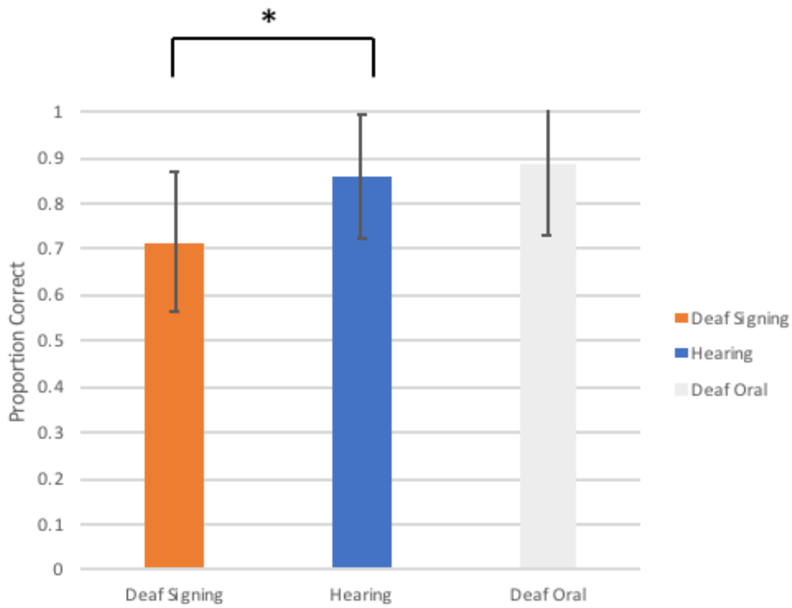

Figure 3: Performance on English Syllables by Group; *SD* bars reported

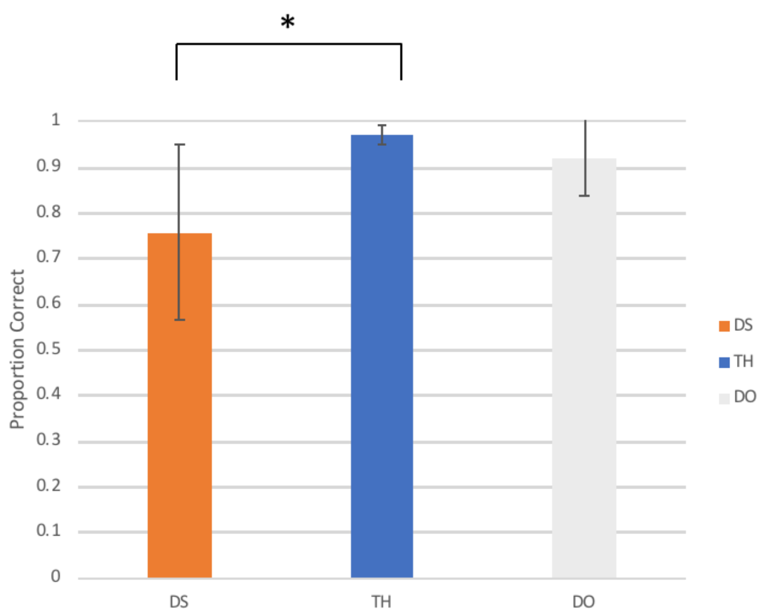

Figure 4: Performance on English Rhymes by Group; *SD* bars reported

The speechreading tasks appear to be difficult for all participants. However, t-tests indicate no differences between group average scores for any of the speechreading tasks (speechreading rhyme: t= -1.12, p = 0.3; ToCS words: t= 1.69, p = 0.11; ToCS sentences:

t= 0.05, p = 0.62). Figure 5 shows the average scores by group on the speechreading rhyme task.

Only one oral/aural deaf participant participated in the ToCS due to purchasing of the task license after the first participant; thus no standard deviation is reported in their scores. Both groups appear to struggle with the sentences condition on the ToCS (see Figure 6), though means are trending to favor deaf signers (see Figure 7). It is noteworthy, however, that there is wide variability in the ToCS sentences condition. It appears that all participants struggle with this task in particular. Speechreading scores across all tasks do not vary significantly between deaf signers and hearing controls.

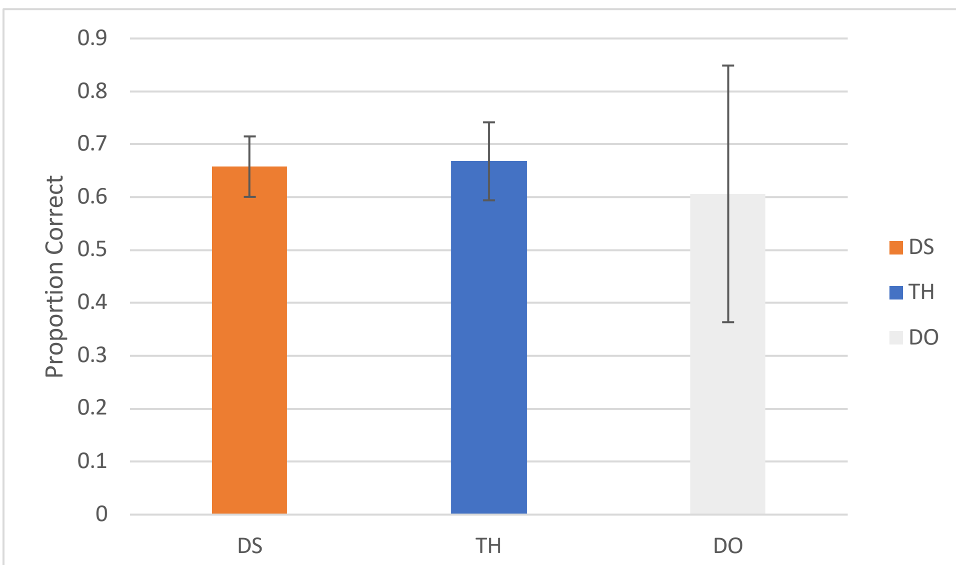

Figure 5: Performance on Speechreading Rhyme Judgment by Group; *SD* bars reported

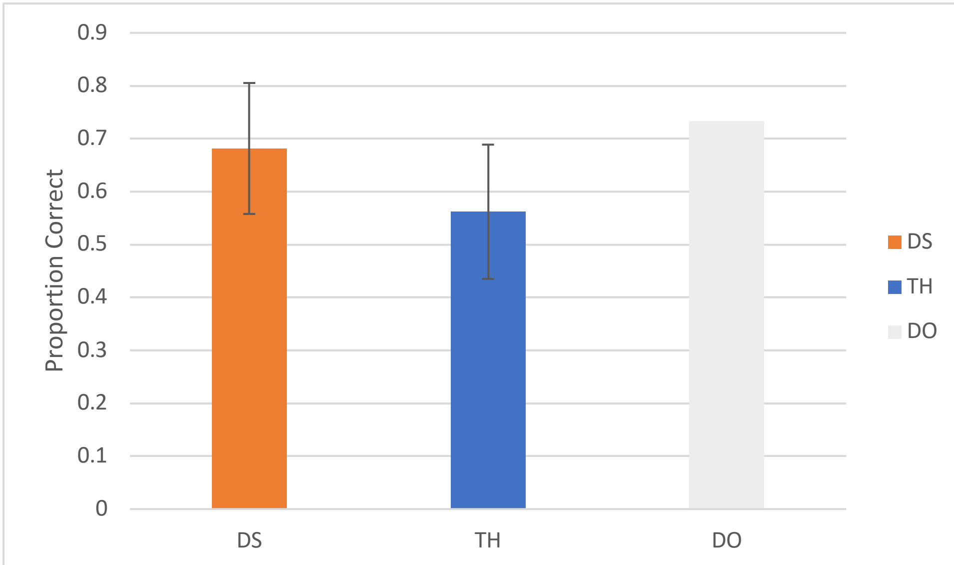

Figure 6: Performance on ToCS:Words by Group; *SD* bars reported for DS and TH groups

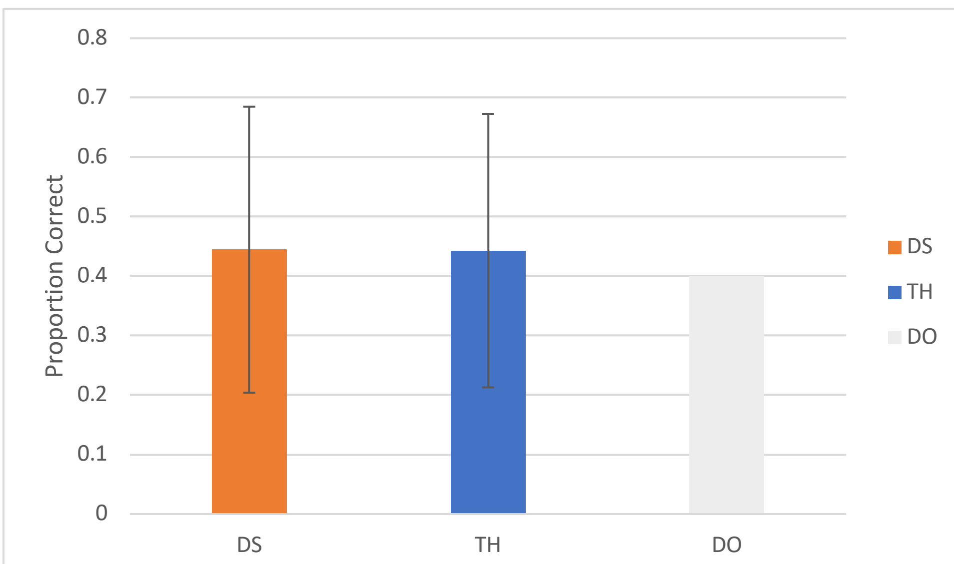

Figure 7: Performance on ToCS: Sentences by group; *SD* bars reported

With regards to ASL performance, deaf signers have the highest scores on ASL phonological awareness, as was expected. It is interesting to note that the hearing controls did well in these tasks as well. However, there is wide variability in ASL-PA scores in typically hearing participants, and lower variability in the deaf signers. Overall, a t-test analysis indicates that the difference between deaf signers and hearing controls on the ASL rhyme task between is approaching significance (t= 1.89, p = 0.08), though average scores on the ASL-PA do not vary significantly (t= 1.28, p = 0.22). See figures 8 and 9 for average ASL task scores.

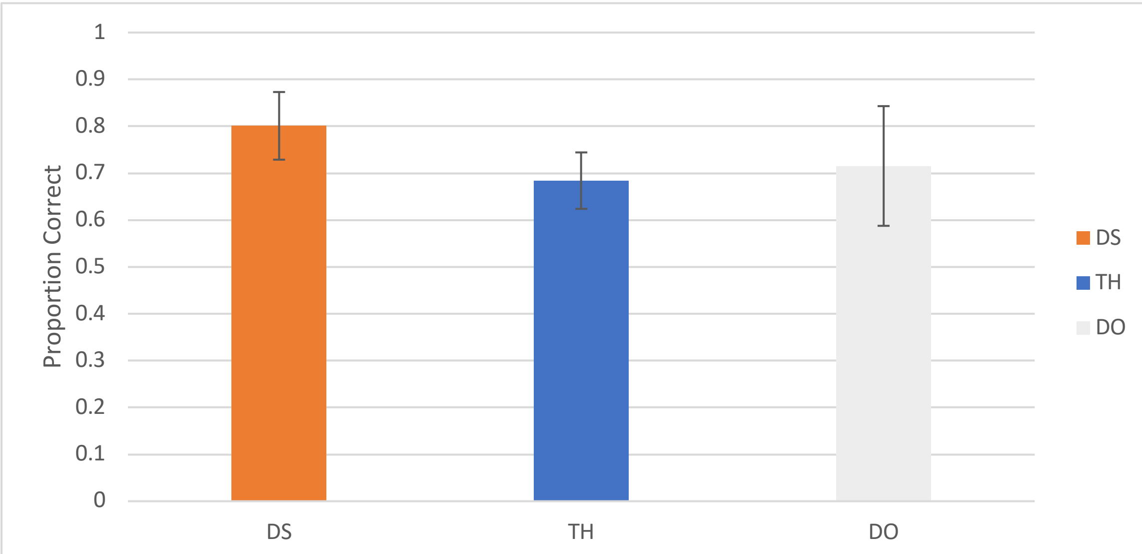

Figure 8: Performance on ASL Rhymes by Group; *SD* reported

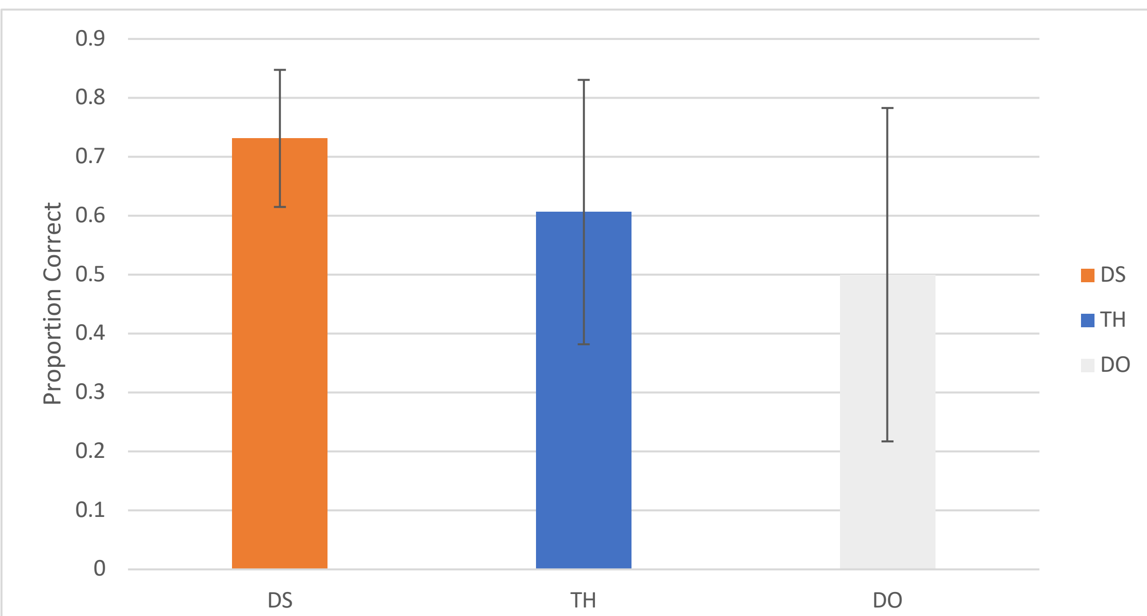

Figure 9: Performance on ASL PA by Group; *SD* reported

Independent Measure of Reading Fluency

Of particular importance regarding behavioral language data is the Woodcock Johnson III (WCJ-III). Scores on the WCJ-III are based on age equivalencies. Our deaf native signers performed above their actual ages (m = 11.7, *SD* = 1.13 years; see Figure 10), though there is a great degree of variability among these participants. It is important to note that one participant outperformed her peers (age equivalent: 30; grade equivalent: 12.9). Figure 11 depicts WCJ-III scores with that outlier removed. With the outlier removed, deaf participants appear to be reading at or slightly above their reading level. Figure 12 shows deaf and hearing scores together.

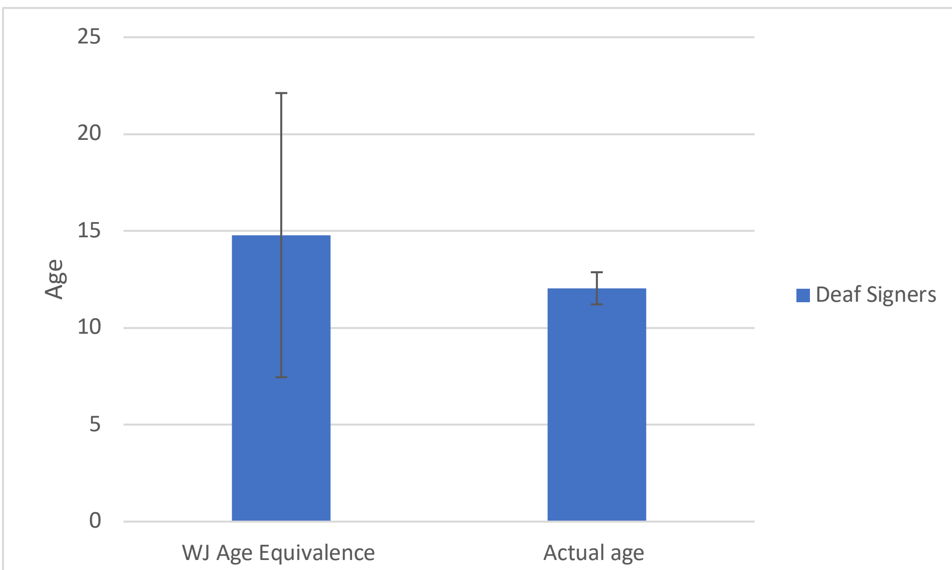

Figure 10: Performance on WCJ-III for Deaf Signers Including Outlier; *SD* reported

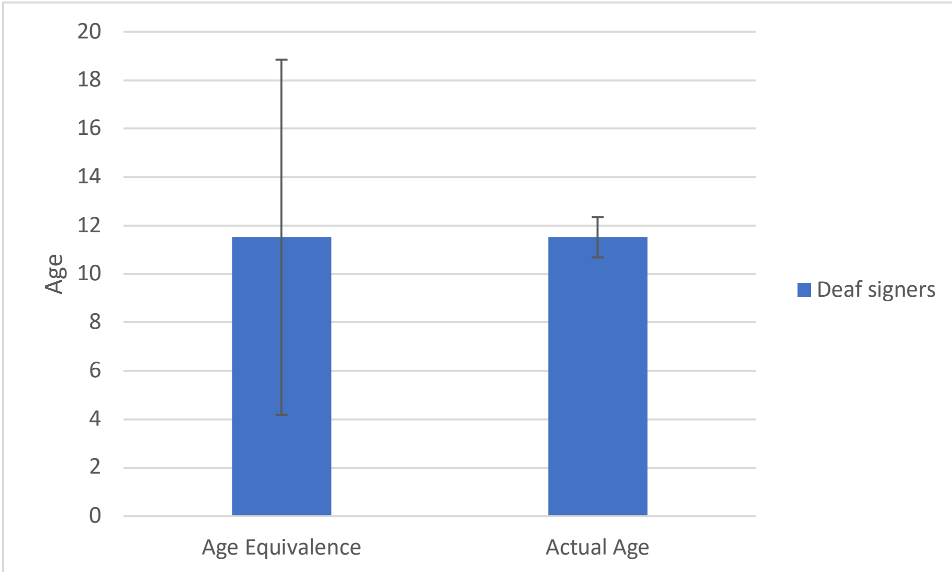

Figure 11: Performance on WCJ-III for deaf signers, outlier removed; *SD* reported

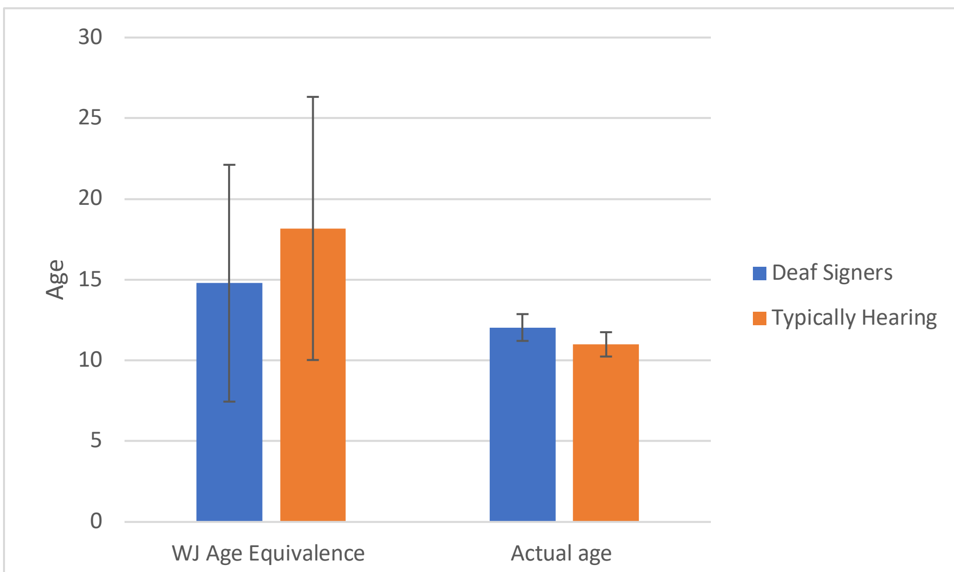

Figure 12: WCJ-III Age equivalents vs. actual age; *SD* reported

Eye-tracking results

All eye-tracking data were acquired, cleaned, and analyzed by the University of Massachusetts Amherst eye-tracking software. Raw data are produced in the form of EDFs, EyeLink Data Files. EDFs must first be converted into ASC files before being processed.

Once EDFs are converted into ASC files, they are cleaned with a Python program from UMass, Robodoc. Robodoc compiles all raw data in the ASC files and removes unnecessary gaze data (i.e. prior to the presence of the stimuli, spill-over gaze data between items, and calibration specifics) and produces .da1 files with gaze and blink information. Finally, .da1 files are compiled and analyzed by EyeDry, a DOS program that configures eye-movement data with the original stimulus scripts and allows for flexible analysis with a variety of eye-tracking related reports.

For the purposes of this project, only information pertaining to region 2 (R2) have been analyzed considering R2 contains the single target word embedded in each sentence in one of the three experimental conditions (i.e. homophone foil, correct target, and spelling control; see above). Future projects related to this data will analyze regions 1 and 3 (R1 and R3) to analyze general reading fluency, considering that R1 and R3 could not be compared across sentences due to varying lengths. Further, due to such low participation numbers and a loss of data to blinks, no eye-tracking data from the oral/aural deaf group will be reported.

To gain an understanding of the degree of disfluent reading of the target word, first pass reading time (i.e. the time of the first fixations on the target region R2), total reading time (i.e. all fixation times regardless of first pass or following a regression back into the target region R2), and number of regressive eye-movements into the target region R2 are compared across groups and conditions. Analysis of these measures provide an understanding of degree of disfluency across experimental condition considering that disfluent reading is marked by increased regressive eye-movements back into the target region, thus increasing total reading time (Rayner 2009).

First pass reading time does not differ significantly between groups (Figure 13; t= 0.52, p = 0.6). In addition, Deaf signers first pass times are approaching significance between the correct and homophone foil conditions (t= -1.78, p = 0.076) and between the correct and spelling control conditions (t= 1.83, p = 0.06). Hearing controls do not show any differences between first pass reading time during the correct condition and homophone foil (t= 0.31, p = 0.76) or spelling control conditions (t= 0.16, p = 0.87).

Deaf signers had an average first pass reading time of 243.26 ms (*SD*= 80.82 ms) in the correct condition, compared to an average 268.86 ms (*SD*=108.85 ms) in the homophone foil and 223.13 ms (*SD*= 67.04 ms) in the spelling control conditions. Hearing controls had an average first pass reading time of 242.42 ms (*SD*=75.99 ms), compared to 237.23 ms (*SD*= 109.09 ms) in the homophone foil and 240.09 ms (*SD*= 82.73 ms) in the spelling control conditions. To better understand the degree of disfluency caused by each condition, we must look at total reading time and regressions back into the target region.

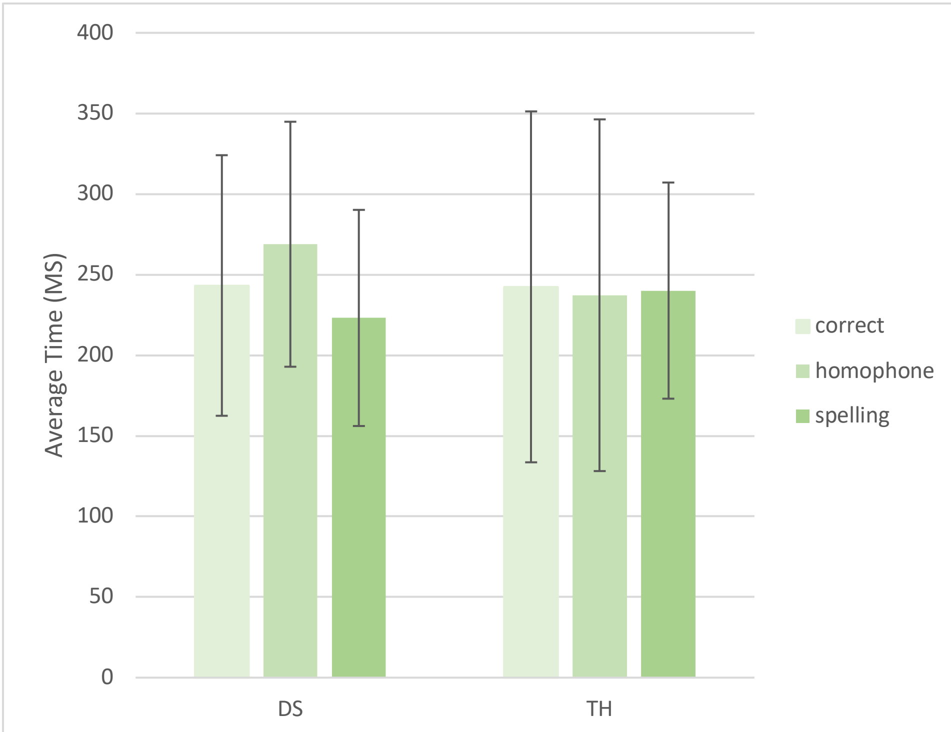

Figure 13: First pass reading times by group; *SD* reported

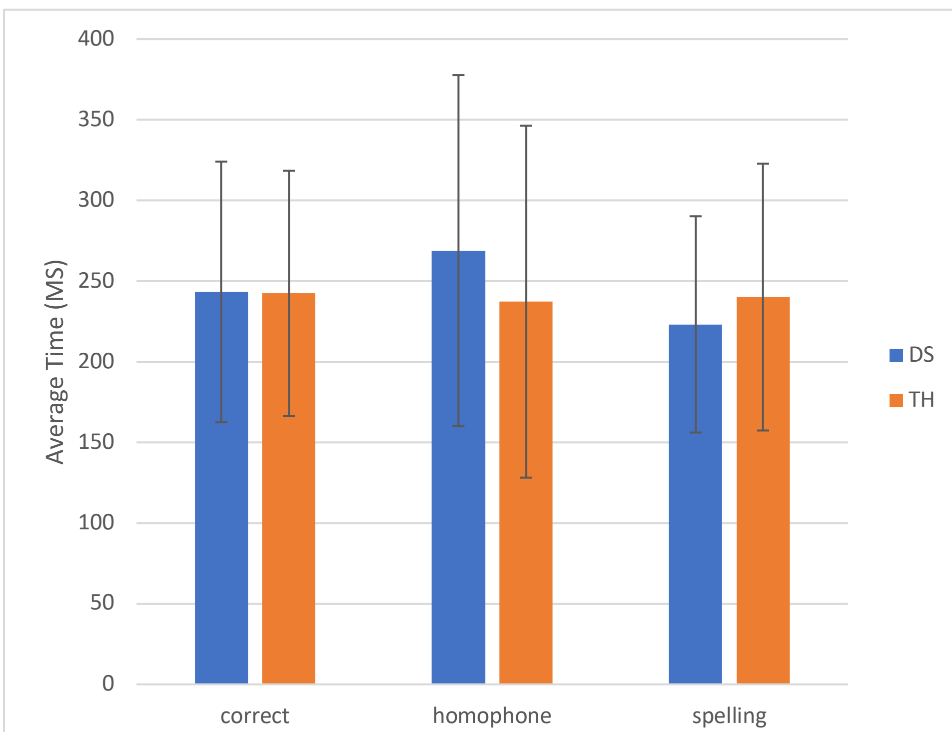

Figure 14: First pass time; *SD* reported

The number of regressions back into the target region can provide evidence of disfluent reading. Regressions into a region can indicate a need to disambiguate or reevaluate the content of that particular region. In this case, increased regressions into the target area for homophone foils and spelling controls will indicate that the error in the sentence has been noticed. Deaf signers performed regressive eye-movements into R2 an average of 0.31 times in the correct condition, compared to 0.35 times in the homophone foil condition and 0.44 times in the spelling control condition. Hearing controls performed regressive eye-movements into R2 an average of 0.43 times, as compared to 0.55 times in the homophone foil condition and 0.59 times in the spelling control condition.

A few significant differences are evident with regards to proportions of regressions. In deaf signers, there is a significant difference between number of regressions in the homophone vs. correct conditions ($t = -1.98$, $p = 0.048$). Similarly, typically hearing readers have a significant difference in proportion of regressions between correct and spelling control conditions ($t = -1.93$, $p = 0.05$). Despite no significant difference between proportion of regressions during the correct and spelling control conditions ($t = 1.58$, $p = 0.12$), deaf signers and hearing controls do differ significantly in the homophone foil ($t = 2.68$, $p = 0.008$) and spelling control conditions ($t = 1.94$, $p = 0.05$). Figures 15 and 16 show the proportion of regressions into R2 by group and condition respectively.

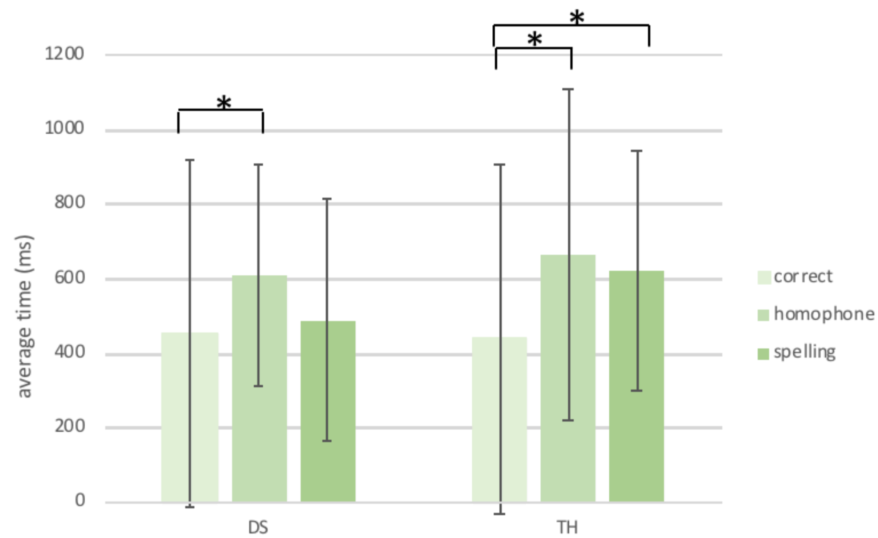

Figure 15: Proportion of regressions into R2 by group; *SD* reported

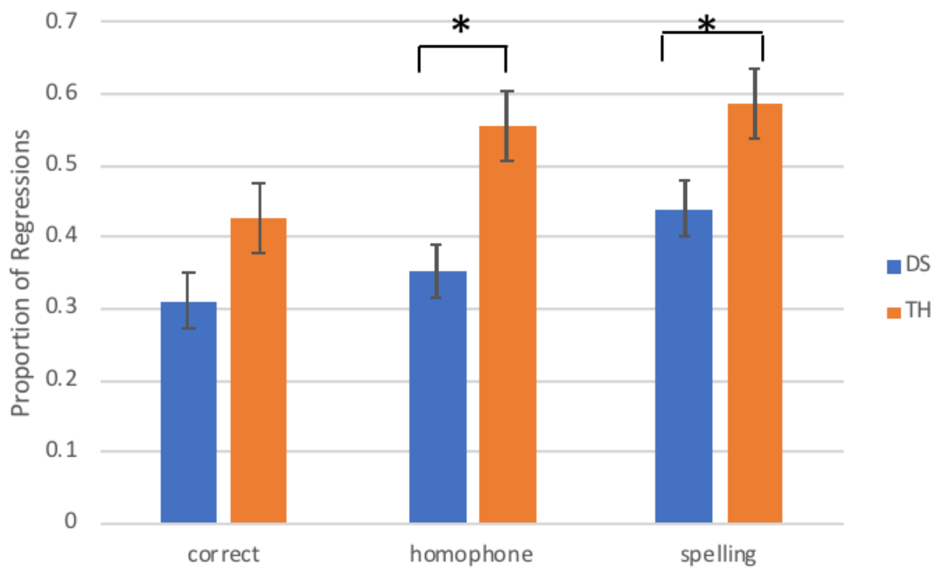

Figure 16: Proportion of regressions into R2 by condition; *SD* reported

Native signers perform regressions most during the spelling control condition, but less consistently during the homophone foil condition. Hearing controls overall perform significantly greater proportion of regressions during the homophone foil and spelling control conditions as compared to the correct condition. There is no significant difference between proportion of regressions during the homophone foil and spelling control conditions. To further understand the degree of disfluency caused by each condition, we must consider total reading time. Total reading time indicates overall looking time into a region, regardless of first, second, etc. pass. Increased total time indicates longer fixations on the target word, which indicates the need to disambiguate or reevaluate the content of that region.

Total reading time across groups (figure 17) and conditions (figure 18) do show some interesting trends. Both deaf signers and typically hearing participants have longer reading times for both homophone foil and spelling control conditions. Deaf signers have the lowest average total reading time in the correct condition (m=453.47 ms; *SD*=468.44), as compared to higher total reading times in the homophone foil condition (m=610.8 ms; *SD*=323.69) and spelling control condition (m= 488.05 ms; *SD*=323.69). A t-test indicated that the difference in total reading time during the homophone foil condition compared to the correct condition is significant ($t= -2.8$, $p = 0.006$) but not between the spelling control and correct conditions ($t= -0.79$, $p = 0.43$). Similarly, deaf signers have significantly higher reading times in the homophone foil than in the spelling control condition ($t = 2.22$, $p = 0.028$). Hearing controls followed a similar pattern with the lowest total reading times in the no change condition (m=438.11 ms; *SD*= 298.04), as compared to similar and higher reading times in the homophone foil condition (m=663.41 ms; *SD*=444.72) and spelling control condition (m=622.06 ms; *SD*=459.10). A t-test indicated that the total time between the correct condition and both the homophone foil ($t= -3.63$, $p = 0.0004$) and spelling control (t= -2.84, p = 0.005) conditions vary significantly in hearing readers. However, spelling control and homophone foil conditions do not differ significantly (t = -0.55, p = 0.58), unlike the signing group.

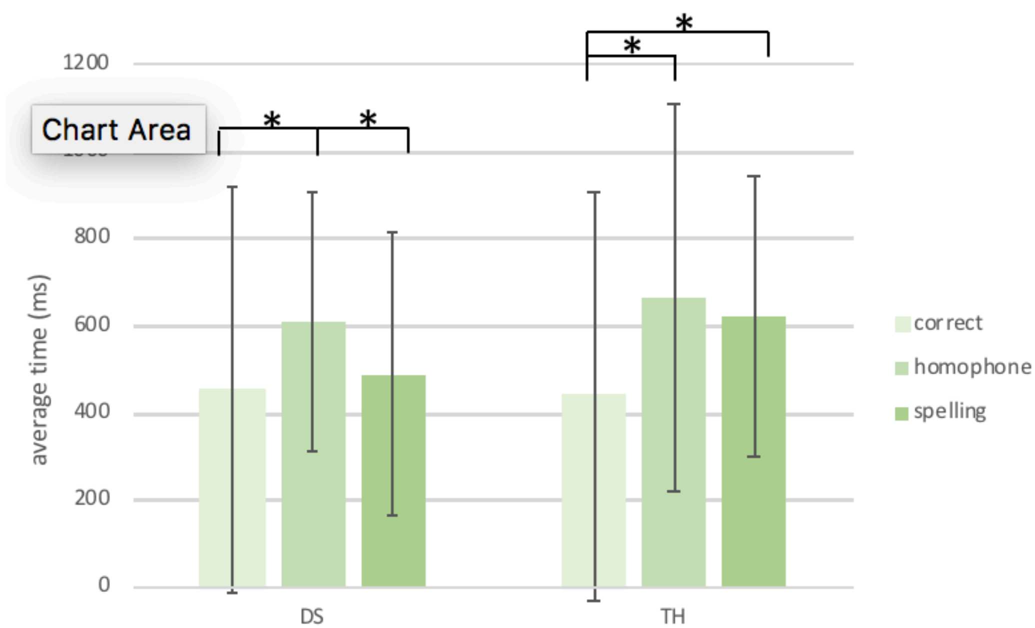

Figure 17: Total reading time by group; *SD* reported

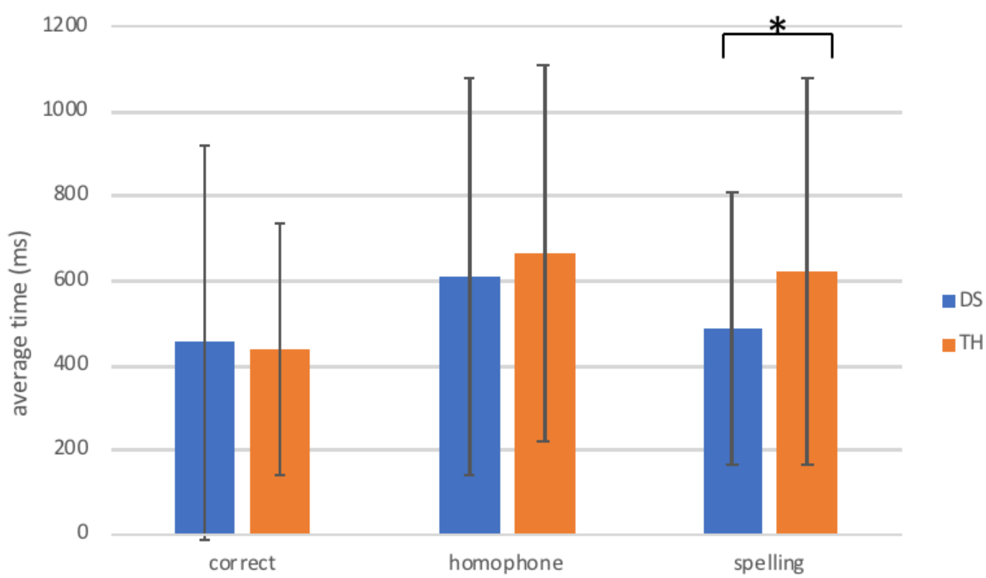

Figure 18: Total reading time by condition; *SD* reporte

4. DISCUSSION

Keeping in mind that the results are based on only half of the expected deaf signing and typically hearing participants, a few trends have become clear from our preliminary analysis. Currently, the results of our measures of phonological awareness have generally followed our predictions. Deaf signers do indeed have significantly higher ASL phonological awareness than hearing controls, with scores on the ASL rhyme task approaching a significant difference, and typically hearing children have significantly higher English Rhyme scores than native signers. The ASL-PA and English Syllable Judgement Task do not vary significantly between groups.

Perhaps of most importance to the discussion of the behavioral data is the performance across groups on the Woodcock-Johnson III (WJIII) measure of silent reading. The typically hearing group are outperforming their ages overall. This could be due to the overall higher socio-economic status (SES) of the hearing group or the higher average parental education level. Nonetheless, the deaf signers performed very well on the WJIII as well. Even with the removal of the outlier who outperformed her age group and grade equivalence significantly, deaf signers are reading at their age level despite lower English phonological awareness. They do not appear to be delayed in their reading skills, despite some reports indicating that deaf signers tend to read about two grade levels lower than their actual grade level (Trybus & Karchmer 1977; Wolk & Allen 1984; Dew 1999; Easterbrooks & Beal-Alvarez 2012).

A few interesting trends are beginning to emerge in the eye-tracking data that are important to note, and indeed a few statistically significant differences have appeared already. First pass reading time does not vary significantly across groups or conditions. This measure indicates how long participants fixate on the target word during their first encounter with the target while reading the sentence. Considering the similarity in first pass reading times of deaf and hearing participants, in conjunction with at- or above-age reading skills as measured by the WCJ-III, indicates that deaf and hearing readers are reading at roughly the same speed and efficiency. This is a logical explanation, considering that deaf readers have been shown to make use of parafoveal information when reading more than hearing readers, making them overall faster readers (Belanger et al. 2015). Future investigations will analyze eye-movement patterns while reading the non-target regions, regions one and three, to gain a better overall understanding of reading efficiency in early deaf readers.

When we consider the amount of regressions back into the target region, both deaf signers and typically hearing readers perform regressive eye-movements into the region of interest during the change conditions (i.e. homophone foil and spelling control conditions). Proportions of regressions differ significantly on all change conditions between hearing and deaf participants. Further, both deaf and hearing groups have a significantly lower proportion of regressions during the correct condition than during the spelling control condition. An increased proportion of regressions into the target region indicates that an error has been detected and the eyes regress back in an attempt to disambiguate the meaning of the sentence (Rayner 2009). This data suggests that deaf and hearing readers both detect the error in the homophone foil condition, indicating that both groups are reading via the direct route of meaning activation, bypassing phonological activation.

Analysis of total reading time across conditions and groups has yielded the most interesting trend thus far. Both the deaf and hearing groups differ significantly in the total reading time between the correct and homophone foil conditions. Hearing controls also have significantly higher total reading time during the spelling control condition than deaf signers. This further indicates that both the deaf signers and hearing readers recognize the error in the homophone foil condition, indicating a similar lack of reliance on phonological recoding in both groups. In addition, deaf signers and typically hearing controls have no significant differences in total reading time in the correct and homophone foil conditions. This pattern supports the hypothesis that deaf signers read similarly to hearing children of the same age and do not perform phonological recoding during reading.

Interestingly, though deaf signers have significantly lower total reading time during the spelling control conditions than the homophone foil conditions, deaf signers also have significantly higher proportion of regressive saccades in the spelling control condition than the homophone foil condition (see Figure 19). Considering that increased proportion of regressive eye-movements back into the target region as well as increased total reading time in a target region both indicate disfluent reading or error detection (Rayner 2009), this pattern is surprising. It appears that although deaf signers perform more regressions into the region in the spelling control condition than the homophone foil condition, they spend more time fixating on the homophone foil. Increased total reading time suggests the error is detected in the homophone foil condition.

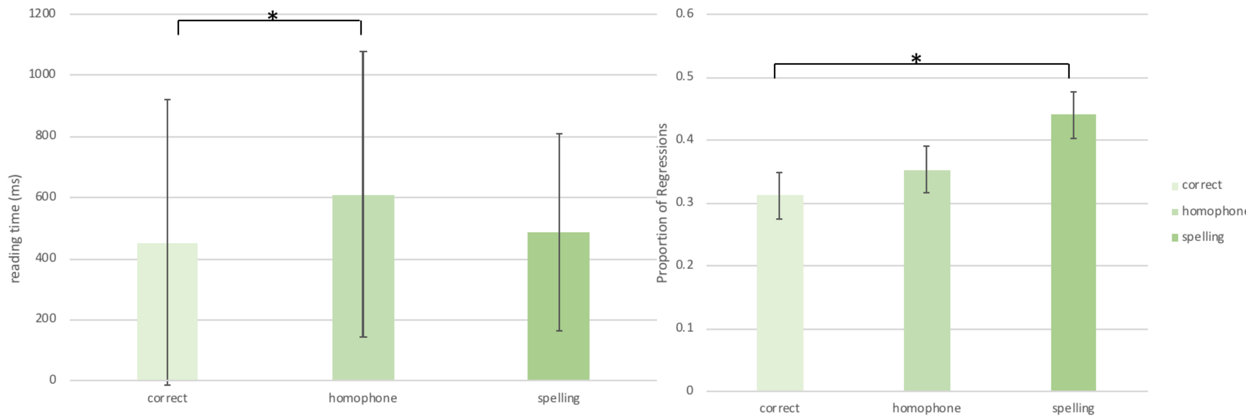

Figure 19: Total reading time vs. Proportion of regressions in deaf signers; *SD* reported

This could indicate that deaf signers are detecting the homophone foil and require more time to disambiguate the homophone foil than the obviously incorrect spelling control. Further investigation will be required to further elucidate this pattern, including a measure of spelling proficiency. This could be that although deaf signers are reading without activation of English phonology, some degree of orthographic similarity is causing more disfluent reading in the homophone foil condition. The sentences were constructed taking into account orthographic similarity and high vs. low frequency words (Jared et al. 2015). Further analysis of reading patterns in each sentence and condition needs to be analyzed to fully understand whether orthographic regularity is playing a role in this pattern. Similarly, we may consider testing participants' spelling in a post-eye-tracking spelling test of particular target words within the paradigm. This may help us gain an understanding of the degree to which deaf participants are relying on English orthographic regularity.

Importantly, the results from our hearing group mirror the original results from Jared, Ashby, Aguaus, and Levy (2016) from which eye-tracking stimuli were borrowed.

They report overall gaze duration (i.e. total time) in typically developing, typically hearing children on the three conditions. Similar to the data reported in this paper, their participants demonstrated lowest reading times during the correct condition (m=337 ms) with higher reading times in the homophone foil (m=356 ms) and spelling control condition (m=381 ms). However, they report that homophone foils are significantly less disruptive than the spelling control condition. In our data set, there is no significant difference in total reading time in the homophone foil and spelling control conditions for both of the analyzed groups. This could be due to the fact that in the original participant pool in Jared et al. (2016), some of the participants were average to below average readers. These readers may be skewing the average reading times slightly towards more novice reading patterns, with evidence of some degree of phonological recoding during online reading. In our dataset, however, all of the typically hearing readers read at or above their age level, as tested via the Woodcock-Johnson III Test of Silent Reading Fluency. This could explain why homophone foil looking times vary between the current dataset and the original dataset in Jared et al. 2016.

5. PRELIMINARY CONCLUSIONS

Though our goal is to have 20 participants per experimental group, some very interesting trends have become apparent and trends in the data have followed our predictions. Indeed, despite not reaching recruitment goals, some of the statistics have already reached significance. Behavioral data indicate that deaf signing children are reading at their grade level, and that some are reading above their grade level. Similarly, it is interesting that deaf signers are strong and proficient readers despite having the lowest scores on the English phonological awareness tasks. This could be, in part, be explained by the highest overall ASL skills.

Also, though some of the eye-tracking results demonstrate no significant differences in reading patterns between deaf and hearing participants, total reading time across conditions indicates that deaf signers and typically hearing controls similarly read via the direct route of meaning activation bypassing the level of phonology. This is evidence because total reading time of the target region is significantly greater during the homophone foil condition than the correct condition in the deaf signing group and in the typically hearing controls. I suggest that current trends in the data indicate that deaf children and hearing children employ the same cognitive processes when reading and that deaf children do indeed read via the direct route of meaning activation, bypassing the level of phonology.

I am confident that with more data and further analysis, we will ultimately have a greater understand of the role of the visual language signal on reading in deaf children.

6. NEXT STEPS

Most importantly, I aim to have 20 participants per experimental group by the end of this project. With 20 participants per group, coupled with the high number of sentences per experimental condition being read by each participant, I anticipate to have data with results that can be generalized to the populations at large. Similarly, we will push recruitment for oral/aural deaf participants so that we can compare reading patterns between deaf children with different experiences with language.

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