Phonological and orthographic processing in deaf readers during recognition of written and fingerspelled words in Spanish and English

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Declaration

I, Laura Raquel Monroy Camarena, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

This thesis is specially dedicated to my son Leonardo who has been growing inside me as I have been writing this thesis. I also dedicate this to my husband and my parents for their unconditional love and support.

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Abstract

The role of phonological and orthographic access during word recognition, as well as its developmental trajectory in deaf readers is still a matter of debate. This thesis examined how phonological and orthographic information is used during written and fingerspelled word recognition by three groups of deaf readers: 1) adult readers of English, 2) adult and 3) young readers of Spanish. I also investigated whether the size of the orthographic and phonological effects was related to reading skill and other related variables: vocabulary, phonological awareness, speechreading and fingerspelling abilities.

A sandwich masked priming paradigm was used to assess automatic phonological (pseudohomophone priming; Experiments 1-3) and orthographic (transposed-letter priming; Experiments 4–6) effects in all groups during recognition of single written words. To examine fingerspelling processing, pseudohomophone (Experiments 7–9) and transposed-letter (Experiments 10-12) effects were examined in lexical decision tasks with fingerspelled video stimuli. Phonological priming effects were found for adult deaf readers of English. Interestingly, for deaf readers of Spanish only those young readers with a small vocabulary size showed phonological priming. Conversely, orthographic masked priming was found in adult deaf readers of English and Spanish as well as young deaf readers with large vocabulary size. Reading ability was only correlated to the orthographic priming effect (in accuracy) in the adult deaf readers of English. Fingerspelled pseudohomophones took longer than control pseudowords to reject as words in the adult deaf readers of English and in the young deaf readers of Spanish with a small vocabulary, suggesting sensitivity to speech phonology in these groups.

The findings suggest greater reliance on phonology by less skilled deaf readers of both Spanish and English. Additionally, they suggest greater reliance on phonology during both word and fingerspelling processing in deaf readers of a language with a deeper orthography (English), than by expert readers of a shallow orthography (Spanish).

Impact Statement

Difficulties in reading skill have been observed in many marginalised populations, including deaf people (McKee et al., 2015). The fact that there are exceptionally skilled deaf readers (Hirshorn et al., 2015) clearly indicates that deafness itself is not the direct cause of these reading difficulties. Nevertheless, it has been reported that a significant percentage of deaf children struggle to achieve high performance on reading tasks (Conrad, 1979; Lederberg, et al., 2013). Thus, it is important to elucidate the factors that could underlie such differences.

The goal of reading is to understand the meaning of a given text and in order to achieve this, it is essential to first have access to the individual words comprising that text. Readers that have a high performance in word recognition are also good at reading comprehension (Nation & Snowling, 1998; Rayner et al., 2001). Given that phonological processing has been found to be essential for reading alphabetic languages in hearing readers (Castles et al., 2018; Frost, 1998), a lot of the research in deaf readers has focused on assessing whether deaf readers can achieve some level of phonological processing. However, whether deaf readers automatically use phonological information from words during word recognition is still a matter of debate. There are some factors that might explain the mixed results (e.g., variability in participant's reading skills, methodological differences or differences in orthographic depth of the languages tested).

In this thesis, experiments were conducted to investigate whether deaf readers of English (adults) and Spanish (adults and young readers) use phonology automatically during SWR. Furthermore, it has been proposed that orthographic processing might be a better predictor of deaf reader's reading ability than it is of hearing reader's reading ability (Bélanger & Rayner, 2015; Emmorey, 2020; Gutierrez-Sigut et al., 2019; Meade et al., 2019). Therefore, it is also explored how deaf readers use orthographic codes during SWR.

The work in this thesis furthers the understanding of the interplay between phonological, orthographic in a developmental trajectory (e.g., readers that are a different stage of reading development). Additionally, given that fingerspelling (manual representation of the alphabet) has been found to correlate with literacy in deaf children (Haptonstall-Nykaza & Schick, 2007) and serve as a bridge between orthography and phonology when learning how to read, fingerspelled word processing was also explored.

It is important to identify the factors that positively affect reading ability in deaf readers. Therefore, this thesis focused on the mechanisms used for visual word recognition by deaf readers and their relationships to phonological awareness, vocabulary, speechreading, and fingerspelling. This has several implications for deaf readers which are in different stages of development. The studies in this thesis can inform us how deaf readers process single words (printed and fingerspelled) and thus, create better interventions in learning and improving reading ability. As this thesis included participants from different orthographic depths (English and Spanish), the findings could also give a picture of the role of orthographic depth (opaque vs transparent) in the processing of SWR.

Table of contents

List of Figures:

List of tables:

1. Introduction

In modern society, reading is a fundamental skill that provides access to a variety of valuable knowledge and information. Knowing how to read greatly facilitates our daily activities, from reading short, simple messages (e.g., short texts from our family and friends or a prescription), to reading longer, more complex texts (e.g., books or scientific papers). Although often taken for granted in modern society, good reading skills can positively impact a person's life and can empower us to lead independent, fulfilling lives. Reading not only gives us access to education, which is known to be associated with socio-economic status and living standards (Huurre et al., 2006), but it also broadens our cultural engagement (e.g., poetry and literature) and more generally provides us with the possibility of constantly acquiring information that is of paramount importance for our health, safety and welfare (Castles et al., 2018). Conversely, having poor reading skills may have a negative impact not only in education but also on our general well-being (McArthur & Castles, 2017). In this chapter I will give a brief introduction of reading ability and its main components in deaf and hearing people. Furthermore, I will put emphasis on the factors that have been proposed to influence reading development in deaf people. For example, phonology, early language experience in learning how to read, age of onset and level of deafness.

The ultimate goal of reading is to understand the meaning of a given text. However, in order to achieve this goal, it is essential to first have access to the individual words comprising that text. It is important to note that for hearing people, reading is ‘parasitic on spoken language’ (M. J. Snowling & Hulme, 2012).That is, in hearing people, learning to read single words predominantly involves mapping the letters (i.e., orthographic representations) into existing sounds (i.e. phonological representations), which unlocks access to the semantic, grammatical and pragmatic content already linked to the word’s sound. In general, readers that have a high performance in word recognition are also good at reading comprehension (Nation & Snowling, 1998a; Rayner et al., 2001). The ‘simple view of reading’ (Gough & Tunmer, 1986) proposes that good reading comprehension requires both strong language skills and good word decoding. In this context, decoding is defined as the ability to convert the letters into their sounds, thus written words can activate the related spoken language phonology. The importance of decoding skills is clear when we consider that the inability to decode has been identified as the main factor to explain reading impairment in dyslexic children (Firth, 1972; Snowling, 2013; Snowling & Hulme, 2012; Vellutino et al., 2004). The ‘simple view of reading’ (Gough & Tunmer, 1986) also proposes that, in addition to having good decoding abilities, good language skills (e.g., vocabulary size) are essential to achieve good reading comprehension. Having good decoding but low language skills has been found to result in reading comprehension impairments. In this situation children do not understand the meaning of words, but nonetheless they can accurately read them aloud (Nation & Norbury, 2005).

Spoken language vocabulary has been identified as one of the main longitudinal predictors of reading comprehension (Muter et al., 2004; Protopapas et al., 2013), in different stages of reading development (e.g. see Yovanoff et al., 2005). Many studies have shown that vocabulary positively correlates with word identification, decoding skills, and comprehension processes (Ouellette, 2006; Storch & Whitehurst, 2002). In fact, a large proportion of reading comprehension variance can be attributed to vocabulary measures (Ouellette, 2006). Even though this thesis does not focus on the assessment of language skills, language background details are collected for all participants in order to better describe the participants. In addition, vocabulary size is used as an approximation of their language skills for use in analyses.

For a variety of reasons, difficulties in reading skill have been observed in many marginalised populations, including deaf people, (McKee et al., 2015). The fact that there is a number of exceptionally skilled deaf readers (Hirshorn et al., 2015) clearly indicates that deafness itself is not the direct cause of reading difficulties. However, a significant percentage of deaf children struggle to achieve high performance on reading tasks (Conrad, 1979; Lederberg et al., 2013; Qi & Mitchell, 2012; Wauters et al., 2006). For example, Conrad (1979) found that deaf students leave school at the age of 16 with reading levels of 9 years old. In a literature review by Lederberg, et al., (2013) it was shown that even though developmental trajectories of deaf children (particularly with hearing parents) have improved in recent years thanks to early identification and interventions, many children are still showing some weaknesses in their grammar development. These language limitations have a domino effect in other areas of development, such as theory of mind and literacy development (Lederberg, et al., 2013).

Given that phonological processing has been found to be essential for reading alphabetic languages in studies with hearing readers (Castles et al., 2018; Frost, 1998), a lot of the research in deaf readers has focused on assessing whether deaf readers can achieve some level of phonological processing. These studies have sought to establish whether underspecified phonological representations explain the vast majority of the reading deficits in this population (as proposed for example by McCandliss et al., 2003). However, despite the amount of research in the area, whether deaf readers automatically use phonological information from words during word recognition is still a matter of controversy in the field. There are several factors that might explain these mixed results and lack of consensus, for example: the high variability of deaf people's language background; the wide distribution of reading skill in the deaf population; methodological differences between the studies (e.g., task requiring explicit manipulation of phonology or not); or differences in orthographic depth of the languages tested. This will be discussed in more detail in Chapter 3 of this thesis.

A primary aim of this thesis is to examine reading in deaf people who read orthographies that differ in terms of 'depth'. The depth of orthography in the context of alphabetic orthographies is defined as the grade to which a written language matches its letters to sounds. For example, if the words have a direct production based on how they are written (i.e., one to one correspondence letter-phoneme), they are considered to have a transparent orthography (e.g., Spanish and Italian). On the opposite end of the spectrum, there are also opaque orthographies, which contain several inconsistencies on their letter-sounds matching, making it more difficult to pronounce a word based only on its spelling (e.g., English). Depth of orthography of the language tested is a particularly relevant factor for word recognition in alphabetic languages, as previous research has shown that phonological effects are usually stronger in transparent orthographies such as Spanish, in which the phoneme and grapheme have a one-to-one correspondence (Frost, 1994), than in languages with a deeper orthography such as English—in which phonemes can be spelled in multiple ways (e.g., two or three letters can represent one sound, and vice-versa one letter can represent two sounds (see Algeo & Butcher, 2013). One of the main aims of this thesis is to examine the use of phonology by deaf participants during SWR, exploring two languages with different orthographic depths (English and Spanish). Therefore, phonological effects will be explored during a Lexical Decision Task (LDT) in deaf readers of English and Spanish. The way that phonological effects will be calculated in response time (RT) and accuracy are as follows: responses to pseudohomophones minus responses to orthographic control words. With regard to RTs, if the difference score is negative, this will mean that participants are responding faster to targets preceded by pseudohomophones (e.g., kup - CUP) vs orthographic controls (e.g., fup, CUP). With regard to accuracy, if the difference score is positive, this will mean that participants have better accuracy for targets preceded by pseudohomophones vs orthographic controls. I aim to establish whether deaf readers of English (adults) and Spanish (adults and young readers) use phonology automatically during single word recognition (SWR).

Orthographic processing (i.e., the identification of each letter and its position within a word) has received much less attention in deafness-related research than research with hearing readers. This will also be addressed in this thesis. Orthographic manipulations have been often included in studies comparing word recognition in deaf and hearing participants to establish a baseline to interpret possible differences in phonological processing (e.g., Gutierrez-Sigut et al., 2018). Of the few studies that have examined orthographic processing, these have typically not reported any differences in orthographic processing between deaf and hearing readers, alongside the typically reported phonological effects present for hearing but not deaf readers (e.g.,Costello et al., 2021). However, it has been proposed that orthographic processing might be a better predictor of deaf reader's reading ability than it is of hearing reader's reading ability (Bélanger & Rayner, 2015; Emmorey, 2020; Gutierrez-Sigut et al., 2019; Meade et al., 2019, the details of Orthographic coding will be discussed in depth in Chapter 4). In this thesis a well-known effect in orthographic processing, the letter transposition effect, is used to investigate the mechanisms underlying orthographic processing in deaf readers. Furthermore, whether individual differences in orthographic precision are related to reading ability in deaf readers will be investigated.

Another feature of reading examined in this thesis is Fingerspelling. Fingerspelling is. the manual representation of the alphabet on the hands to represent individual letters. It has been proposed that fingerspelling can serve as a link for deaf children between the semantic concepts (accessed through signs) and the orthographic representation of words (Padden & Ramsey 2000). Recent research has also suggested that fingerspelling can provide access to spoken word phonology (see Haptonstall-Nykaza & Schick, 2007). This will be expanded upon in Chapter 3. This thesis will examine the mechanisms underlying phonological and orthographic processing of written words as well as fingerspelled words. Moreover, the possible links between individual differences in processing of fingerspelled words and reading ability in a wide range of deaf signers is investigated. This is important because there are only a few studies exploring orthographic and phonological processing of fingerspelled words.

In summary, the main goal of this thesis is to further our understanding of the processes of word recognition in deaf readers, with an emphasis on phonological and orthographic processing, while also assessing the contribution of fingerspelling to successful word recognition. More specifically, this thesis studies the automatic use of orthographic and phonological codes during printed and fingerspelled word recognition, in readers of languages with different orthographic depths (English and Spanish) and across different stages of literacy acquisition. In the case of deaf English readers, the word recognition mechanisms exclusively in adults are studied, whereas in the case of deaf readers of Spanish the developmental trajectory across teenagers and adults is investigated, to further our understanding of the interplay between phonological, orthographic and fingerspelling processing at different stages of literacy acquisition. That is, whether the relative contribution of each type of processing to reading ability varies depending on the stage of reading acquisition will be examined.

In the sections below reading in deaf people, level of deafness, early language experience in learning how to read, and reading ability are reviewed.

1.1. Reading in deaf people

A wide range of variability has been observed in the reading skills in deaf people. Whilst there are some extremely skilled deaf readers (Hanson, 1989), there are also many deaf children that only achieve a lower reading performance than their hearing peers (e.g., Conrad, 1979; Lederberg et al., 2013). Very often this reading difficulty continues into adolescence and adulthood. Deaf children have a heterogenous language background and different educational experiences that could contribute to their reading development. While there are indeed many societal factors that could contribute to these observed differences, the lack of fully formed phonological representations, evidenced by the lack of phonological effect during word recognition or low scores in phonological awareness tasks, has been suggested as one of the main factors that explain some of these deficits in their reading development (Perfetti & Sandak, 2000). Altered access to the sounds of words is thought to prevent deaf children from matching the upcoming letters to existing sound-based phonological representations, a process that is essential for successful reading development in hearing readers (Goswami, 2002).

As is the case in hearing readers, many studies in deaf readers have also established a link between the poor reading outcomes and difficulties in spoken language phonological processing. For example, it has been proposed that one of the reasons why deaf readers leave high school with a reading age equivalent to a 9 year-old hearing child (Conrad, 1979; DiFrancesca, 1972; Kyle & Harris, 2010), is their relatively low phonological awareness (Perfetti & Sandak, 2000). However, people born deaf might be able to build a phonological representation using information transmitted visually through speechreading (Kyle & Harris, 2011) and fingerspelling (Haptonstall-Nykaza & Schick, 2007). Phonology is important for hearing people learning how to read and it is often regarded as extremely important for reading in deaf children too. This will be discussed in depth in section 3.4. Phonological Awareness.

Language comprehension is one of essential factors for successful reading according to the 'simple view of reading' (Gough & Tunmer, 1986). Some of the factors that can influence language comprehension in deaf readers are age of onset and level of deafness and language experience. Level of deafness is measured in decibels (db). Please see in Table 1 the categorization of deafness, language use description and examples of missing sounds:

Table 1. Level of deafness

Categorization of deafness	Decibels	Language description use and examples of missing sounds:
Mild	25-39db	- struggle to hear speech in noisy environments

		- can hear all sounds
Moderate	40-69db	- may need hearing aids to follow speech - can't hear vacuum cleaner
Severe	70-94db	- difficulty following speech without hearing aids, and usually relies on speechreading - can't hear baby crying
Profound	95+db	- usually relies on speechreading or sign language -can't hear aeroplanes.

This thesis focuses on adults and adolescents who are severely or profoundly deaf with an onset before the age of 3 yrs.

1.1.1. Early language experience in learning how to read

Ninety to ninety-five percent of deaf children are born to hearing parents (Mitchell & Karchmer, 2004). These children have wide-ranging early language experiences. However, one commonality is that their early exposure to spoken language is impoverished. This ends up being critical to the reading development in deaf children and also affects their early language experience.

In hearing children reading is learned after some degree of proficiency with spoken language has been established (Muter et al., 2004). In contrast, the early language experience of deaf children is different to that of hearing children. While hearing children are exposed to spoken language from birth, around 90% of deaf children are born to hearing parents who do not know a signed language, or know very little, (Mitchell & Karchmer, 2004), and therefore cannot provide a rich visual language input from birth. These deaf children are likely to develop without exposure to sign language and will likely have partial exposure to spoken language. On the other hand, around 5-10% of deaf children are born to deaf parents. This group of deaf children generally have the advantage of having been exposed to sign language since birth and communicate with their parents in their native language. Importantly, these children are exposed to a rich language at a critical stage of development.

Sign Languages are natural human languages with a complex linguistic structure (Emmorey 2001; Goldin-Meadow & Mylander, 1998) as well as critical periods for acquisition (Mayberry & Eichen, 1991; Meier & Newport, 1990). Deaf communities have developed their own sign languages where there has been group of deaf people together and a pressure to communicate (Morgan & Woll, 2002). In fact, it has been argued that sign language may be considered as the first human language (e.g., use of gestures; Pfau et al 2012; Armstrong & Wilcox 2003). Even deaf children that have not been exposed to sign language, can develop certain gestures to communicate between them that seem to contain some of the linguistic structure found in natural languages (Goldin-Meadow & Mylander 1998; Senghas & Coppola, 2001). It is important to clarify that there is no such thing as a “universal sign language” and each individual country has their own sign language, with its variations from one region to another. However, it is important to understand that BSL is not merely a representation of spoken English (Sutton-Spence et al., 1990).

Sign languages are not only conveyed in a different modality to spoken languages (visual-gestural), but they also have their own syntax and grammar, which differs from the way spoken languages are structured and organised. For example, while English is the de facto official language of the United Kingdom, British Sign Language (BSL) is the language predominantly used by deaf signers in the UK (Irish Sign Language are used by a lower proportion of the population). The samples of deaf population included in this thesis are users of BSL and users of Mexican Sign Language (LSM, Lengua de Señas Mexicana).

The fact that the majority of deaf children have reduced access to language input from birth could partially explain why many deaf children are generally labelled as "language delayed" (Kuntze 1998). This language deprivation in deaf children can bring a delay on their development of cognitive skills that are closely linked to their linguistic abilities (Humphries et al., 2014), as well as have detrimental consequences for successful reading acquisition. Previous research has shown that the speed of language acquisition in deaf children exposed early to sign language (e.g., in ASL) is similar to that of hearing children, showing the same language development milestones (e.g., Newport & Meier, 1986). Moreover, many studies have shown that deaf signers have better performance at school than those who do not sign (Padden & Ramsey 2000) and, crucially, studies have found that signing skill positively correlates with reading proficiency (Chamberlain & Mayberry, 2008).

Regardless of early sign language exposure, all deaf children eventually learn English in written and spoken forms to some extent, effectively becoming sign-

speech or sign-print bilinguals (Woll & Macsweeney, 2016). However, it has been observed that deaf children who are provided with a rich accessible language environment, for example, learning sign language at an early stage, and using a sign language as their primary way of communication, puts them at an advantage also when learning spoken and written language, over those deaf children who have, to some extent, limited communication with their parents (see Chamberlain & Mayberry, 2000). The knowledge of sign language provides deaf people with a robust first language to which they can have full access to (as opposed to the limited access they have to spoken language). This enables them to build a robust semantic knowledge base upon which they can start to map written words. In other words, linking the printed word and meaning established via sign language. As semantic knowledge interacts with orthographic and phonological information, this helps in the process of word recognition proficiency (Seidenberg & McClelland, 1989).
Vocabulary is also one of the main factors that influence the development of literacy in hearing (Dickinson et al., 2003) and deaf children (Kyle et al., 2016; Kyle & Harris, 2011), playing an important role not only in recognizing single words (Nation & Snowling, 1998b) but also later in reading comprehension.

The role of vocabulary

Vocabulary is the foundation of language (Gardner, 2013) and it plays a key role during reading development, as it is one of the main predictors of word recognition (Dickinson et al., 2003) and reading comprehension (Muter et al., 2004; Verhoeven et al., 2011). Particularly the size of vocabulary is an important predictor of reading proficiency in children and adults (Verhoeven et al., 2011). This has been shown from early measures (e.g., children from 2 years old) of vocabulary size predicting literacy performance across the span of 9 years (Lee, 2011). Kyle et al (2016) found that vocabulary knowledge is also important in deaf children when learning to read. Similarly, Mayberry et al., (2011) found in a meta-analysis research that language skills (e.g., vocabulary measure) were the major contributors to reading.

In a longitudinal study by Kyle & Harris, (2011), hearing and deaf children were tested twice on a variety of cognitive and language-based tasks for two years. In the beginning stages of reading development their progress in literacy was similar, however, over the first 2 years of schooling, they started to use different strategies. The longitudinal correlates of reading in deaf children were earlier vocabulary, letter-sound knowledge and speechreading. In this thesis we measure English vocabulary size in deaf readers of English and Spanish vocabulary in deaf readers of Spanish. Vocabulary size is used as a proxy measure of language skill in deaf readers.

1.1.2. Studying reading ability in deaf readers

A wide range of variability in reading skills has been observed in deaf children and adults. According to the 'simple view of reading' language and decoding skills are the most critical aspects of learning to read in hearing readers. This seems to be also relevant to deaf people, however, it is not clear yet the weight of decoding skills on their reading development. Some studies (e.g., Gutierrez-Sigut et al., 2018) have showed that deaf readers use phonological codes to recognise words, but others have found that they seem to rely more on orthographic codes (e.g., Cripps et al., 2005; Fariña et al., 2017). One way to explore the weight of phonology and orthography codes used by deaf readers is through single word recognition tasks. Word recognition is an automatic and effortless process when words are presented in isolation (Rayner et al, 2012). There are specific paradigms that can explore the mechanisms of visual word recognition.

As it has been mentioned in this section, deaf children have a heterogeneous background on different dimensions. For example, language skills (e.g., strong sign language skills, but low or medium understanding of the spoken language, being the spoken language represented in written words, (see Hermans et al., 2010; Lederberg et al., 2013), level of deafness, and the reading related skills that they developed in different levels to access to phonological information when reading (e.g., speechreading and fingerspelling skills). The characteristics of these factors together with the mechanisms of visual word recognition can bring a better understanding on reading processing in deaf children and adults.
Therefore, this thesis will focus on the mechanisms used for visual word recognition by deaf readers and their relationships to phonological awareness, vocabulary, speechreading, and fingerspelling. In the following section the process of visual word recognition is described.

2. Visual word recognition

Visual word recognition (recognising visually presented words) is essential for skilled reading comprehension. Most of what we know about the mechanisms underlying visual word recognition has been learnt from skilled adult readers, for whom word recognition is automatic and effortless (Rayner et al., 2012). The process of visual word recognition has been studied mainly from two approaches: on the one hand, identifying which skills are used by experienced readers; on the other hand, focusing instead on how children learn to read and how they acquire and develop such skills. One of the complexities of taking such a developmental perspective in cross-sectional studies is that not all children start learning from the same starting point nor do they develop at the same pace. For example, there can be a lot of variability in children's language skills (e.g., vocabulary size) and decoding skills (e.g., phonological awareness) which are known to have great impact on their process of reading acquisition (Gough & Tunmer, 1986). This means that some children will find this learning process much more challenging and effortful than others. Given this inherent variability, which could lead to wrong interpretations of the process of word recognition (e.g., children are in different starting point when they are learning how to read, therefore they might use in different level their reading skills -decoding, vocabulary- for word recognition). It has been proposed that findings from reading development studies are grounded on the knowledge generated in studies of adult expert readers (Rayner et al., 2012). In other words, understanding the end-point of reading provides us with the advantage of being more precise in identifying the factors and tools that readers use to become successful readers. Although there could be the risk of not identifying key factors during the development of the reading skill. However, as we consider that there are more advantages than disadvantages this is the approach taken in this thesis. First, I assess the end-point of processing by studying the use of phonological and orthographic information from words in adult deaf readers of two languages with different orthographic depth (English and Spanish). Second, I use the same experimental paradigms to examine the progression of the word recognition mechanisms in a large group of deaf Spanish developing readers with different levels of reading skills. In the rest of this chapter, I first review the main models of visual word recognition, developed using data from adult skilled readers, to then discuss how children reach this end-point of reading development.

2.1. Models of Word Recognition

In this section I will briefly review three influential computational models of Visual Word Recognition (VWR) that have been proposed to account for VWR (see (Castles et al., 2018; Coltheart et al., 2001): Dual Route Cascade, Triangle Model, and the Connectionist Dual Process model. Although these models have fundamental differences in their approach (e.g., fixed dual route vs parallel connectionist processing, hard-wired vs learning models with modifiable connections), they all share the assumption that word recognition requires the involvement of orthographic (i.e. spelling), phonological (i.e. sound) and semantic (meaning) processing (e.g. (Coltheart et al., 2001; Harm & Seidenberg, 2004; Perry et al., 2007; Plaut et al.,1996; Seidenberg, 2005). For example, all of these models allow for bidirectional connections between the orthographic, phonological and semantic levels (see e.g., Carreiras et al., 2014; Rastle, 2016).

Dual Route Cascaded model (DRC, Coltheart et al., 2001)

The Dual Route Cascaded (DRC) model (Coltheart et al., 2001) of word recognition is a model of skilled word reading and has been a highly influential theoretical account of word processing. The DRC model suggests two different routes for readers to recognize words: direct and indirect (See Figure1). In the direct route, readers access the meaning of the word directly from print. That is, there is a direct orthography to semantics mapping (orthographic route), it is proposed that they subsequently gain access to the phonological properties of the word, but this is not necessary for word recognition (i.e., print – meaning – sound). This route is fast and used for highly familiar words by skilled readers. In contrast, in the indirect route (readers map from orthography to phonology and then access semantics). It has been proposed that this route is used mostly for new, low frequency and irregular words, and also for nonwords (Treiman & Kessler, 2007). The indirect route requires more effort and processing is slower than through the direct route. Evidence in support of this model comes from the finding that regular and high frequency words are recognized faster and more accurately than irregular and low frequency words

(Paap & Noel, 1991; Seidenberg et al, 1984). This has been explained in terms of the extra time needed for mapping sounds to letters (phoneme-grapheme conversion) when new, low frequency and less familiar words are encountered. As both routes play a crucial role during visual word recognition, it has been proposed that both are triggered by a word and the faster route wins (Paap et al., 1982; Paap, et al., 1987; Paap & Noel, 1991). According to the DRC model, during development, all words are initially processed through the phonological route, then experience with reading provides the basis for some words to become more familiar and be processed through the direct route (Coltheart et al., 2001). Thus, even when both routes are preserved and can be activated, the DRC model assumes a developmental transition between the extent of use of indirect and direct routes.

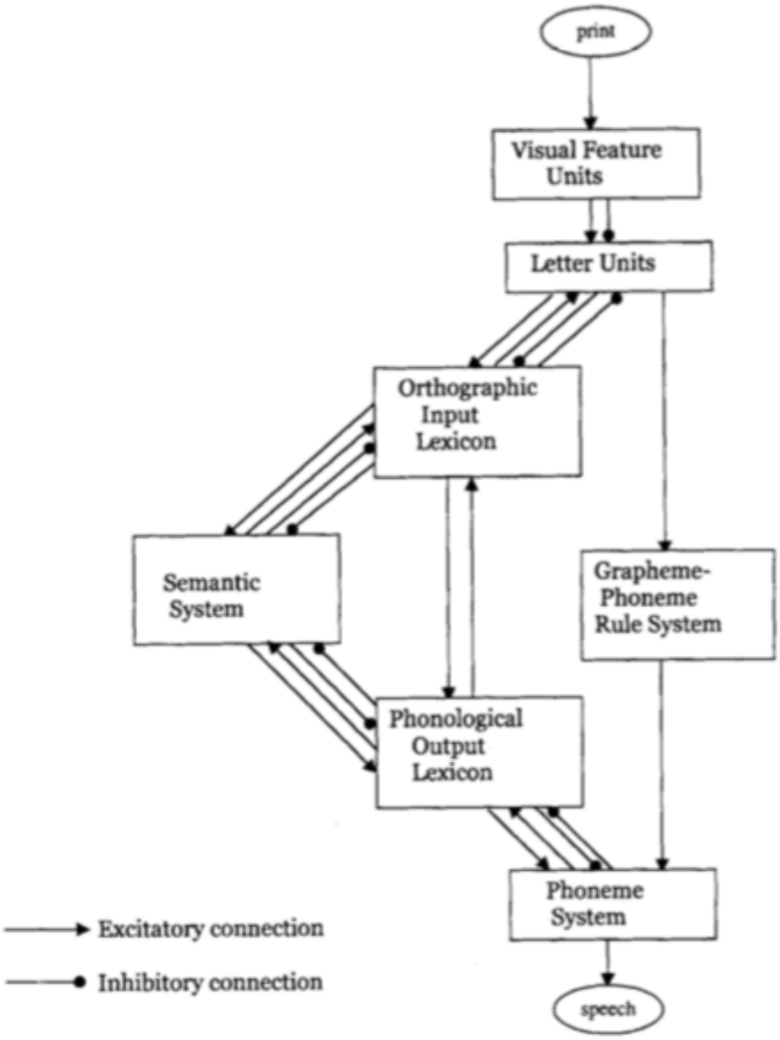


Figure 1. The Dual Route Model of Word Recognition DRC Model (taken from Coltheart et al., 2001).

The DRC model can also explain cases of individuals with reading difficulties such as dyslexia, where some of the difficulties can be observed in the phonological or/and in the orthographic routes, which can be simulated in the DRC model. For example, the DRC model was able to simulate four different types of acquired dyslexia: phonological dyslexia (see Coltheart, 1996; e.g., difficulty in reading nonwords), surface dyslexia (see Bishop & Snowling, 2004; Frost, 1998; Patterson et al, 1985; e.g., difficulty in reading irregular words by using the grapheme-phoneme correspondences), pure alexia (letter-by-letter reading, see Coltheart, 1998, e.g., cannot recognise words by rapidly looking at it); deep dyslexia (see Coltheart, 2000; Coltheart et al., 2001, e.g., reading aloud with semantic errors: ‘ill’ instead of ‘sick’, and with morphological errors. By “lesioning” certain components or elements of the DRC model (i.e., running simulations with extreme modification of original parameter values), it is possible to represent or mimic some of the deficits observed in individuals that have dyslexia (Coltheart, et al., 1996; Nickels et al., 2008).

Even though the DRC model is not a learning model and therefore can tell us very little about actual reading development, the model can provide a framework of the required components that a child needs to develop in their reading system (Coltheart et al., 2001). Therefore, an impairment that affects reading development could be interpreted in terms of impaired components of the model of the DRC model’s architecture (see Figure 1). For example, a child with developmental ‘phonological dyslexia’ could successfully acquire words via the lexical route. However, s/he would have difficulties with learning words via the non-lexical route (see Snowling & Hulme, 1989; Castles & Coltheart, 1993). On the contrary, a child with developmental ‘surface dyslexia’ may be able to learn via the non-lexical route, however, they may have difficulties with the lexical route (e.g., difficulties in reading aloud irregular words, (see Broom & Doctor, 1995; Castles, 1996, Castles & Coltheart, 1993). The presence of these two types of developmental dyslexia supports the idea that the DRC model can be used not only as a framework for skilled reading, but also for learning to read and developmental dyslexia.

Triangle Model <u>(Harm & Seidenberg; 2004; Plaut et al., 1996; Seidenberg & McClelland, 1989)</u>

The triangle model was first introduced by Seidenberg and McClelland (1989) and developed further by Plaut et al., (1996) and by Harm & Seidenberg, (2004), see figure 2.. This connectionist model, or collection of models, can account for both, reading development in children and skilled reading in adults.

The models include separate layers of units, each representing or encoding one of three types of information: orthography, phonology and semantic, (ergo 'triangle'). There are intermediate layers of "hidden units" between each of the main three components which increase computational capacity of the network and serve as abstraction units combining information and activation between nodes (Figure 2 shows 'The Triangle Model"). Unlike the DRC model, where the activation of the routes is seen as a competition between mutually exclusive pathways with a race between them, the triangle models assume that the activation of semantic units come from the simultaneous activation of both pathways contributing and sharing the processing labour.

Another key difference is that while the DRC is a hard-wired model, the triangle models are connectionist models with modifiable connections between the nodes that change with 'experience' (i.e., training iterations or epochs). The more reading experience, the stronger the connections in the network (Cortese & Balota, 2012). Similar to the DRC model, the triangle model proposes that 'beginner' readers rely more on phonological information but in the course of mastering reading, they increase their use of visual (orthographic) information. However, instead of just assuming this transition like the hard-wired DRC model does, the triangle model can simulate an early reliance on the phonological mediated connections (orthography-phonology-semantic) which can later develop into direct activations of the orthographic to semantic nodes with additional training of the model (Harm & Seidenberg, 2004).

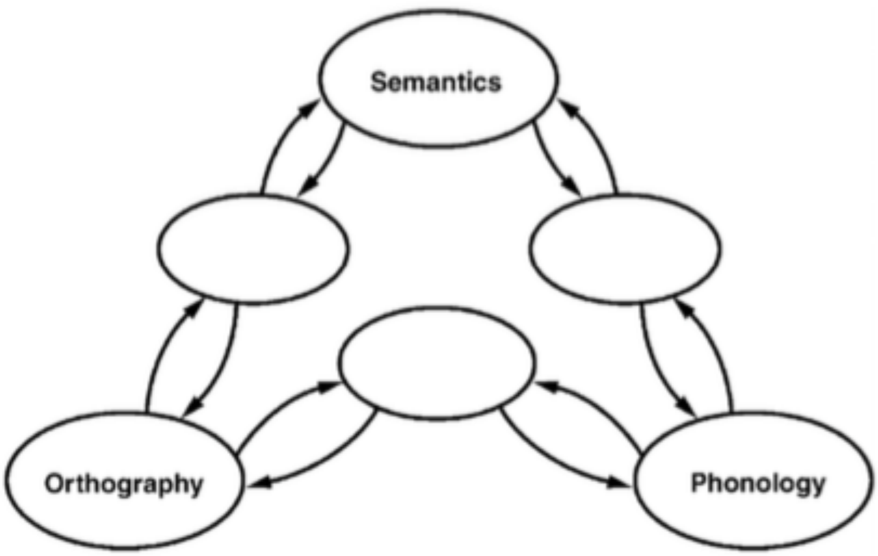


Figure 2. The 'Triangle' Model (taken from Seidenberg, 2005).

The Connectionist Dual Process model (CDP+, Perry et al., 2007)

The CDP+ model is a hybrid (connectionist and dual route) architecture combining aspects of the DRC and Triangle models. It uses a nested modelling approach, which means that instead of being a completely different model, it contains features of their direct predecessor models, incorporating the best features, while addressing some of their limitations and as a result showing a more robust performance (Perry et al., 2007). The CDP+ model is a development of the CDP model initially developed by (Zorzi et al., 1998), which showed high error rates when tested on nonword reading.

The model takes a similar approach to the triangle model in terms of using a connectionist architecture with modifiable connections (see Figure 3). However, unlike the triangle model, the CDP model incorporates an explicit distinction between lexical and sublexical processes which is similar to the dual-route model. The lexical route of the model is almost identical to the interactive network previously used in the original DRC model, with a few modifications to make it compatible with the output of the sublexical route. The CDP+ model includes an orthographic buffer within the sublexical route, based on the spelling model of (Houghton & Zorzi, 2003). For more details on the architecture, activation and equations implemented in the model see Perry et al., (2007).

Given that the CDP+ model is a learning model (i.e., connections are modifiable through experience), this means that changing the parameter of the model allows for the simulation of a variety of reading disorders and behavioural effects (for more details see (Zorzi, 2010). Moreover, it outperforms previous models in nonword reading performance (Perry et al., 2007), including the previous CDP version. The CDP+ is a hybrid model that combines and builds upon the strengths of previous computational models. By reconciling the seemingly opposite approaches (dual route vs triangle model) into an overarching architecture that incorporates aspects of the DRC as well as previous connectionist approaches providing a rich and robust computational model of single word reading (Perry et al., 2007). There have subsequently been two further upgrades have been developed for this model (CDP ++ by and CDP++parser by (Perry et al., 2010).

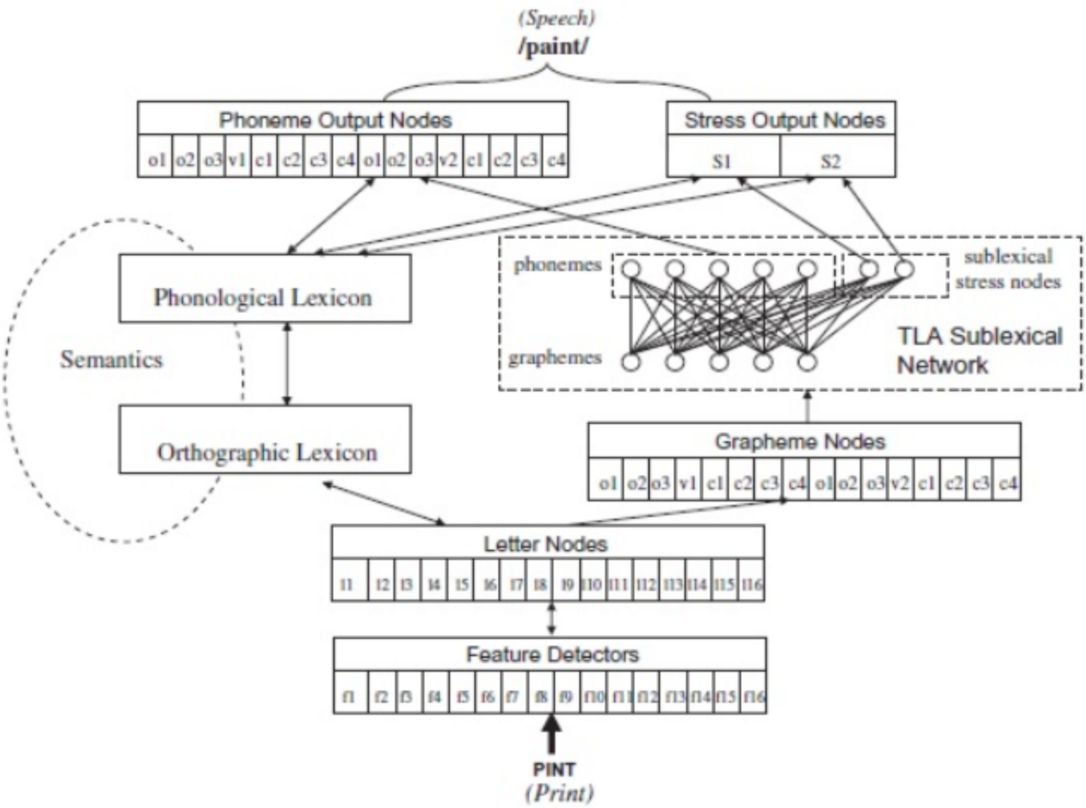


Figure 3. The Connectionist Dual Process Model (CDP+, Perry et al., 2007) taken from: http://ccnl.psy.unipd.it/CDP.html.

Note: O=onset; V= vowel; C=coda; TLA= two-layer assembly; IA=interactive activation; L=letter; F= feature

In summary, these three theoretical frameworks identify the emergence of two important paths or mechanisms for word recognition, a direct pathway from text (orthography) to meaning (semantics) and the indirect phonological pathway which access to the meaning (semantics) from text through sound (phonology). Furthermore, they support the idea that reading becomes fluent and automatic for regular high-frequency and more familiar words, either by using the direct pathway print to meaning (i.e., orthographic- lexical semantics in the DRC model) or by increased connectivity of orthographic to semantic nodes (in connectionist models). Even though these models were designed for typical readers; they can also either simulate (by changing parameters in learning models) or provide a theoretical framework (in the fixed dual route model) for understanding reading disorders like dyslexia (from brain injury or atypical reading development) and account for other reading effects (e.g., Zorzi, 2010).

It is important to mention that, although this is not a modelling thesis, the three modelling frameworks for visual word recognition presented in this section emphasise the relevance of phonology in reading. Either by assuming an indirect phonological mediated route (DRC model) or via layers of phonologically activated units that, through modifiable connections, (Triangle model and CDP+) enable the strengthening of orthographic to semantic connections. Therefore, the main implication is that if deaf readers have impoverished access to spoken language phonology, they would almost unequivocally struggle with word recognition. However, we know that this is not always the case, as there are indeed many proficient deaf readers. More recently, further adaptations have been proposed to the DRC and the CDP++ models to try to account for how deaf and hard-of-hearing (HoH) learn to read (see Doering, 2020). The modifications are based on reducing the importance of teaching auditory phonological processing. Instead, focusing on the use of different reading strategies that were identified in the deaf and HoH readers. For example, adding multisensory phonological processing guidance and increasing teaching in semantic knowledge. However, these proposed model adaptations need to be further tested empirically.

The Lexical Quality Hypothesis

The Lexical Quality Hypothesis (LQH) is a theoretical framework that extends the scope of previous theories, by contextualising the role of word recognition within reading comprehension (Perfetti & Hart, 2002). Within this view ‘effortful’ word recognition would leave the reader with less cognitive resources available for reading comprehension, since cognitive resources for reading are limited. It then follows that improvement in word recognition would result in better reading comprehension as more resources are allocated to comprehension (see e.g., Breznitz & Share, 1992; Tan & Nicholson, 1997). Therefore, if there is effortless word recognition, it should be related to good reading comprehension (see Lervåg et al; 2018). However, some studies have shown no relationship between speed of word recognition and comprehension (see Fleisher, Jenkins, & Pany, 1979; Perfetti, 1985). In other words, within this theory not everything is about fluency (i.e., quick word recognition), there are other “unspecified” factors that contribute to the quality of word representations that explain individual differences in reading ability. Moreover, the LQH emphasises the individual differences in reading comprehension by considering quality of word representations. In this context, quality is a more abstract term that includes not only the knowledge of form and meaning of words, but also more pragmatic features of word use, which allows for a more “precise” and “flexible” representation of the words. Precision is used to refer to the specificity of the orthographic representations, which allow readers to distinguish quickly between words with slightly different spellings such as ‘knight’ and ‘night’. It is important to note that precise representations are fully specified, which allows for the lexical representation to be activated by the visual pattern of a word with less interference (or competition) from similar words (Andrews & Lo, 2011). Phonological knowledge is also fundamental to word precision, as it increases redundancy of the representation (redundancy in terms of increased lexical and sublexical connections between orthography and phonemes, see Perfetti 1992), and hence ultimately increases lexical quality. ‘Flexibility’ is related to meaning - for example, to understand the same meaning from different words (e.g., fast and quick).

To sum up, a high-quality lexical representation is a mental representation of the word that comprises the form (orthography and phonology) and meaning in a precise, and flexible way (Perfetti, 2007, 2017). Within this view, the knowledge about each of these three key components varies not only by words but between individuals (Perfetti, 2017). Another key feature of this theory is that during word recognition skilled readers usually benefit in parallel from orthographic, phonological, and semantic knowledge by activating them simultaneously and not in separate parts (Perfetti, 2017). Furthermore, the LQH predicts variation among skilled readers in how they have developed a precise orthographic representation, and how these individual differences influence how they recognise single words (see Andrews and Lo 2012 and Mead et al., 2020). This will be discussed further in; Chapter 4.

2.2. Methods to study visual word recognition

The previous subsection (2.1) described some of the most influential models and theoretical frameworks of word recognition. In this subsection, the empirical approaches and methods that have been used to study visual word recognition are described.

2.2.1. Lexical Decision Task

The 'Lexical Decision Task' (LDT) is widely used in experiments to measure word recognition (Meyer & Schvaneveldt, 1971). In this task, participants are presented with a letter-string that can be a real word in the language or a nonword. Participants are instructed to press a specific key for a "word" target and another key for a "nonword" target. The LDT is a simple, fast and efficient way of assessing single word recognition (see Rayner et al., 2012). The LDT has been used in many studies (e.g., behavioural and neuroimaging) to explore the use or activation of lexical (e.g., word frequency, neighbourhood, etc.) and sublexical (e.g., phonological, orthographic, etc.) information when identifying visual target words. In a LDT, response Times (RT) and accuracy rates are recorded and analysed. Different features of the stimuli can be manipulated to examine their contribution to VWR. For example, Ferrand et al., (2011), found that word frequency accounted for 40% of the variance in RTs in a LDT. When examining a particular feature, it is of course necessary to control for other features of the words. For example, in a study of word frequency it would be necessary to control for: a) bigram frequency; which is a measure of the orthographic structure of a letter string (Rice & Robinson, 1975) and refers to how many times an adjacent pair of letters called “bigrams" occur in a text; b) word length, number of letters in a word, and, when relevant, c) age of acquisition (AoA), that is an average estimation of the age that a given word was acquired. All of these elements are considered in the experiments included in this thesis (see Chapter 6, and 7). This thesis uses the LDT in combination with a masked priming paradigm and an unprimed LDT, both are described in the next section.

2.2.2. Unprimed lexical decision and masked priming paradigms

Unprimed Lexical Decision

In an unprimed lexical decision experiment, a target (word or nonword) is presented in isolation. The experimental design typically consists of presenting a fixation cross (+) followed by the word or nonword for the participant to perform a LDT. Depending on the manipulation (usually over the nonword), this paradigm can be used to investigate phonology, orthography, or semantic coding. For example, this paradigm has been used to explore the use of phonological and orthographic information during visual word recognition in studies with deaf adults (, Fariña et al., 2017, Costello et al., 2021) and children (Transler & Reitsma, 2005). In this thesis, the unprimed LDT is used to investigate the use of phonological and orthographic information in experiments with fingerspelled stimuli (Chapters 6 and 7, section 6.1 and 7.1 for phonology and sections, 6.2. and 7.2. for orthography).

Masked priming paradigm

The masked priming technique (Forster & Davis, 1984; Kinoshita & Lupker, 2004) provides the opportunity to tap into an automatic processing during visual word recognition. In masked priming experiments, the target stimuli are preceded by briefly presented primes that bear a relationship with them (e.g., a pseudohomophone prime that is phonologically related, such as cet - SET). The primes are accompanied by a mask, (e.g., #####), that is usually the same length of the prime, that is presented either immediately before (forward mask) or after (backwards mask) the prime.

A prime can be orthographically, phonologically or semantically related to the target (Cortese & Balota, 2012). Typically, participants are asked to perform LDT to the target word, and differences in target processing are attributed to the influence of the prime. For example, in hearing skilled readers faster and more accurate responses are typically found to targets preceded by pseudohomophone primes than to those preceded by orthographic control primes (e.g., phonological prime, brane-BRAIN vs orthographic prime, brant-BRAIN; Carreiras et al., 2005; Grainger et al., 2006, Frost et al., 2003; Lukatela & Turvey, 1994; Perfetti & Bell, 1991). The faster and more accurate response is typically interpreted as indicating facilitation of the prime to recognise the target word.

Depending on the research question, the primes can be either words or pseudowords. Previous studies have shown that words as primes activate lexical competitors of the targets, causing an inhibitory effect (longer responses Davis et al., 1998). On the other hand, pseudoword primes are thought to pre-activate sub-lexical properties of the target and tend to yield facilitatory effects (faster responses, e.g., Lukatela et al., 1998). The experiments in this thesis focus on the role of phonology and orthography. Therefore, the primes used in the critical conditions in the present masked priming experiments were pseudowords (e.g., pseudohomophones and orthographic control primes).

One experimental setting that has been extensively found to influence the amount of priming is the time allocated to process the prime (see Ferrand & Grainger 1993). Although phonological effects can be observed with primes as short as 50ms in adult skilled readers (Holcomb & Grainger, 2006), this time might not be enough to processes phonological information from the prime for less skilled and developing readers (Comesaña et al., 2016 and see Gutierrez-Sigut et al., 2017 for the full argument). This might be one of the reasons why the few previous studies using masked priming with deaf readers have failed to find a phonological priming effect (Cripps, 2005: prime duration 67ms; Bélanger et al., 2012: prime duration 40 or 60ms, and none of these experiments had a blank window between the prime and target). In this thesis, primes are presented during 50ms and are followed by a 50ms blank window in order to allow for enough processing time. Furthermore, the 'sandwich masked priming' technique is used to explore the automatic use of phonological and orthographic information in deaf readers (See Experiments of Phonology, Chapter 6 and Experiments of Orthography Chapter 7). The 'sandwich masked priming' technique (Lupker & Davis, 2009) has been developed to boost existing masked priming effects in conditions in which they are typically small. The sandwich masked priming involves a brief (33ms) and visually dissimilar (i.e., smaller font) presentation of the target, followed by the prime and finally the target word The use of the sandwich technique has been shown to increase the size of priming effects (Lupker & Davis, 2009), in comparison to the standard priming paradigm where the target is only preceded by the prime.

The sandwich masked priming paradigm has been specially used for studies looking at the Transposed Letter effect (TL) with non-adjacent letter. Besides, its use in research into orthographic processing (Meade et al., 2020, Perea et al., 2008), the sandwich technique has been also used successfully in previous studies looking at the phonological or/and the orthographic priming effects with hearing children (Comesaña et al., 2016) and adult deaf readers (Gutierrez-Sigut et al., 2017, Meade et al., 2020).

2.3. Orthographic depth

Different writing systems reflect an individual association to the structure of their spoken language (Frost & Katz; 1992). Orthographies can be classified in terms of the linguistic information that they convey (De Francis, 1989). According to DeFrancis (1989) the writing systems are primarily built to represent the phonetic (i.e sounds of speech) characteristics of the spoken language. DeFrancis (1989) proposed a Writing Classification Scheme (see Figure 4), which describes how phonetic elements are represented in graphic or alphabetic symbols across different orthographies and whether syllables, consonant sounds or all the phonemes of the language are represented in the written symbols. Moreover, it considers if the orthographic codes include morphological information (with non-phonetic cues).

Figure 4. 'Writing Classification Scheme' *taken from DeFrancis (1989, page 58).*

Note:

syllabic systems "meaning + sound" = morphosyllabic systems
consonantal systems "meaning + sound" = morphoconsonantal systems
phonemic systems "meaning + sound" = morphophonemic systems
The dotted lines with arrows represent some genealogical information from parent languages to descendants.

This ‘Writing Classification Scheme’ by DeFrancis (1989) highlights that there is a phonetic base in all the orthographies. It also describes three levels of writing systems 1) Syllabic, 2) Consonantal and 3) Alphabetic, and whether the orthography has morphological (e.g., word structure) information coded in a script or whether it is purely phonetic. The orthographies that are characterised as purely phonetic show a grapheme-phoneme correspondence (GPC), such as Spanish (a Latin language), with one-to-one correspondence between sound and letter (e.g., the letter ‘a’ always maps to the same sound /a/, amor - love) (Frost, 1994). In contrast, deep orthographies (opaque or less transparent), such as English, the GPC is more irregular, and phonemes can be spelled in multiple ways. For example, two or three letters can represent one sound e.g., sc, /s/, science or /pi:s/ piece), and vice-versa one letter can represent two sounds (e.g., u, /ōō/, truth, see Algeo & Butcher, 2013). This is less common in Spanish as it only has five digraphs (a combination of two letters that represent one sound: ch, ll, gu, qu, rr).

It is unclear whether the process of learning to read in alphabetic languages is affected by the orthographic depth of a particular language (e.g., transparency, regularity, consistency). However, one factor that influences how orthographic and phonological information is used during word recognition and reading is the degree of GPC. For example, the English language is considered to have a relatively deep orthography, and as a result readers of English may rely more on orthographic information rather than processing phonological information (Miller. 2019). Research has shown that besides using multiple routes to access the meaning of words; (Brysbaert, 2001 & Coltheart et al., 2001), readers of English have to learn more sets of pronunciation rules (if there is a consonant between vowels, the pronunciation of the first vowel is as long vowel, e.g., face) than readers of more transparent orthographies (Kargin et al., 2012). Consistent with this view, a cross linguistic study with hearing individuals from transparent orthographies show that word recognition is easier for them during learning how to read, than it is for individuals from deep orthographies (e.g., a direct comparison between readers of Turkish and English, Durgunoğlu & Öney, 1999).

However, not many studies have addressed these differences in deaf populations. Kargin et al., (2012) investigated word reading skills of deaf (n=132) and hearing children (n=124) in reading transparent (German and Turkish) and less transparent (English, Hebrew, and Arabic) orthographies. The results from this study did not show the expected advantage for transparent orthographies previously observed in hearing readers: faster and more accurate reading of a transparent language. Participants were asked to respond if the displayed pair of words were the same or not. The words were presented either in a 'Perceptual condition': the pair of words were displayed either in print or in cursive script (e.g., napkin napkin, picture apple; or, *napkin napkin, picture apple*) or in a 'Conceptual condition' (from the pair of words; one word was in print and the other in cursive script (e.g., napkin *napkin*, picture *apple*). Importantly, the authors acknowledged that several cultural and educational variables that were not controlled, such as level of education, reading experience, sign or oral support at the school, might play a relevant role in the process of word recognition. These factors might have introduced enough variability to mask the possible effects of the type of orthography. Additionally, the task used in their study may not be well-suited or sufficiently sensitive to detect the effect of phonology. Because they do not measure access to phonology in the task, the authors just assumed that because the responses of the hearing and deaf participants in accuracy and RT were comparable during word processing, phonology may not have been used by deaf readers during the task, otherwise they would have underperformed responses compared to the hearing readers.

In this thesis I will compare responses to targets preceded by pseudohomone primes and orthographic control conditions using a sandwich masked priming paradigm (see Chapter 6). An unprimed LDT with fingerspelled words and pseudowords will be used, comparing RT and accuracy from pseudohomophones and orthographic controls. The same experiments (similar manipulations but different stimulus sets) are conducted in deaf readers of a transparent orthography (Spanish) and a deep orthography (English).

So far, I have considered the three main computational models of visual word recognition that have been proposed to account for VWR (see Coltheart et al., 2001, Castles et al., 2018): Dual Route Cascade, Triangle Model, and the Connectionist Dual Process model. These theoretical frameworks identify the emergence of two important routes for word recognition, a route from orthography to semantics and a phonologically mediated route which access to the semantics from orthography through phonology. Subsequently, I describe methods that have used in this thesis to explore visual word recognition. (e.g., masked priming and unprimed LDT). In addition, the orthography depth (e.g., transparency of the languages: one to one correspondence between letter and sound), has been argued to be one of the factors that influences how orthographic and phonological information is processed during SWR. In the next chapter I review previous studies that have used these approaches to investigate the role of phonology in visual word recognition in hearing and deaf readers at different stages of reading development.

3. The role of phonology in visual word recognition

Phonological processing is commonly accepted as one of the main contributors to visual word recognition in hearing adults (Frost, 1998). In hearing readers, the role of phonological processing is particularly important at the early stages of reading development (Nation & Snowling, 2004). However, as readers gain expertise they begin to rely more on orthography (visual information) to quickly recognise the words they encounter (Castles & Nation, 2006). Milledge and Blythe (2019) nonetheless argue that phonology is still used even in skilled readers, just to a lesser extent and more automatically than by developing readers. Hence, phonological processing does not fully disappear, but it takes a less important role as one becomes a more skilled reader (Castles, et al., 2018).

For example, the Dual Route Cascaded (DRC) model proposes that skilled readers rely more on visual codes (direct route; 'printed word' – letters – orthographic lexicon) to recognise highly familiar words, as their reading ability increases. Given that with the practice and exposure to reading they became experienced readers, they do not need to decode every single word as they start to recognise them by sight. On the other hand, there is a phonologically mediated pathway (indirect route: 'printed word' – letters – sounds – phonological and orthographic lexicons), that supports the process of converting the orthographic letters to phonological codes to facilitate visual word recognition. Although it is usually a slower process than the direct pathway, this route is used for low frequency words or nonwords which cannot be accessed by sight only (see section 2.1).

Below studies that explored the role of phonological processing in reading in hearing adults and children are discussed. The following section starts with studies of adult readers, who are likely to be at the end state of development. Then, studies with young readers are discussed, from which we can gain insight of the conditions under which the role of phonological processing may become crucial for word recognition. A similar structure will be followed by studies with deaf readers (section 3.2).

Previous research with skilled adult readers has consistently shown phonological effects during VWR. For example, masked priming studies using pseudohomophone primes have shown that the sub-lexical information provided by the primes facilitates recognition of the target word (Rastle & Brysbaert, 2006). However, unprimed lexical decision studies have shown that rejecting a non-word which sounds like a word (a pseudohomophone) is more difficult and takes longer than rejecting other types of pseudowords (Rubenstein et al. (1971) or subjects make more errors to homophonic items than non-homophonic in categorisation tasks (Van Orden, 1987). These studies suggest that depending on the experimental paradigm used, the direction of the effect can either show ‘facilitatory’ recognition effects (e.g., responding quicker and better to the target when the prime is presented), ‘inhibitory’ effects (e.g., longer responses and more mistakes when rejecting non-words) or simply no effect at all (i.e. no significant difference with control items). Davis et al., 1998, found that by using heavily masked homophones as primes, instead of pseudohomophones (i.e., words that have the same sound to the target, but different meaning – e.g., which - witch) show null priming phonological effects. The authors only found evidence of a phonological effect in some children suggesting individual differences on the use of phonology during development. Other factors that could modulate the direction of the effect are, type of paradigm (e.g., masked priming paradigm, unprimed LDT), task (LDT, naming task, rhyme task), participants (skilled readers vs developing readers), among other variables (see Lesch & Pollatsek, 1993). Therefore, when designing an experiment, it is important to take into consideration all these factors.

3.1. Hearing readers

3.1.1. Adult readers

While most models of word recognition in hearing adults agree that phonology plays a role during VWR, they disagree on the strength and relevance of this role. Some research findings with adult readers suggest that the use of phonological information (i.e., phonological representations) is important for single word recognition tasks (see Drieghe & Brysbaert, 2002; Frost, 1998; Lukatela & Turvey, 1994). However, other findings support the notion that as reading experience increases, the more the direct orthographic pathway is used (Castles & Nation, 2010) and the phonologically mediated route takes a minor role. As we discussed above, the differences in experimental paradigms may account for these mixed results. Another important factor to consider is that the mixed results in the phonological effects reported in the literature are also modulated by individual differences such as stage of development of the reading ability, vocabulary, phonological awareness, exposure to language. We will discuss some of this evidence in more detail below.

The masked priming paradigm has become an important technique in exploring the automatic use of phonology during the process of visual word recognition (Forster and Davis,1984). This paradigm has been found to be extremely useful in providing a robust way of investigating the influence of phonological codes in VWR (Ferrand & Grainger 1992; Perfetti et al., 1988, see section 2.2.2.). Numerous experiments using a masked priming paradigm have found facilitatory phonological priming effects in an LDT (see Rastle & Brysbeart, 2006). These effects are generally observed as faster Response Times (RTs), and/or better accuracy, when the target (e.g., CUP) is briefly preceded by a pseudohomophone (e.g., kup) than when is preceded by the orthographic/grapheme control (e.g., fup) in a LDT. The orthographic prime is used to act as a control for the influence of orthography by providing a stimulus with similar visual (orthographic) information as the phonological prime. Therefore, it is thought that the phonological effects are shown because the phonological primes pre-activate the sub-lexical phonological representations of the target words, causing a fast and accurate recognition of the targets (see Berent & Perfetti, 1995; Ferrand & Grainger, 1992; Lukatela et al.,1998; Perfetti et al., 1988;

Perfetti & Bell, 1991). This robust effect elicited by a briefly presented, and quickly masked, prime is suggested to indicate that the phonological assembly is 'automatic' and facilitates the process of VWR (Grainger & Ferrand, 1994; Humphreys, Evett, & Taylor, 1982; Perfetti et al., 1988).

Rastle and Brysbaert (2006) presented a meta-analytic literature review of studies that used different experimental paradigms to explore the phonological priming effects in hearing adult readers of English. For example, one of the paradigms was the forward masked perceptual identification paradigm (e.g., a pattern mask '#####' was followed by a brief word or pseudoword prime stimulus, then masked by a target with a different case), participants had to do a LDT. Also, studies with a backward masked perceptual identification paradigm were reviewed (e.g., a forward masked pattern "#####" was followed by a target, then by a brief verbal mask and finally followed by a pattern mask). These studies showed that the homophone prime (either words or pseudowords primes) facilitate the process of visual word recognition (VWR). Studies that used forward masking in their paradigm showed greater phonological effects (e.g., Berent, 1997; Grainger & Ferrand, 1994; Lukatela & Turvey, 2000; Davis et al., 1998; Experiment 1 , Lukatela et al., 1998; and Holyk & Pexman; 2004), compared to the ones that used backward masking (e.g., Berent & Perfetti, 1995; Perfetti et al., 1988; Perfetti & Bell, 1991; Tan and Perfetti, 1999; Verstaen et al., 1995; and Xu & Perfetti, 1999).

Rastle and Brysbeart (2006), also explored phonological effects in two masked phonological experiments during LDT, finding significant phonological priming effects in hearing adults' readers of English from Australia or New Zealand. The pseudohomophone primes stimuli used in their studies were phonologically but not orthographically identical to their base word target. However, unlike other studies where just one grapheme was changed (e.g., Lukatela et al 1998, klip, CLIP) the pseudohomophone primes had from one (e.g., cet, fet, SET), two (e.g., peese, pethe, PEACE) and three (e.g., yuice, douke, USE) graphemes differed from the target word. All the pseudohomophone primes had a paired orthographic control prime (see the stimuli used in Rastle & Brysbaert, 2006, p.,136-142). According to the authors, having a wide range of orthographic overlap in the stimuli allowed the masked phonological priming effects to emerge, provided that participants were sensitive to the phonological activation of the prime during visual word processing and not to the orthographic overlap between the target and the prime.

Other masked phonological priming studies with adults have also found significant phonological effects (e.g., Lukatela & Turvey; 1994, and Ferrand & Grainger; 1992;1993; 1994). However, it is worth mentioning that some studies have failed in finding phonological effects even when a masked phonological priming paradigm was used (e.g., Davis et al., 1998). Davis et al., (1998) tried to understand why the phonological effects were not replicated in their study. University students had to do a go/no go task (exp 1). Participants saw the target (WHICH), that was preceded by one of the four following prime conditions; identity (which), 'sound-the-same' (witch), 'form-control' (wirch) and 'all-letter-different' (blate). The conditions of interest were: 'sound-the-same' vs 'form-control' (witch vs wirch). The authors suggested that one possible explanation of the lack of phonological effects, is that the go/no go task

might not be sensitive enough to show the phonological priming effect in hearing adults. It was also mentioned that most of the primes differed in two or more letters from the target and that could also have affected the process of word recognition. The stimuli used in Davis et al., (1998) study were two sets of 48 high-frequency words and a set of 48 orthographically legal nonwords, from 4-5 letters. The target words were preceded by 4 primes, and there were 4 different lists (each list with the same target but different prime). Thus, each participant saw only 24 primes per condition, therefore perhaps more stimuli per condition was needed in order for the phonological effect to emerge. Besides, the prime stimuli used for the 'sound-the-same' (i.e., homophone) condition were half words and half pseudowords. This potentially could alter the direction of the effect, as it has been reported that short words used as primes could cause an inhibitory effect (as there is a lexical competition between the prime word and the target word) and not the expected facilitatory effect using a masked priming paradigm.
Unsurprisingly, the majority of the studies that have reported phonological effects have used pseudohomophone primes rather than homophones. In this thesis, the conditions of interest were always pseudohomophones vs orthographic controls primes).

The abovementioned studies were mostly conducted with readers of English language. In terms of studies exploring the phonological effect in other languages like French, Grainger and Ferrand (1994, 1996) as well as Carreiras, Ferrand, Grainger & Perea (2005) did find a masked phonological priming effect in hearing French adults. French language is considered opaque (irregular letter-sound mapping), (Borleffs et al., 2017), which is found somewhere in between Spanish (transparent) and English (more opaque). French words are estimated to be only 12% “feedforward” inconsistent (the spelling of the word has many pronunciations), where in English, this is estimated to be 31% (Davis et al 1998; Ziegler, et al., 1996).

With respect to studies that have explored the masked phonological effects in a more transparent orthography as Spanish, Pollastsek, Perea and Carreiras (2005) found a masked priming phonological effect during a LDT. In their experiment there were key prime-target pairs and each with their matched controls. Participants saw a target preceded by a prime that differed in one vowel letter from the target and that manipulation changed the sound of the initial letter “c” of the one prime pairs (e.g., cinan–CANAL vs conan–CANAL). These pairs showed the same orthographic similarity to the target words but differed in their phonology. There were also control pairs target-primes, where the vowel manipulations were exactly the same but here the initial letter did not change its sound in any of the primes (e.g., pinel-PANEL vs ponel-PANEL). Responses were faster for the phoneme-same primes, and slower when the sound of the first letter of the prime differed from the target when presented with 66ms SOA (Stimulus Onset Asynchrony, amount of time between the prime and the target). No differences were observed for the control pair target-primes, as their manipulation did not alter the sound of the first letter of the primes. This supports the idea that phonology plays an essential role in word recognition in readers of Spanish.

The masked priming paradigm has been also used in nonalphabetic scripts to explore the phonological effects in visual word (character) recognition. For example, Forster and Yoshimura (1994) and Chen, Yamauchi, Tamaoka, and Vaid, (2007) reported in a LDT that when the Japanese Kanji (logographic) stimuli were used in their masked priming experiments there was no phonological effects observed. In Kanji, the characters' orthography of the phonological primes is completely different to the characters' orthography of the target. In contrast, when the Hiragana (syllabic) stimuli were used in the experiments, participants showed phonological priming effects (here, the orthography and phonology information of the prime and the target are related). A similar effect was observed when the stimuli were combined between pairs: Hiragana-primes and Kanji-targets. Chen and colleagues (2007) suggested that readers of logographic scripts (e.g., Kanji) tend to use the direct route relying on the orthographic pathway to access the meaning, while Hiragana might recruit phonology.

Shen & Forster, (1999) suggested that in the logographic languages the effect could be modulated by the tasks demands, as in their study they used LDT and a naming task, where phonological priming effects were only observed in the naming task. According to the authors, during the naming task the phonological priming could be retrieved when reading out loud and consequently had a facilitatory response when naming the target. In contrast, the LDT did not require reading out loud.

Studies with deep orthographies like Hebrew have also found robust masked priming phonological effects in university students (Frost et al., 2003). Hebrew is considered to have a deep orthography because the consonants are usually represented by letters, but the vowels are either diacritical marks (e.g., points under, over or inside the letters) or some vowels (/o/, /u/, /i/) can also be written as letters. Additionally, the Hebrew orthography has 12 homophonic letters (i.e., two letters representing the same phoneme). These characteristics of a language with deep orthography allowed researchers to do different phonological manipulations with the stimuli in order to explore a masked priming phonological effect (See Frost et al., 2003). They found that adults readers were using phonological priming codes to recognise target words faster than when they were preceded by the prime control condition.

In summary, the fact that responses to targets are facilitated when preceded by pseudohomophone primes compared to orthographic primes, provides supporting evidence of automatic prelexical phonological processing during VWR. There are several studies that have showed robust masked priming phonological effects in hearing readers with different orthographies as well as across different SOAs (e.g., in English, Davis et al., 1998, Perfetti and Bell (1991), SOA of 40ms; and Lukatela, Frost, & Turvey, SOA of 57ms and 29ms, in French, Grainger and Ferrand (1994; 1996) SOA of 64ms and 43ms, Duch; Brysbaert (2001) SOA of 43ms, and Drieghe & Brysbaert, 2002, Servo-Croatian: Lukatela & Turvey, 1990, SOA: 20 and 40ms, Hebrew; Frost et al, 2003 SOA: 10-40ms).

Nevertheless, as mentioned earlier, there have been also few studies showing null phonological effect, (e.g., in English; Davis et al., 1998, in French; Ferrand and Grainger, 1992, SOA 32ms; in Duch: Brysbaert (2001) SOA of 29ms and in Chinese: Shen & Forster, 1999, SOA: 50ms, in Japanese Kanji: Chen et al., 2007, SOA: 85 and 150ms). It has been difficult to reconcile these mixed findings, however, certain methodological differences have been identified as potential sources of influence or interference in phonological masked priming. Particularly because these factors seem to play an important role in either increasing or decreasing the size of the phonological effect when it has been found. For example, individual differences in the participants (e.g., development of reading skill, language ability), luminance of the experiments, (Lukatela et al.,1998, 1999, Frost et al., 2003), SOA (i.e., duration of the exposure of the prime), that time exposures of the prime (Ferrand and Grainger, 1993), type of paradigm (regular masked priming or sandwich masked priming) and characteristics of the stimuli used, (see Frost et al., 2003) all appear to play a role. Analyses of the reasons why a number of studies did not find a significant effect of phonology has advanced our understanding of the methodological factors that should be considered. In the current thesis for example, a sandwich masked priming technique was used during an LDT, with a SOA of 100ms (50 prime + 50ms blank screen), and then the target until participant's response or a maximum of 2500ms, (see more details of the procedure in section 7.1.1.1.4.).

In sum, although sometimes the phonological effects have been small (Rastle and Brysbaert, 2011), the majority of masked phonological priming studies with hearing adults reading in different languages with different orthographic depths have showed evidence of the automatic phonological priming effect during visual word recognition. In the next section I will discuss studies that have used a similar methodology with hearing developing readers.

3.1.2. Young hearing readers

The use of phonology during VWR has also been explored in children and in different languages, though to a lesser extent than in adults. Goswami et al., (2001) explored the pseudohomophone effects in English and German children aged 7-9 years. Participants had to read aloud words and pseudowords. There were three conditions: (1) pseudohomophones (i.e., non-words that sound like real words, e.g., faik), (2) nonwords that were phonologically and orthographically similar to real words (e.g., dake) and (3) nonwords that were phonologically and orthographically dissimilar to real words (e.g., koog). English children were faster to respond to pseudohomophones than to control nonwords, that were phonologically and orthographically similar to real words, but no effects were found in the German children. This suggests that English children seem to activate phonology to a greater extent when reading words, compared to the German readers.

In another study with hearing children, readers of English (9 and 10 year old). Davis et al., (1998) explored the use of phonology in a go/no-go task and in an LDT, using masked phonological priming. Results showed that developing readers of English were not sensitive to masked phonological priming. However, phonological effects were found in the analyses by item during the LDT. Therefore, the authors suggested that this might be attributed to some individual differences in the participants, and some children used phonological information during the task, but some others did not. It was suggested that the children that benefited from the phonological information were the slower readers.

In a cross-sectional study with 6-10yr old readers of French, Ziegler, Bertrand, Lété, & Grainger, (2014) found a phonological effect on VWR across the whole age range studied. In order to amplify the size of any phonolofical effects, a sandwich masked priming paradigm was used (see Lupker & Davis, 2009) in a LDT. The children first saw a fixation point for 1000ms, then in lowercase a letter-string the same as the target for 27ms, then the prime also in lowercase with a SOA of 70ms, and finally the target in uppercase until response. There were 33 target words preceded by either pseudohomophone primes or by their orthographic control primes, with 4-5 letters length (e.g., target: VASE; pseudohomophone prime: vaze; orthographic control prime: vare). The orthographic control primes were visually similar to their pseudohomophone prime pair and to the target. Children of all ages, and regardless of their reading ability, responded quicker when the target was preceded by the pseudohomophone prime than their orthographic control. According to the authors these findings challenge the idea that as reading ability increases the use of phonology during word recognition decreases. However, one could also argue that the decline in the use of phonology is not yet evident in the age ranges explored in this study. Similarly, it may be argued that the children in these groups were not yet skilled enough to show evidence of this transition in the use of phonology.

In terms of evidence from a transparent language, Comesaña et al., (2016) replicated the findings in Davis et al., (1998) and did not find any phonological effects in young readers of Spanish. Comesaña et al., (2016) conducted a sandwich masked priming paradigm with children (mean age: 9.4). The critical comparison was between measures (RTs and accuracy) of targets preceded by: pseudohomophone vs orthographic control primes (e.g., BOCINA, vocina vs nocina, respectively). Note that in Spanish the letter 'v' and 'b' sounds the same /b/. In these tasks the time exposure of the prime was 50ms (same duration that has been used in the past studies with adult readers of Spanish (see Perea & Carreiras, 2006, 2008; Pollatsek et al., 2005). However, the study did not find phonological effects. Comesaña and colleagues (2016) suggested that future research could use longer durations of the exposure of the prime (i.e., SOA) with developing readers (greater than 67ms), given that as other studies in French have done this previously and have found masked priming effects (e.g., Chetail & Mathey, 2012, and Ziegler et al., 2014), suggesting that the SOA could be critical to whether or not phonological effects during a masking priming task are observed in children. In our current study using sandwich masked priming technique during a LDT, we used an SOA of 100ms.

In summary, in young, hearing readers, many studies have argued that phonology plays a relevant role in visual word recognition of English and Spanish. However, there are also conflicting studies that did not find any evidence of phonological effects in young hearing readers. Differences in the experimental parameters (e.g., stimuli or SOA) may account for some of these mixed results.

In the next section, I discuss studies that explore the role of phonology in deaf people during VWR.

3.2. Deaf readers

3.2.1. Adult deaf readers

Several studies have shown that deaf readers can make use of phonological information if it is explicitly required by the task. For example, when measuring the ability to represent and manipulate the sound units from words (Melby-Lervåg et al., 2012) or when the tasks include rhymes or syllable counting (Charlier & Leybaert, 2000; Hanson & McGarr, 1989; MacSweeney et al., 2013; MacSweeney et al., 2008; Emmorey et al., 2013). These studies showed that access to phonology is possible by deaf readers, however that does not necessarily mean that it is automatically used during VWR. It is still unclear if the activation of phonological codes is regularly involved in the process of VWR on more implicit tasks (i.e., where the representation of the sounds is not explicit to the participant) e.g., Hanson et al., 1991; Hanson, Shankweiler, & Fischer, 1983; Kelly, 2003; Sehyr et al., 2017; Perfetti & Sandak, 2000). Therefore, the interplay between orthographic and phonological processing during word recognition affects reading ability in deaf adults is still an open question that requires further research.

Previous studies that have examined the role of phonology in deaf readers have not been consistent in their findings. While some studies have found that deaf readers use phonological information during implicit tasks (e.g., Hanson et al., 1991; Sehyr et al., 2016), other studies have concluded that deaf readers do not seem to use phonological information, or that its use is reduced compared to hearing readers (Chamberlain, 2002; Bélanger et al., 2012; 2013; Hanson et al., 1983).
In studies with readers of deep orthographies like English, Hanson et al. (1991) investigated the use of phonological information by deaf (n=16) during tongue-twister sentences, on which participants had to make a semantic acceptability judgement (e.g., Tom and Tim talked together). Deaf readers were less accurate judging tongue-twister sentences than control sentences, showing that phonological information affected their response. In addition to judgement tasks, studies requiring the recall of items in deaf skilled readers, have shown that deaf skilled readers can show evidence of phonological effects (e.g., poorer recall for similar words than for dissimilar, Sehyr et al., 2016). However, some studies of visual word recognition in deaf readers have failed to find significant phonological effects. For example, Cripps et al., (2005), conducted a masked priming experiment, where repetition and pseudohomophone priming conditions were tested in 14 deaf signers (n = 14, age range = 23-53), and hearing participants (n = 20, age range = 18-62). Effects of repetition priming were found in both groups; however, the phonological priming effect was only significant for hearing participants. The authors suggested that this

lack of phonological effect could be explained by the altered access to phonology in deaf people.

Studies of the deaf French readers, a ‘shallower’ orthography than English (though not as shallow as Spanish) have also shown mixed results. Bélanger, Baum and Mayberry (2012), investigated the automatic use of phonological and orthographic codes using a masked priming paradigm and in a recall task with French deaf adults. French deaf readers (skilled and less skilled) and hearing (skilled) readers used orthographic codes during word recognition and recall tasks. However, they did not show evidence for the use of phonological codes. However, the authors discussed that it is also possible that skilled deaf readers compute phonological codes more slowly than hearing participants and thus the use of phonological codes during word recognition may not have been detected. Their study could not address this since the masked priming experiment displayed the pseudohomophone prime only for either 40 or 60ms. In contrast, with the sandwich masked priming paradigm used in this thesis, deaf participants saw the pseudohomophone prime condition for 50ms followed by a blank screen for 50ms (total of 100ms), then the target appeared on the screen, which gives the participants the extra processing time that they needed to automatically process the prime.

In summary, there seems to be again mixed results exploring the use of phonological information by deaf adult readers of English (and other opaque languages like French) and a lack of consensus in the role of phonology in deaf readers. This may be explained due to differences among the tasks.

In terms of evidence coming from even more transparent languages such as Spanish, Deaf readers of Spanish are also, on average, poorer readers than their hearing peers (Rodríguez-Ortiz et al., 2015; Moreno-Pérez et al., 2015). Recent studies of deaf readers of Spanish have investigated the role of phonology and orthography in reading and they have also shown mixed results (e.g., Costello et al., 2021; Domínguez et al., 2014; Fariña et al., 2017; Gutierrez-Sigut et al., 2017, Moreno-Pérez et al., 2015). For example, Gutiérrez-Sigut et al. (2017) explored the automatic use of phonological information during visual word recognition in deaf adults (n=24, mean age=36.5) using masked priming while ERP data were collected. Prime pseudowords were presented before target words. Participants were faster to respond to pseudohomophones and to identity primes than their respective control prime conditions. Interestingly, the size of the phonological effects from behavioural and ERP data was similar to the size of the effects in the hearing control group.
In another ERP study by Costello et al., (2021) the phonological effects were also explored during an LDT. Participants were deaf and hearing adult skilled readers of Spanish. The study found that hearing readers were affected by the phonological information of the pseudohomophone condition, as they made more errors and their responses were slower when rejecting the pseudohomophone primes as words, compared to the orthographic control condition. Additionally, they showed a reduced N400 effect for pseudohomophone primes compared to orthographic controls. In contrast, deaf readers did not show any phonological effects, neither in the behavioural data, nor in their ERP responses. They treated pseudohomophones the

same as pseudowords. Based on their results Costello et al., (2021) concluded that skilled deaf readers do not activate phonological information during VWR.

While Gutiérrez-Sigut et al. (2017) found a phonological effect in their deaf participants, Costello et al., (2021) did not find evidence of phonological effects. One factor that could account for this difference is that the participants had different levels of reading ability in each experiment. While the participants in the Costello et al., (2021) study were highly skilled deaf readers, the Gutierrez-Sigut et al., (2017)'s participants showed a wide range of reading ability (14-100% accuracy on the TECLE – assessment of sentence reading; Carrillo & Marin, 1997). Methodological differences are also likely to account for some of the differences, as the phonological effect is typically small, and the tasks should be sensitive enough to capture it. Costello and colleagues' (2021) choice of paradigm – an unprimed lexical decision task (isolated visual word recognition), might not have been sufficiently sensitive to capture subtle differences as the sandwich masked phonological priming paradigm. Despite the differences, one similarity between these studies is that having a high reading ability was not dependent on the use of phonological codes from words. Costello and colleagues did not find a phonological effect in skilled readers. Although, Gutierrez-Sigut et al., (2017) found an effect, they did not find a correlation between reading skill and size of the phonological effect.

Similar to the case of the hearing population, there is a debate on whether phonological effects are shown or not in adult deaf readers. It is still unclear how deaf readers recognise a word and how phonology and orthography contribute to word decoding or whether deficits in one or the other are associated with their lower reading skills (compared with average hearing skilled readers). It has been argued that altered access to phonology could be underlying the reading deficits associated with the deaf population. Thus, one would expect to find differences in the role that phonology plays between languages having a different level of transparency. Despite the fact that in all alphabetic languages there is a relationship between graphemes (letters) and phonemes (sounds), the strength of this relationship varies. In some languages like Spanish (a transparent language) the association of letter to sound is stronger and more consistent than in languages such as English (an opaque language). Previous research indicates that readers of transparent languages make more use of phonological codes and find phonological processing easier (Frost, 1994; Carreiras et al., 1993). It would be expected to perhaps find similar effects in the deaf population from transparent languages. Nevertheless, this assumption is not necessarily supported by all studies. The inconsistencies or contrasting results found across studies could be partly attributed to the use of different experimental tools to explore the use of phonological and orthographic information in each task (e.g., see Mayberry et al., 2011, for meta-analysis). Further research is required to elucidate the role of phonology in deaf readers, which is what largely motivated the work presented in this thesis.

3.2.2. Young deaf readers

Merrills, Underwood, & Wood, (1994), explored how young deaf readers of English, (n=20, age range: 11.8-15.06, M=12.11) recognise single words during an LDT in comparison to 3 different hearing groups: good readers (age range:11-13.09, M=12.07), poor readers (age range: 11.06-14.04, M=9.06), and younger readers (age range=7.04-9.01, M= 8.01). Participants were matched on sex, intelligence and chronological or reading age. The experiment manipulated the spelling regularity of the English words: (1) regular (e.g., cake, help), (2) exception (e.g., half, pint), and non-words: (3) pseudowords (readable non-words e.g., flup, plig), and (4) unpronounceable non-words (e.g., fght, ndwn). Overall, deaf readers responded faster than the younger and poor hearing readers groups but slower than the good hearing readers. Suggesting that deaf readers can outperform hearing readers that are still in development but still cannot reach the level of skilled hearing young readers. Interestingly, the authors reported that deaf young readers of English decoded pronounceable non-words activating phonological information, suggesting that deaf readers indeed use pre-lexical phonological information to read unknown readable words.

In line with the previous research, an eye tracking study conducted by Blythe, Dickins, Kennedy & Liversedge (2018) showed that deaf teenagers can process phonology during silent reading of English sentences. This is an interesting approach because it can provide insight to reading behaviour without requiring overt responses. In this task, the sentences had a target word and conditions generated from that based target word CHURCH (e.g., pseudohomophone, orthographic control conditions; cherch - charch, respectively). The group of deaf readers was matched with hearing controls in age and in reading ability. Results from directly fixated words and parafoveal preview words showed an advantage (shorter reading times) of pseudohomophones vs orthographic control conditions in deaf readers. The results were similar to the hearing matched groups, however there was a delay in the deaf group. Blythe and colleagues suggest that this phonological processing appears to be pre-lexical, as the use of the phonological information from the pseudohomophones was activated before lexical access, which seems to facilitate the access to a word that already is in the mental lexicon.

Studies with Dutch children have also shown mixed results. On the one hand, a study with deaf Dutch children (age range 6.8 to 13.5) by Transler and Reitsma (2005) found phonological effects in an LDT. The phonological effects were small but significant in deaf children, as more mistakes were apparent with pseudohomophones than with control pseudowords. Even though deaf children made less errors than the hearing control group (Errors % pseudohomophone, 13.9% vs 56.5%, respectively), the results suggested that deaf children also activate phonological coding during word recognition. On the other hand, Ormel, Hermans, Knoors, Hendriks, & Verhoeven (2010) found no phonological effects in deaf Dutch children (age mean 11.13). Children were required to decide whether the presented letter-sting was spelled correctly and if it matched with a picture. In a second experiment, they had to respond whether the word sounded like the picture. Results showed very little effects of phonology in deaf compared to hearing children. Thus, Ormel et al., (2010) concluded that deaf children do not use phonological information during word reading.

Phonological coding was also explored in (n=34) deaf teenagers (13.7yrs to 20.0 yrs) readers of Chinese Mandarin (Yan et al., 2021), a logographic script (i.e., symbols that represent the whole word or morpheme). An eye tracking study was conducted with a group of deaf teenagers matched with hearing readers in their chronological age and matched with another group in their reading ability. Participants had to read a sentence with correctly spelled characters (e.g., He wore blue jeans), homophones (blew) or orthographic control (blow) characters, while their eye movements were recorded. The findings did not show any differences between the homophones and orthographic control characters in the deaf readers. However, Yan, et al., (2021) hypothesised that variability in the use of phonological information might be driven by differences in reading levels across deaf participants. This hypothesis was based on their previous study which showed that skilled deaf readers benefited more from phonological information than less skilled readers (see Yan et al, 2015). Therefore, the authors decided to split the deaf group into skilled and less skilled readers and see whether their reading level was related to phonological coding. The deaf skilled readers showed a significant phonological advantage, as they had shorter times in reading sentences with homophones than with unrelated/spelling control characters. Based on these results, the authors associate the use of phonology with levels of reading ability suggesting that the more skilled deaf readers of Chinese use phonological coding for sentence reading and that these individual differences in the development of reading skill seem to boost the activation of phonological coding in the skilled deaf readers of Chinese. However, unlike deaf less skilled readers of Chinese, who were not influenced by the pseudohomophones, the hearing control group with less reading skills did show a phonological advantage when reading the sentences. Therefore, these findings suggest that reading ability itself does not modulate the use of phonological information during sentence reading in the less skilled deaf readers. The authors concluded that not all deaf readers develop the reading skill in the same way. Taking both interpretations for skilled and less skilled deaf readers, there seems to be something else as part of their individual differences that may contribute to the activation of phonological coding in deaf readers.

Apart from the differences shown based on mere age differences, there are specific reading related skills that seem to influence the process of reading ability in deaf readers, for example phonological awareness (Dyer, et al., 2003; MacSweeney, et al., 2013), speechreading ability (Arnold & Kopsel, 1996; Kyle et al., 2016; Kyle & Harris, 2006, 2010), and fingerspelling (Emmorey & Petrich, 2012; Haptonstall-Nykaza & Schick, 2007; Puente et al., 2006). In the following section phonological awareness and speechreading skills will be discussed. Fingerspelling will be discussed in the next chapter (Chapter 4) that discusses the “Role of Orthography in visual word recognition”, as fingerspelling ability can be considered as a bridge between orthography and phonology in the process of learning how to read, by deaf readers.

3.3. Phonological Awareness

Phonological awareness of speech is generally described as the ability to recognise and manipulate the sublexical components of a spoken word and it comprises the ability to manipulate and segment them (e.g., mental processes on the elements of speech, Denton et al., 2000, Goswami and Bryant, 1990). This includes the awareness of the words as speech units, independent of their meanings (Denton et al., 2000). For example, “dog” is a word created by combining sounds /d/ /ɒ/ /g/.

Phonological awareness is an important contributing factor to hearing children’s reading development (e.g., in English: Castles & Coltheart, 2004, in Spanish: Carrillo, 1994). Previous studies suggest that phonological processing difficulties are the primary cause of developmental reading deficits (Hoover & Gough, 1990; Gough & Tunmer, 1986; Harm & Seidenberg, 1999). In the case of deaf children, deficits in phonological awareness may account for some of the reading deficits found (Charlier & Leybaert, 2000; Hanson & McGarr, 1989; MacSweeney et al., 2013; MacSweeney et al., 2008; Emmorey et al., 2013). Given that the access to phonological information is mostly indirect for deaf readers, their use of phonology has brought some controversy to the field. For example, it has been discussed whether or not deaf children use phonology for reading and if it is used in a similar way to their hearing peers (e.g., at early stages of reading development: when they are learning how to read).

Previous studies have reliably reported a strong relationship between phonological skills and the development of word recognition ability in hearing children (Castles & Colheart 2004; Carreiras, et al 1993). As we have mentioned earlier, in alphabetic languages, the letter of a word generally represents a sound (i.e., phoneme) from the spoken language. Therefore, in the process of learning how to read, it becomes useful for the child to develop early spoken phonological awareness in order to become a proficient reader of an alphabetic script (Liberman et al., 1974). In line with this, Muter et al., (2004), found in a longitudinal study with 90 British children (range age= 4.2 – 5.2) that phonological skills (phoneme sensitivity and letter knowledge) predicted word recognition skills.

It has been proposed that hearing skilled readers can recognize words without accessing phonological information (Harm & Seidenberg, 2004). Even if this may be true for skilled readers, it is recognised that the role of phonology seems to be crucial when readers are learning how to read, especially for readers of alphabetic languages (e.g., English, Spanish; Anthony & Francis; 2005). However, the way the transition between using phonology in the early processes of reading, to the minimal (or none) use of it at the end of the reading process in skilled readers is not yet clearly understood. This developmental change in reading processing might be affected by many individual factors. For example: vocabulary, phonological awareness, exposure to language, etc.

In terms of deaf readers, the lack or altered phonological awareness might be one of the factors of reading delay in deaf children (Dyer, et al., 2003). Nonetheless, Deaf readers are able to develop some phonological representations of the spoken words by using a variety of inputs, (e.g., self-articulation, speechreading, fingerspelling, among other abilities).

On the other hand, Mayberry et al., (2011) reported in a meta-analysis study that 'phonological coding awareness' predicted only 11% of the variance in their reading outcomes. This suggests that phonological ability has a low prediction on reading proficiency compared to other factors like language ability, which predicted 35% of the variance, having a larger impact on reading development in deaf participants.

Different types of tasks can be used to measure ‘phonological awareness’. For example, in English, the rhyming task is often used (e.g., presenting a pair of printed words and asking participants to decide whether they rhyme or not, see Campbell & Wright, 1988; Goswami & Bryant, 1990; MacSweeney et al, 2013) to measure phonological awareness in children and adults. Rhyme tasks in Spanish can be used in pre-readers (see Carrillo, 1994). Given that Spanish is a transparent language, it is hard to control the use of visual (orthographic) information to solve rhyming tasks (e.g., gato – pato). However, an explicit phonological task like the “counting syllables task” seems to be more accurate to measure phonological awareness in individuals that know how to read in Spanish (see Carreiras et al 1993, Gutierrez-Sigut et al., 2017).

Therefore, in this thesis, the tasks used to measure Phonological Awareness were: “Rhyming task” in deaf adult readers of English (see description of the task in section 6.1.1.1.2.), and “Syllable counting task” in young and adult readers of Spanish (see description of the task: section 6.1.2.1.2.). It was explored if phonological awareness was related to their reading ability. Additionally, the correlation between ‘phonological awareness’ and any experimental effects of phonology or orthography during visual word recognition was investigated. The aim was to have a better understanding of the relation of phonological awareness, and the cognitive process of visual word recognition in deaf readers of English and Spanish.

3.4. Speechreading

Speechreading is the ability to understand speech by simply looking at the talker's facial movements, when auditory information is unreliable or non-existent (Campbell, 2011; Calvert et al., 1997; Paulesu et al., 2003). Speechreading ability is particularly important for deaf people as it is one of their main ways to access speech, but it is also relevant for the hearing. For example, in the hearing population, the McGurk effect is a perceptual phenomenon that shows the interaction between the sound and the view of the lip pattern in speech perception (McGurk & MacDonald, 1976).

Most deaf people and use speechreading as their main means of communication with hearing people (Mohammed et al., 2005). Moreover, speechreading could be used as a bridge to improve other abilities in spoken language (Kyle & Harris, 2011). Deaf readers can gain some access to the sublexical structure of words, including phonology, through visual information. Consistent with this notion, previous research has found that one of the variables that predicts reading performance in deaf children is their speechreading (lipreading) ability, this is the case both for correlations at concurrent time points and in longitudinal studies (Arnold & Kopsel, 1996; Kyle et al., 2016; Kyle & Harris, 2006, 2010).

Based on the simple view of reading (Gough & Tunmer, 1986), the reading model shown in Figure 5 was proposed for deaf readers by Kyle (2015). This model shows a direct link between linguistic knowledge (vocabulary) and reading ability. Decoding (phonological decoding can be accessed via measures of phonological awareness) is developed via reading and speechreading abilities. Once decoding is established, it may positively affect reading. Subsequently, these two skills develop a reciprocal relationship.

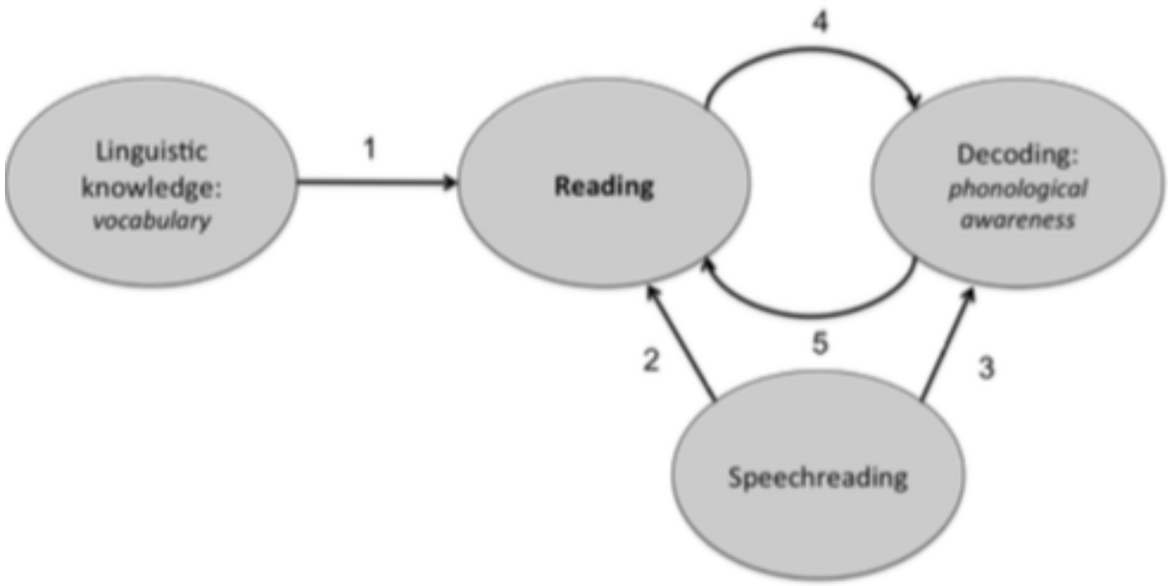


Figure 5. Proposed model of reading in deaf children taken from Kyle (2015).

In this thesis the speechreading ability in deaf participants was measured, and its correlation to reading ability and other reading related skills was explored. See section 6.1 to see description of the task.

4. The role of orthography in word recognition

Reading involves recognising and understanding printed words which could be presented in isolation or within sentences and longer texts. Orthographic processing is the part of word recognition that allows us to identify a series of letters and to access words visually. The main subcomponents of orthographic processing are 'letter identification' and 'letter position identification' (i.e., order identification). If the word is well-known (e.g., it is a frequent word, and its orthographic representation has been established), the written word could directly lead to word recognition and access to meaning. In other words, the lexical representation can be activated directly by the visual pattern of a word with little competition from words with similar spellings (Andrews & Lo, 2012). Even though most of what we know about orthographic processing has been learnt from skilled readers, a growing number of researchers have become interested in the study of individual differences in orthographic processing (e.g., Andrews & Lo, 2012; Meade et al., 2020).

From a developmental point of view, beginner readers transition from slow word recognition processes using alphabetic decoding to fast automatic word recognition, based on the words' orthography (Castles and Nation, 2006; Nation 2009). This process is known as orthographic learning, a life-long process that develops and becomes faster over time (Castles & Nation, 2008) and exposure to print (Andrews & Lo, 2012; Stanovich & West, 1989). Since readers have different language experiences (e.g., prior vocabulary knowledge, frequency of exposure to print, etc.), individual differences in orthographic learning are likely to start during childhood and to continue in adulthood (see e.g., Perfetti, 1992). Perfetti, (1992) proposed that the development of precise orthographic representations is crucial to achieve high lexical quality (see Section 2.1). It is widely accepted that as a reader consolidates more written words into their lexicon, the precision of their orthographic knowledge increases (Perfetti, 2007). One way in which researchers have studied orthographic knowledge is by exploring the lexicality effect.

4.1. Lexicality Effect

The lexicality effect refers to the faster and more accurate processing of real words over pseudowords. This advantage has been widely replicated in behavioural (Reicher, 1969; Cattell, 1886, Acha and Perea, 2008) and neuroimaging studies (Fiez et al., 1999; Taylor et al., 2013). The effect of lexicality has been generally explained in terms of both the familiarity with the words (i.e., how much the reader has seen that particular word) and the fact that only words can be retrieved from long term memory. That is, in terms of the benefits of lexical level information over word processing.

The strength of the lexicality effect has been associated with the orthographic knowledge of the reader and has been shown to contribute to the development of literacy skills (Conrad, et al., 2013). For example, Zoccolotti et al., (2009) found a lexicality effect in Italian children 6.8 to 13.9 years old. In children from 8yrs old onwards, the lexicality effect increased as a function of their reading experience (Zoccolotti et al., 2009). Recent findings of lexicality effects in preliterate children (e.g., Cuetos, et al., 2006; Seymour et al., 2003; Zoccolotti et al., 2009) have challenged traditional 'stage theories' (see Ehri, 1999; Frith, 1985, Jackson & Coltheart, 2001) of reading development, which proposed that mastering grapheme to phoneme conversion was necessary before developing orthographic learning. This alternative view proposes that if the child is exposed sufficiently to a word, they incorporate the visual representation of that word into their orthographic lexicon (Seymour et al., 2003; Zoccolotti et al., 2009) which leads to higher lexical quality. The association between the strength of the lexicality effect and reading experience, has been shown in languages with transparent orthographies (e.g., Spanish: Acha & Perea, 2008; Italian: Zoccolotti et al., 2009) and also in languages with opaque orthographies (e.g., English: Ziegler et al., 2014). Interestingly, in a cross linguistic study, Paulesu et al., (2010) found greater lexicality effects in adult readers of English than in readers of Italian. The authors argued that readers of English develop links between graphemes and whole word representations at early stages of reading acquisition, while readers of transparent orthographies can rely on the regularity of grapheme to phoneme conversion for longer (for a similar argument see also Ziegler & Goswami, 2005).

In this thesis the lexicality effect (faster responses and better accuracy to words vs pseudowords) during visual word recognition is examined using a lexical decision task (LDT) in adult and adolescent deaf readers of Spanish (transparent) and of English (opaque). The experiments 1-6 address this issue in written word LDTs (see

Chapter 6). Experiments 7-12 examine this issue during fingerspelling perception (see Chapter 7). Broadly speaking, evidence of a lexicality effects in these studies would suggest that deaf readers benefited from the lexical information from the target words.

4.2. Orthographic processing

Research into orthographic processing has focused on the study of letter identity and position. The focus in this thesis is on letter position. Classic models of visual word recognition posit that letters are assigned to specific positions within the word (e.g., Coltheart et al., 2001; McClelland & Rumelhart, 1981). However, recent evidence with adult readers has shown that there is some flexibility on the encoding positions of the letter within the word (Comesaña et al., 2016; Lupker et al., 2008; Meade et al., 2020). Some models have addressed this flexibility. For example, the overlap model by Gómez, Ratcliff, and Perea, (2008) proposed that the letters in the visual stimulus have a distributed activation across neighbouring positions. In other words, the representation of one letter can be expanded across the adjacent letter positions within the word.

The Dual-route orthographic model (Grainger & Ziegler, 2011) incorporates the open bigram which improves the precision and robustness of orthographic processing. Thus, the word processing can occur via two routes that are associated with the dual-route architecture. The coarse-grained route provides fast and direct access to semantics by using the information taken from the open bigrams (e.g., CAT: CA, AT, CT) in order to identify the word. The fine-grained route is more sensitive to the precise positions of letters and involves assigning individual letters to precise serial positions. The orthographic precision can vary across tasks (e.g., LDT), word characteristics (e.g., neighbourhood density), lexicality of the primes (e.g., words vs pseudowords primes), and, interestingly, individual differences of the readers (e.g., reading ability and reading related abilities; Andrews & Lo, 2012; Davis & Lupker, 2006; Forster et al., 1987). In this thesis, individual differences such as reading ability, vocabulary size and fingerspelling ability are measured in deaf participants to examine their relationship to the size of the orthographic effect. Moreover, in terms of the orthographic effect, more flexible or less precise orthographic representations are interpreted to show susceptibility to the activation of the transposed letters primes (TL), resulting in larger TL priming effects. Therefore, if participants show a large orthographic size effect, this may inform us about how precise deaf participants' orthographic representation is.

Generally, studies that have explored the orthographic effects in hearing adult readers with a TL priming paradigm in a Lexical Decision Task, have found response times to target (JUDGE) faster when it is preceded by TL prime (JUGDE) than by RL prime (JUNPE) (see, Comesaña et al., 2016; Ktori et al., 2014; Lupker et al., 2008; Perea & Carreiras, 2006, 2008; Perea & Lupker, 2004). This suggests that letter position encoding might be more flexible (or less precise) than proposed by the traditional coding schemes where the letters within the word were assigned to specific locations. Participants benefit from the prime when the letters are transposed, showing some flexibility in the location of the letters.

Measuring the responses to stimuli with TL has been one of the most common ways to explore orthographic precision. Indeed, it has been proposed that the TL masked priming paradigm reflects well the flexibility of orthographic processing (e.g., encoding positions of the letter within the word). This effect has been also found in experiments with words and pseudowords in unprimed LDT (Perea & Lupker; 2004). In this thesis the early orthographic processing is investigated by contrasting responses to targets (e.g, HOSPITAL) preceded by two types of critical primes: transposed letter (TL, hostipal) primes and their replaced letters (RL, hosfigal) control primes. The size of the Orthographic Effect used for correlational analyses was calculated by subtracting the measures of the RL primes from the TL primes (e.g., TL – RL) separately for response times (RT) and accuracy (see Chapter 6, section 6.2). In addition, the impact of letter transposition in fingerspelled words presented in isolation was explored (see Chapter 7, section 7.2).

In the following section I review relevant studies investigating orthographic effects using a transposed letter masked priming in adult and then young hearing readers. Finally, I summarise previous studies with deaf readers

4.3. Hearing readers

4.3.1. Adult readers

Andrews & Hersch (2010) explored orthographic processing in university students (average age= 19.1), using orthographic masked priming. The target was preceded by an orthographic neighbour prime (e.g., jury FURY). Overall, students showed a facilitatory neighbour priming effect. However, better spellers showed an inhibitory neighbour word prime effect and poorer readers a facilitatory effect. This suggests that good spelling ability is related to a more precise lexical representation than is poor spelling ability. In this study, the direction of the effect seemed to be determined by the individual differences in a group of skilled readers (e.g., their level of spelling ability). However, it is important to mention that these were university students with already good reading levels, so the poorer readers in this sample size might actually be good readers (i.e., above average) compared to the general population. In terms of similar visual characteristics of the primes to the target, the 'neighbour word' primes used in the previous study (see Andrews & Hersch (2010) do not share all the letters with the targets (i.e., differ by one letter) and also the number of neighbours vary. In contrast, the TL primes share all the letters with the target, and the number of neighbours is similar given that it contains the same letters. According to Davis and Lupker (2006) skilled readers with precise orthographic representations are able to fully specify 'identity' and 'order' of the prime and targets' letters. Therefore, the TL primes (clot - COLT) should show a stronger inhibitory effect in comparison to the neighbour word primes (slot - CLOT) because they share more letters. However, readers with less precise lexical representations might not be sensitive to differences between the neighbour and the TL primes, and both primes might produce facilitatory priming effects.

In this thesis the primes used to explore the orthographic precision of the readers were 'TL primes' and their controls 'RL primes' in a sandwich masked priming paradigm. This approach was chosen for two main reasons. First, given that TL primes share all the letters with the target, this allows us to study whether the order and identification of the letters in the primes influence the orthographic processing of the target words. For example, if participants respond quicker and better in the LDT when TL primes preceded the target than the RL primes then we have a transposed letter effect. Second, because deaf readers generally have large variability across different reading related variables (e.g., reading levels, vocabulary size etc) and using TL primes might allow us to identify whether the size of the orthographic effect and the direction are modulated by these individual differences of the participants, like Davis and Lupker (2006) showed in the individual differences of their hearing participants.

Andrews and Lo (2012) studied whether the individual differences in the effects of lexical competition could explain the effects of the type of prime (e.g., neighbour primes or TL primes). They also explored the influence that the ‘letter identity’ and ‘letter order’ have in the lexical precision of the participants, using a masked priming LDT. The effects of neighbour primes were compared to the effects of the TL primes using the same target words. Andrews and Lo (2012) found masked priming orthographic effects with both types of primes, and that the variance shared by the reading measures (reading, spelling and vocabulary) was related to a greater inhibition from TL nonword primes and to greater facilitation from neighbour nonword primes. These findings were in line with Davis and Lupker (2006); and Andrews (1996), as the direction of the effects seemed to be influenced by the type of the prime used in the experiments. Based on these results, the authors argued that the

TL primes appear to be stronger lexical competitors than the neighbour primes to the target.

Irrespective of the lexicality of the prime, readers with less literacy proficiency (i.e. grouping the measures of: reading, spelling and vocabulary abilities) show a facilitatory priming effect, whereas readers with higher literacy proficiency on these measures showed an inhibitory or null effect (Andrews & Lo, 2012). Moreover, spelling ability seemed to provide a particular contribution to inhibitory TL priming effects, showing more sensitivity to orthographic representation (strict letter position). This means that individual differences (e.g., reading spelling and vocabulary abilities) play a key role in orthographic processing.

In the current thesis with deaf participants, we measure vocabulary, reading level and fingerspelling ability as potential factors that could play a role in orthographic processing. In addition, to gain a fuller picture of factors that may contribute to orthographic processing, speechreading ability and phonological awareness were also investigated (even though they are more relevant to phonological processing) to explore any relation with their size of the orthographic effect.

Some studies have also used TL word primes paired to target (e.g., diary, DAIRY; signs, SINGS) as their stimuli. However, given that there are fewer instances of 'TL word' primes that can be paired to target words, recent studies have instead used 'TL pseudowords' primes (e.g., jugde, JUDGE) and used replaced letters primes (RL, junpe, JUDGE) as their matched controls. In this thesis we also used TL pseudoword primes to assess orthographic effects.

According to Ferrand and Grainger (1994), orthographic masked priming effects emerge earlier than the phonological effects (see also Grainger et al., 2003; Perfetti & Tan, 1998; Pollatsek et al., 2005; Ziegler et al., 2000). In line with this, event related brain potential (ERP) and behavioural data have shown that orthography is activated earlier than phonology (e.g., Carreiras et al., 2009; Grainger et al., 2006; Grainger & Holcomb, 2009). Even in studies where the primary goal is to explore the role of phonology in visual word recognition, the influence and role of orthographic processing is generally taken into account. This also serves a useful check on our experimental design, to make sure our items make a clear distinction between phonological and orthographic conditions. For example, Rastle and Brysbaert (2006) mentioned that some of the past studies of word recognition have used pseudohomophones prime conditions that are orthographically (i.e., visually) similar to the target word (e.g. car, kar). Therefore, if they have reported phonological effects, they could have been actually orthography effects (i.e., responses influenced by the visual information of the word, rather than by how the word sounds). This confound is controlled in this thesis by having appropriate orthographic controls matched to phonological primes.

The majority of studies reporting orthographic effects mentioned above have used the English language. This thesis explored the use of orthographic information in deaf readers from different orthographies and in different age groups (Spanish- teenagers and adults and English - adults) during visual word recognition using a masked priming experiment (Chapter 6, section 6.2) and an experiment where fingerspelled words were presented in isolation (Chapter 7, section 7.2).

Perea and Lupker (2004), previously conducted a TL study in Spanish (a more transparent orthography) where they used three masked priming experiments and one single-presentation Lexical Decision Task. In Experiment 1, the two nonadjacent transposed letters were consonants (TL-C e.g., caniso, CASINO), showing priming TL effects when compared to orthographic controls (RL-C replaced letters, e.g., caviro-CASINO). In Experiment 2, the vowels were transposed TL-V, (e.g., anamil-ANIMAL), results did not show a TL effect. In Experiment 3, both stimuli were used (TL consonant and TL vowel) with their respective controls. The findings were consistent to the previous experiments as they only showed TL effects when the consonant letters were transposed. The authors speculate that perhaps the lack of TL effects in the vowels transposed priming condition could be due to a more noticeable change in the pronunciation of the word than when consonants are transposed. In the experiments conducted in this thesis with deaf teenagers and adults' readers of Spanish, given the paucity of literature in the field, both types of stimuli were used; transposed consonants (TL-C) and transposed vowels (TL-V), Perea and Lupker (2004) also reported a TL consonant effect in an LDT task with single words (i.e., no priming). Participants showed more errors for the pseudowords than for the word targets. There was a TL consonant effect participants showed longer RTs and more errors for the TL consonant target pseudowords than for the control condition. Unlike the previous experiments, there was also a significant TL vowel effect. According to the authors, it is not clear yet why there are differences between vowels and consonants, as the 'position-specific' models scheme predict the TL effects for both even when the letters are non-adjacent (see for discussion, Perea & Lupker, 2004). It has been proposed that the difference could be related to the sub-lexical phonological level (Perea & Lupker, 2004). Given that when a consonant is transposed, the pseudoword (RELOVUCION) sounds more like its base word (REVOLUCION) than when the vowels are transposed (REVULOCION). Therefore, one possible implication is that it is possible that phonological processing might also play a role when recognising these stimuli. However, this hypothesis needs to be further tested.

Other authors have tried to explain the differences between the TL-C and TL-V. According to Berent & Perfetti, (1995) the difference between vowels and consonants is because they are actually different linguistic units that have a different time course in their phonological assembly. Consonants are more reliable and informative, and they have a lower temporal duration in the speech signal than vowels. Caramazza et al., (2000) suggests that there are basic processing differences between consonants and vowels and that they are completely independent and actually processed by different neural mechanisms. Hence, different effects of transposition would be expected.

However, this might differ depending on the language (e.g., English being more inconsistent with sound-letter in vowels vs Spanish with consistent sound-letter representations). Consistent with this view, in this thesis the experiments with the groups of deaf readers of Spanish had TL conditions with both consonants and vowels transposed and their respective controls (replaced letters conditions). Nevertheless, the group of deaf readers of English had only the TL consonant condition and its control. This is, first, because most of the TL effects in the literature have been found with transposing consonant conditions. Second, because English is an opaque orthography and the transposition of the vowels might alter the orthographic processing due to a high inconsistency of the sounds in the vowels (e.g., in British speakers it has been identified around twenty different sounds from the five vowels, Deterding, 2004).

Perea and Acha, (2009), also explored whether the consonant/vowel differences in TL priming could be due to task differences. In their first masked priming paradigm experiment with a LDT, results showed only the TL consonant priming effects. The other three experiments used a ‘same-different’ task. For example, a probe (i.e. same as the target) was presented above the mask in lowercase with 6 #’s (######) during 1000ms, then the probe disappeared, and the prime replaced the forward mask for 50ms, finally the target was displayed on the screen in uppercase until participant’s response (see Perea & Acha, 2009 for details in the Experimental design). Participants were told to press a key if the ‘probe’ was the same as the target or press another key if they were different. The target could be preceded by the TL prime or the RL prime control. For the ‘same’ responses, for probe and target, (E.g., probe: cartel, prime TL: catrel or RL: cafnel, target: CARTEL). For the ‘different’ responses (probe and target), the probe was visually different to the target, but the length was the same (e.g., probe: carril, target: SARTÉN), with their respective primes (TL or RL). According to the authors the task taps an earlier perceptual process. The results for the three experiments showed a TL priming effect regardless of the consonant or vowel transpositions. Therefore, unlike the LDT, the ‘same-different task’ does not seem to be influenced by phonological processing when the vowels are transposed (see Perea & Acha, 2009). Based on these findings the authors suggest that letter position coding seems to occur even before the distinction of the type of letter (i.e., consonant or vowel) in the process, where the influence of the vowel or consonant seems to appear later in the phonological processing, and to take a more important role. Perea and Acha, (2009), showed that orthographic processing could be affected by the type of task used in the experiments (e.g., LDT vs same-different task). However, the use of the LDT has been replicated in many studies showing robust findings in TL-C effects (e.g., Lupker et al., 2008; Perea & Acha, 2009; Perea & Lupker; 2004). Therefore, that was one of the reasons to use that task in the experiments conducted in this thesis. The 'same-different task' has a particular experimental design, which might need more replication to confirm the effectiveness of the paradigm and the findings in Perea & Acha (2009) study. Moreover, the task was to identify whether the "probe" (same as the target presented before the prime) was the same as the Target. This is a different process compared to a LDT where participants have to decide whether the target is a real word or not.

In sum, masked orthographic priming effects can be found in adult hearing readers of both English and Spanish using TL consonant prime pseudowords, generated from a base target word (e.g., HOSPITAL/HOSTIPAL). It is still inconclusive why the priming of TL vowels is less robust than the TL effect in consonants, although some suggestions have been discussed above. Some researchers have also explored orthographic effects during VWR in young readers, who are in a developing stage of their reading abilities. In the next section I present studies that have used the TL paradigm with hearing developing readers.

4.3.2. Hearing Young readers

In a study with developing readers of English, Kohnen and Castles (2013) explored the letter position coding in children (age range: 8 -10 years) using a reading aloud task. They showed that they made many more errors on “migratable” words (e.g., parties- pirates; three - there) than on “non-migratable” words (e.g., blown, forks, heard). Similar findings were seen on nonwords that could ‘migrate’ to actual words (e.g., brid - BIRD). These errors increased across grade levels and correlated with word reading skills. According to the authors these findings suggest that the direct orthographic pathway was reached through the coarse-grained orthography coding, where some flexibility is allowed in terms of the words’ letter position. Thus, as readers get more exposure to words (e.g., acquire more vocabulary) they show more flexibility of the letter’s positions within the word, thus showing a larger orthographic effect. It is informative to see how vocabulary size played a role in the orthographic effect, as this suggests that having more vocabulary gave larger flexibility to find the right the letter position within the word. This thesis tests a group of developing deaf readers of Spanish (n = 54) with huge variability on a variety of reading parameters. Therefore, we applied a battery of reading tests, including the assessment of vocabulary. This allowed us to understand whether the orthographic processing of deaf developing readers might be modulated by individual differences, such as vocabulary size and other reading related measures.

Given that some authors have attributed the differences between consonant/vowel effects in adults to greater phonological processing for TL vowels than TL consonants (Comesaña et al.,2016; Perea & Acha, 2009; Perea & Lupker, 2004), recent research has started to explore TL consonants and TL vowels effects in developing readers, in whom phonological coding might play a relatively more important role than in adult readers. Comesaña et al., (2016) examined TL effects in Spanish 9 year old children using masked priming and also sandwich masked priming paradigm. Interestingly, there was a transposition effect with both TL consonant and TL vowel conditions. This could mean that as the authors expected, the TL-V effect might be influenced by a greater sensitivity to phonology in developing readers, than more experienced readers (Comesaña et al., 2016; Lupker et al., 2008; Perea & Acha, 2009; Perea & Lupker; 2004). However, this hypothesis needs further testing, as it also raises a question whether the TL- vowel effect is purely orthographic or phonological, or whether it might be a combination of the two. The TL effects were found using both paradigms (standard and sandwich masked priming). However, as predicted, the magnitude of the TL effect was larger in the sandwich masked priming paradigm (Lupker & Davis, 2009). The authors argue that their findings suggest that the origin of the differences between consonant/vowel transposition does not commonly occur at an early orthographic stage in readers. Therefore, the authors support the claim that the differences between TL-C and TL-V might occur in phonological processing (see Perea & Lupker, 2004).

In this thesis sandwich masked priming was used with a group of deaf young readers of Spanish. However, the sandwich masked priming paradigm used in this thesis was slightly different to one in the Comesaña et al., (2016) study. Since deaf readers may be more influenced by what happens visually before the target, a blank screen (50ms) was included immediately after the prime, (see Experimental Design in Chapter 6, section 6.1.1.1.4). The same sandwich masked priming paradigm was used previously with deaf adult readers of Spanish by Gutierrez-Sigut, et al., (2018).

Acha and Perea (2008) also explored the developmental changes in the use of orthographic information during visual word recognition. The researchers manipulated the length and the transposition of the letters in the stimuli used in the LDT. Participants were beginner (Mean age= 7), intermediate (Mean age= 11) and skilled readers (Mean age= 22) of Spanish. The target words were either short or long (6.5 vs 8.5). Beginner and intermediate readers showed a length effect responding quicker to short than to long target words. Additionally, the target was preceded either by a non-adjacent TL pseudoword or by a RL pseudoword prime (e.g., aminal vs arisal, - ANIMAL). Results showed that beginner, intermediate and skilled readers responded quicker when the target was preceded by the TL prime than when it was preceded by its control (RL prime). All groups showed a significant TL effect; however, the effect was significantly larger in the skilled group than the intermediate and the beginner groups.

A cross-sectional study found a TL effect in French children from 1-5th grade (age range: 6.7 – 10.9) during a LDT (Ziegler et al, 2014). The TL effect gradually increased with grade level and reading age. According to the authors one of the reasons for the increasing size effect observed in this study with children across ages, was because of the type of paradigm used (Ktori et al, 2012; Lupker & Davis, 2009). In comparison with Acha and Perea' (2008) study, children in the Ziegler et al., (2014) study showed smaller TL size effects using the standard masked priming paradigm.

In sum, the role of orthographic processing in visual word recognition increases over time as developing readers become skilled readers. This development is also influenced by individual differences, for example, size of vocabulary, spelling ability. The use of the TL priming paradigm allows us to explore the orthographic representation of the words across different stages of reading development by looking at the flexibility and precision during their orthographic processing. The role of orthography in skilled readers and in reading development may be particularly important for deaf readers for whom access to speech phonology is reduced. This is discussed in the next section.

4.4. Deaf readers

4.4.1. Deaf adult readers

The majority of the single word recognition studies in deaf readers have focused on exploring the role of phonological coding, as it has been suggested to be a critical factor in the process of SWR, particularly in alphabetic languages. It has been also suggested that the altered access to phonology by deaf readers might be one of the possible reasons why some deaf readers have a low reading performance compared to their hearing peers. If deaf people have an underspecified phonological representation, it is possible that they will rely more on orthographic information than hearing readers. Indeed, some studies support this notion (e.g., Bélanger et al., 2012, 2013 and Cripps et al., 2005).

Previous studies with adult deaf readers have suggested that TL priming effects are primarily driven by orthographic representation and not by phonological representations (Comesaña et al., 2016; Lupker et al., 2008; Perea & Acha; 2009; Perea & Lupker, 2004). More recently, Meade et al., (2020) explored orthographic effects in hearing and deaf adults with similar spelling skill, (as spelling ability was found to affect the size of TL priming in Andrews & Lo, 2012 study). Participants performed a LDT in a sandwich masked priming paradigm while ERP data were collected. A prime condition was presented before the target for 50ms. The prime conditions of interest were: TL adjacent (two word-internal adjacent letters were shifted, toaster - TOASTER) and TL non-adjacent (the letters shifted were separated by two letters, toestar – TOASTER), with their respective controls (replaced letters - RL). Both groups responded faster when the target was preceded by both TL primes (TL adjacent and TL non-adjacent) than when it was preceded by their replaced letter RL controls and there were no group differences in either the behavioural or the electrophysiological data. Since the size of TL effect was similar between these deaf and hearing groups, the authors suggested that their precision of the orthographic representations was, as well as how they were accessing it. These participants had good reading skills and showed a facilitation TL effect.

The results from Meade et al., (2020), also found facilitatory TL priming effects in with deaf and hearing readers. These results were similar to Andrews & Hersch (2010) with hearing skilled readers with less precise orthography, that showed the same direction of the orthographic effect (facilitatory). These findings support the lexical quality hypothesis of reading, which predicts variation among skilled readers in how they have developed a precisely specified orthographic representation, and how these individual differences influence how they recognise single words. Additionally, Meade and colleagues suggested that given that the group of deaf readers were using American Sign Language (ASL) as their preferred way of communication, their ability in fingerspelling could have provided them strong access to orthographic representations (See Emmorey and Petrich, 2012; Stone et al., 2015).

In another study, skilled deaf readers of Spanish (age range: 23-45) participated in a SWR study by Fariña et al., (2017), where words were presented in isolation. The stimulus were, 80 target words (8-10 length), and the conditions were created based on the target words: 1) TL-pseudoword; two non-adjacent letters were transposed (e.g., mecidina - from word MEDICINA, “medicine”) and 2) RL-pseudoword control condition; the transposed letters were replaced by two letters visually similar (e.g., mesifina). Results showed a significant TL effect in both deaf and hearing readers. Both groups were slower and had more errors at rejecting the TL- pseudoword than

RL-pseudoword control conditions. Overall, response times for recognising words and pseudowords were faster by deaf than hearing readers. These results in deaf readers replicated the TL effects seen in hearing readers (e.g., Chambers, 1979; O'Connor & Forster, 1981). The results suggest that hearing as well as deaf readers are sensitive to orthographic processes. In this thesis, orthographic processing was explored using TL fingerspelled pseudowords, RL pseudowords and their base word. Similar to Fariña et al., (2017) it was expected that deaf readers were influenced by the TL condition showing slower responses and less accuracy; an inhibitory orthographic effect.

As mentioned, it has been hypothesised that phonology could influence the activation of orthographic representations. Different studies have tested this hypothesis in a LDT using transposed (TL) and replaced (RL) letter conditions with hearing (full access to phonology) and deaf (altered access to phonology, indirect access via speechreading, fingerspelling, self-articulation), matched with age and reading ability (in Spanish, Fariña et al., (2017), and in English, Meade et al., (2020). Both studies found that deaf and hearing skilled readers performed very similarly in visual word recognition tasks. Even using different paradigms (i.e., Meade et al. (2020), used masked priming paradigm and Fariña et al., (2017) single word recognition), the deaf and hearing participants showed no difference in the orthographic size for word recognition, suggesting that both readers have similar orthographic representations despite the hypothesis that deaf people may rely on orthographic representations to a greater extent than hearing because of reduced access to the phonological component of speech.

4.4.2. Young deaf readers

Only a handful of studies have looked at orthographic processing in young deaf readers, none of which have used the TL paradigm. Similar to the reading literature available for adults, most of the reading studies (particularly with alphabetic languages) have focused on the use of phonological coding, especially in the early stages of learning to read in deaf individuals. Thus, orthographic processing in deaf young readers as well as the mechanisms underlying this process are still unclear.

Zhao and Wu (2021) studied the relationship between reading ability and visual processing skills in Chinese deaf children (n= 118, Mean age: 14.6). Children were given 308 characters and non-characters in two 14 x 11 matrices, and they were instructed to cross out as many non-characters as possible in 70 sec. Zhao and Wu (2021) found that visual-orthographic processing was strongly correlated with reading comprehension and predicted reading ability. This task was successfully used in a previous study with hearing children by Liu et al., (2017) and the authors concluded that visual processing skills play a critical role in the ability of deaf children, which is similar to hearing readers, as deaf readers usually rely on visual processing during reading

There is a noticeable lack of research directly studying the orthographic representations in deaf children. Therefore, in this thesis, precision of orthographic representation during written word (Chapter 6 section 6.2.3) and fingerspelled word recognition (Chapter 7, section 7.2.3) was explored in a group of young deaf readers of Spanish.

4.5. Fingerspelling

Fingerspelling can also be used by deaf readers to access orthography (see Emmorey & Petrich, 2012; Puente et al., 2006). Fingerspelling is a system in which each letter of the alphabet is represented by a hand configuration (Sutton-Spence, 1994). Different systems are used alongside different sign languages. For example, British Sign Language (BSL) using a two-handed fingerspelling system (see Figure 6). Whilst Mexican Sign Language (MSL) uses a one-handed fingerspelling system (see Figure 7). Fingerspelling can be used by signers for various reasons, for example, proper names, words that lack a lexical sign (i.e., neologisms) and for specific sign forms (i.e., initialised signs) (Sutton-Spence & Woll, 1999). Fingerspelling is an ability which develops with practice and exposure (Padden, 2006). It has been found that deaf children when they are babies and first learn fingerspelling, learn it as a 'lexical item' (sign), instead of a hand configuration of each of the letters by following an orthography sequence of the printed words (Padden, 2006). However, as soon as reading and writing skills start to develop, deaf children start to match the written letters to the hand configuration letters, creating a link between the alphabet system of their Sign Language to the orthography representation system (written) of the spoken language (Padden, 2006).

Through fingerspelling a child can link a new written word to its sign, thus accessing the meaning more easily. This has been used traditionally by signing teachers of deaf readers, who link the written words to the fingerspelling to the sign – this has been referred to as 'chaining' (Padden & Ramsey, 2000). Additionally, fingerspelling can help to recognise already known words (Haptonstall-Nykaza & Schick, 2007; Hirsh-Pasek, 1987). Therefore, deaf readers who use fingerspelling might have more access to the orthography and phonology of written words than those who don't use it (Haptonstall-Nykaza & Schick, 2007).

Previous studies have found that fingerspelling ability correlates with reading in deaf adults (Emmorey & Petrich, 2012; Puente et al., 2006), and in deaf children (Padden & Ramsey, 2000; Puente et al, 2006). However, the role of fingerspelling during word recognition is still unclear, with some recent suggestions that fingerspelling contributes to improve orthographic processing (Miller et al., 2021) and some researchers arguing that fingerspelling complements phonological processing.

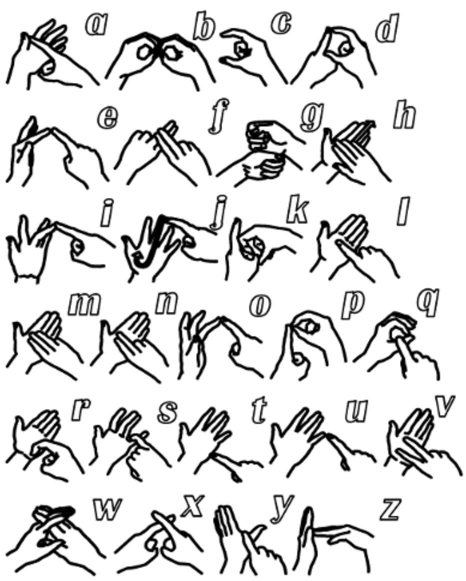
Given the potential benefits of fingerspelling to orthographic learning Miller, Banado-Aviran, & Hetzroni (2021) conducted a 'chaining' intervention program: fingerspelling, written words, and sign meanings, with severe to profound deaf children (n = 4, age 4.5 – 6 years). The intervention led to significant improvements in children' orthographic learning. Even though this intervention was conducted with only 4 participants, it shows that fingerspelling can be an effective mediator for orthographic learning in deaf children that are developing their orthographic lexicon. This supports the view that fingerspelling reinforces the visual route as deaf readers can learn the words represented by both handshapes and their printed word representation.

Other studies have suggested that fingerspelling can help to form a more complete representation of the spoken language (Haptonstall-Nykaza & Schick, 2007). In particular, fingerspelling ability can represent a visual phonological system that could be used as a tool to achieve reading (Brentari, 1998; Haptonstall-Nykaza & Schick, 2007). According to Keane and Brentari (2016), previous research has shown that when a word is fingerspelled fluently as a word or sign-like, (and not letter by letter), it can provide a 'visual-manual phonological representation' of words. This is, because fluently fingerspelled words can show the syllable structure represented by the movement/envelope of the 'sign'. Similar strategies have been used with fingerspelling that seem to help with comprehension: chunking the fingerspelled words or coarticulating sequences of letters that occur with frequency (Brentari, 1998). For example; affixes/prefixes (,-tion: na<u>tion,</u> educa<u>tion</u>; -ness: ill<u>ness,</u> fit<u>ness</u>; pre-: <u>pre</u>vious, <u>pre</u>dict). They are produced as chunks, with minimal distinction of the fingerspelled letters.

Lederberg et al., (2019) assessed fingerspelling ability in 336 deaf children (mean age = 6.7, sd= 1.0). The tasks included the manipulation of the sublexical structure of the fingerspelled words. They were the Fingerspelling Ability and Phonological Awareness Test (FS-PAT; Schick, 2012): (1) the imitation task, participants had to imitate a sequence of fingerspelled words, they increased in difficulty and length (e.g., starting with 'car', and ending with 'caterpillar'); (2) the blending task, participants were asked to blend fingerspelled letters or segments of letters into a real word. There were eight words of increasing difficulty. The sequence started with:

‘t-oy’ and ended with: ‘g-r-a-ss-h-o-pp-e-r’, the hyphens were shown to indicate segmentation; (3) the elision task; the signer instructor fingerspelled a word and told the child to delete a particular section or a specific letter of the fingerspelled word. The child had to fingerspell back removing the instructed fingerspelled chunk from the word reproduced by the signer. There were eight words of increasing difficulty (e.g., starting with: popcorn, without ’corn’, ending with: strain, without ‘r’). The first task was used to assess fingerspelling ability and the last two tasks, phonological awareness in fingerspelling. Fingerspelling was assessed in the two signing groups. The sign language and the bimodal groups showed that reading skill was strongly related to fingerspelling phonological abilities. These results suggest that deaf children learning to read can make use of their fingerspelling ability to manipulate sub-lexical parts of the words in a similar way that the spoken phonological awareness ability is used by hearing children.

One route by which using fingerspelling may be correlated with reading proficiency is that, in combination with mouthing patterns, it may provide information about phonological structure of spoken words. Emmorey and Petrich (2011) studied whether a phonological or orthographic segmentation strategy affected the recognition of fingerspelled and printed words. Deaf participants had good performance segmenting fingerspelled words using phonological syllable break strategy. The authors suggest that the association between English mouthing and the representation of fingerspelled words could support a “phonological parsing preference” for fingerspelled words.



Public domain.

Figure 6. Mexican Sign Language (LSM) Alphabet.

Retrieved from: (Fingeralphabet.org, 2019, http://www.fingeralphabet.org/alphabets/mexico-v01)

Figure 7. British Sign Language (BSL) Alphabet

5. Overview of data collection

This thesis examined how phonological and orthographic information is used during printed (Experiments 1- 6, Chapter 6) and fingerspelled (Experiments 7-12, Chapter 7) word recognition by deaf readers of English and Spanish. Participants included deaf readers of Spanish: adults (n=17, 21-61 years old) and young people in education (n=56, 11-21 years old), and adult deaf readers of English (n= 14, 23-53 years old). Unfortunately, the experiments with the English participants were interrupted due to the COVID-19 pandemic. The data collected from 14 participants prior to the start of the pandemic are reported here. In addition, data from a younger English age group was not possible.

Chapter 6 presents a detailed description of the 'sandwich masked priming paradigm' used in six experiments reported in this thesis. Experiments 1-3 explored Phonological processing (section 6.1), and Experiments 4-6, explored Orthographic processing (section 6.2).

In the Phonological processing Experiments (1-3), participants performed a lexical decision task (LDT) involving printed target words (e.g., FAN) that were preceded by phonological (e.g, phan) or orthographically (e.g., chan) related masked primes (see section 6.1.). Then, in the Orthographic processing Experiments (3-6), participants performed a LDT where the target printed words (e.g., HOSPITAL) were preceded by a masked prime with transposed letters (e.g., hostipal) or replaced letters (e.g., hosfigal) (see section 6.2).

Chapter 7 includes a description of the processing of a LDT with fingerspelled words and pseudowords presented in isolation. Six experiments were conducted with profoundly or severely deaf readers of English and Spanish. Experiments 7-9 explored Phonological processing, (section 7.1), and Experiments 10-12 explored Orthographic processing (section 7.2). Participants performed an LDT, where they had to decide whether fingerspelled words presented in isolation were real words or not. In phonological processing Experiments (7-9); participants saw fingerspelled words and pseudowords (phonologically or orthographically related to their base words, e.g., klue, plue, CLUE, see section 7.1). Then, in Orthographic processing Experiments (10-12), participants saw fingerspelled words and pseudowords (transposed letters or replaced letters conditions, e.g., cholocate, chofonate, CHOCOLATE, see section 7.2).

The research questions and hypotheses that were addressed in this thesis are the following:

<u>Experiments 1-3: Automatic use of phonological information in printed words (Chapter 6, section 6.1).</u>

1.1. Do deaf readers of English and Spanish use phonological codes automatically during visual word recognition?

It was hypothesised that if deaf readers use phonological codes automatically during word recognition, they should show faster RT and less errors for words preceded by pseudohomophone matched to the target (e.g., phan, FAN) than for the orthographic control (pseudoword that is visually similar to the pseudohomophone prime; chan, FAN). This would reflect facilitation due to the pseudohomophone prime.

1.2. Is the size of the phonological priming effect related to reading, speechreading and fingerspelling skills?

It was hypothesised that better readers, speechreaders and those with better fingerspelling skills should show a larger phonological priming effect (defined as the difference between the pseudohomophone and the orthographic control condition in either RTs or accuracy).

<u>Experiments 4-6 - Automatic use of orthographic information in printed words (Chapter 6, section 6.2).</u>

2.1. How precisely do deaf readers of English and Spanish use orthographic codes during visual recognition of fingerspelled words?

it was hypothesised that deaf readers would show faster RTs and less errors during lexical decision for words preceded by a masked prime which is a pseudoword in which two letters had been transposed (e.g., hostipal - hospital) than when preceded by a pseudoword including a replaced letter (e.g., hosfigal - hospital). This would reflect facilitation due to the transposed letter pseudoword.

2.2. Is a larger orthographic priming effect related with reading, speechreading and fingerspelling skills?

It was hypothesised that reading, speechreading and fingerspelling skill will be associated with the size of the orthographic priming effect. The orthographic priming effect was defined as the difference, in either RTs or accuracy, between the transposed letter pseudoword and replaced letter pseudoword control conditions.

Experiments 7-8 – Automatic use of phonological information in fingerspelled words (Chapter 7, section 7.1).

3.1. Do deaf readers use phonological during recognition of fingerspelled words?

It was predicted that if deaf readers use speech phonology during recognition of fingerspelled words (e.g., clue), participants should show slower lexical decision response times and more errors to pseudohomophones (e.g., klue) than to the orthographic control (e.g., plue), as participants would be more easily confused with their phonologically related words.

3.2. Is the size of a phonological effect related to reading, speechreading and fingerspelling skills?

It was hypothesised that better readers, speechreaders and those with better fingerspelling skills will show a larger phonological priming effect, defined as the difference between the pseudohomophone and the orthographic control condition in either RTs or accuracy.

<u>Experiments 9-12- Automatic use of orthographic information in fingerspelled words (Chapter 7, section 7.2).</u>

4.1. How precisely do deaf readers use orthographic codes during visual recognition of fingerspelled words?

It was predicted that if deaf readers use orthographic codes during recognition of fingerspelled words, they should show slower lexical decision times and more errors to nonwords with transposed letters (e.g., cholocate) than to the replaced letter consonant (e.g., chofonate) fingerspelled pseudowords conditions presented in isolation. This is due to the fact that the lexical representation of the real word would be more likely to be activated by the nonword with transposed letters than nonwords with replaced letters.

4.2. Is the size of an orthographic effect related to reading, speechreading, and fingerspelling skills?

It was hypothesised that better readers, speechreaders and those with better fingerspelling skills should show a larger orthographic effect, defined as the difference between the TL and the RL control condition in either RTs or accuracy)

Lastly in Chapter 8, I present a general discussion about the main findings of this thesis. I begin by discussing the results in deaf adult readers of English and Spanish and their implications on the use of phonology and orthographic information during VWR by deaf adult readers from different orthographies (e.g., transparent and opaque). Moreover, I discuss the developmental trajectory of deaf readers of Spanish (young readers and adults) related to their phonological and orthographic effects. To conclude this chapter, I discuss the limitations of this research and provide suggestions for future directions and studies.

6. Visual word processing in deaf readers

The previous chapters provided an overview of the relevant literature and data collection methods used for this thesis. The current chapter contains the first experimental results of the thesis. This chapter includes a detailed description of the sandwich masked priming paradigm that was used in experiments that explored visual word recognition in profoundly or severe deaf readers (Experiments 1-3 Phonological processing, section 6.1 and Experiments 4-6 Orthographic processing, section 6.2.).

6.1. Phonological Processing

In order to assess whether phonological information is used automatically during visual word processing, we used a sandwich masked priming paradigm in combination with a lexical decision task. Furthermore, we used the same paradigm to test groups of readers of languages with different orthographic depth (English vs. Spanish) and different ages (Adult vs. Adolescent). We collected data from adult deaf readers of English, adult deaf readers of Spanish and young deaf readers of Spanish.

The following research questions were addressed in all the groups of the deaf readers:

1. Do deaf readers of English and Spanish use phonological codes automatically during visual word recognition? It was predicted that if deaf readers use phonological codes automatically during word recognition, they should show faster RTs and less errors for words preceded by pseudohomophone than for the orthographic control masked primes (due to facilitation in the pseudohomophone prime condition).

2. Is the size of the phonological priming effect related to reading, speechreading and fingerspelling skills? It was hypothesized that better readers, speechreaders and those with better fingerspelling skills will show a larger the phonological priming effect (defined as the difference between the pseudohomophone and the orthographic control condition in either RTs or accuracy).

The next section details the methods of the sandwich masked phonological priming experiments in the group of adult deaf readers of English (6.1.1.), followed by the adult deaf readers of Spanish (6.1.2.) and finally by the young deaf readers of Spanish (6.1.3.).

6.1.1. Deaf adult readers of English

The conditions of interest in this sandwich masked phonological priming experiment were those where the target was preceded by a pseudohomophone and by an orthographic control prime. As it is common in the literature, we also included an identity condition and an unrelated condition. Contrasting the identity and unrelated conditions allowed us to test the well-known repetition priming effect (Bodner & Masson, 1997; Forbach et al., 1974; Humphreys et al., 1988; Perea et al., 2014), which has been shown to index of visuo-orthographic processing, (rather than phonological coding). As described above, phonological effects have sometimes been unreliable in deaf readers, but visual-orthographic priming effects have been robust. Finding a visual-orthographic priming with the same target words that are used in the phonological and orthographic control conditions allow us to rule out the possibility that potential null phonological effects are due to stimulus characteristics (e.g., unknown targets).

For the participants to be able to perform a lexical decision task, the experiments included equal number of words and pseudowords. The pseudowords were preceded by all four types of prime. However, as masked priming effects are generally not observed in pseudoword, only the lexicality effect will be reported here.

6.1.1.1. Methods

6.1.1.1.1. Participants

Fourteen congenitally deaf adults (6 female) were recruited. All participants were severely or profoundly deaf from birth. Their ages ranged from 23 to 53 years (M = 36.98, SD = 10.67). Five participants were native BSL signers, 5 participants were early signers (AoA between 3 and 9 years old), and the remaining 4 participants learnt BSL after the age of 9yrs and were considered late signers. Thirteen participants were fluent signers of BSL (self-ratings 6-7, in a 1-7 Likert scale) and used BSL as their preferred means of communication in their daily lives. One participant rated their BSL proficiency at 4 and reported using English as their preferred form of communication. This study was approved by the University College London Research Ethics Committee (Project ID Number 10991/001). Instructions were given in BSL and in written English. Participants were asked to provide written consent at the beginning of the sessions and were told that they could withdraw at any time.

6.1.1.1.2. **Offline behavioural measures**

Participants were tested on Non-Verbal IQ, Sentence Reading, Speechreading ability, Fingerspelling ability, and explicit phonological task: Rhyme Judgement task (participant's performance on those tasks is summarised in Table 2). All participants had non-verbal IQ above 85 (IQ score), their reading comprehension score was above 33.3%.

Reading comprehension

The Vernon-Warden reading test (Hedderly, 1996) is a 10-minute multiple choice test that provides a measure of reading comprehension. This test can be used for children from 8 years old to adults. Participants were asked to complete as many sentences as possible. Participants are required to select a word from 4 options to best complete a sentence (e.g., ducks swim in a _____: bucket, pond, yard, garden).

The difficulty of the questions increases thorough the test. Since this test has not been validated for deaf readers, percentage accuracy (after deducting points for incorrect answers from the number of correct responses as specified in the manual) is reported (M = 68.7%, SD = 17.7 see Table 2). In addition, percentage accuracy scores are used for correlations as they allow for a better assessment of individual variability than reading age (see Table 3).

Vocabulary Test

The WASI (Wechsler Abbreviated Scale of Intelligence), Vocabulary subtest (Wechsler, 2011) was used to measure vocabulary. This is a 42-item task that measures productive vocabulary, the level of knowledge of words, and the ability to express the meaning of those words and concepts. The test starts with four pictures that participants are required to name. Then, items 5 to 42 are presented as written words, participants are required to describe each item as accurately as possible in their preferred language (BSL or spoken English). The scores are reported in percentage accuracy (M = 82%, SD = 15.4), see Table 2. The duration of the test was approximately 10 minutes. This test is appropriate to use with deaf participants because the instructions could be given in BSL or English and, more importantly, participants can give their responses in their preferred language (see Kyle et al., 2017). Thirteen participants answered in BSL and one in Sign Supported English (SSE, i.e., syntax from spoken English while simultaneously signing). The percentage of accurate responses was reported (M = 82%, SD = 15.4, see Table 2).

Explicit phonological task: Rhyme Judgement Task

Ninety pairs of monosyllabic English words, 45 rhyming and 45 non-rhyming were used in this Rhyme Judgement Task. The Rhyme Judgement task developed by MacSweeney et al., (2013,) was used here (see stimuli in Appendix A). Participants were required to decide whether words pairs, presented for 5000ms, rhymed or not. They responded using a button press response. Word pairs had different spellings (e.g., rule – pool). Therefore, participants' responses could not be influenced by the orthographic similarity of the words. The duration of the task was approximately 5 minutes. The percentage of accurate responses was reported (M = 73%, SD = 17.5, see Table 2).

Speechreading Ability Test

The Everyday Questions subtest of the 'Test of Child Speechreading' (TOCS; Kyle et al., 2013, https://dcalportal.org/) was used to assess participant's speechreading ability. Although the TOCS extension has only been validated for children (Kyle et al., 2013) it has been used reliably with adult participants. Participants watched 12 silent videos of a person asking everyday questions (e.g., What is your name?). Six videos showed a female speaker and the other six a male speaker. Immediately after each video participants were asked to repeat as much of the question as they could. Participants could respond either in BSL or English. Thirteen participants answered in BSL and one in sign supported English. A point was given for each correct lexical item that they named or signed, the percentage of accurate responses was reported

(M = 91%, SD = 7.5, see Table 2). Thus, speechreading ability of these participants was high.

Fingerspelling Reception Ability test

Participants saw videos of fingerspelled words (n=30) and were required to write down each word. The words had increasing length and decreasing lexical frequency through the test (see the list of words in the Appendix B). The fingerspelled words were produced with mouthing and at natural speed by a skilled BSL signer. The task was self-paced. A point was given to each correct word, the maximum raw score was 30. The scores were reported in percentage accuracy (M = 86.7%, SD = 9.1), See Table 2. The fingerspelling ability test lasted from 5-10 minutes.

Non-Verbal IQ

The Test of Nonverbal Intelligence, Second Edition (TONI- 2; Brown et al., 1990) was used to test non-verbal IQ in deaf participants. This is a language-free test of cognitive functioning through abstract and figural problem-solving ability. The test allows for a wide range of ages (from 5 to 85 years, 11months). This test has been shown to have good concurrent, construct and predictive validity as a tool to assess deaf children (see Mackinson et al., 1997). TONI-2 contains 55 items of incremental difficulty. Participants are asked to select from multiple options the one that best completes a series. In order to point to the correct option, participants must identify the rules that describe the relationship between the figures. The difficulty of the task differs according to both the type and the number of rules that participants have to consider in order to reach the solution (see examples included in figure 8). All participants had non-verbal IQ over 85 (i.e., one SD below the mean) and none of them reported other disorders or learning disabilities. The test takes approximately 15 minutes to complete.

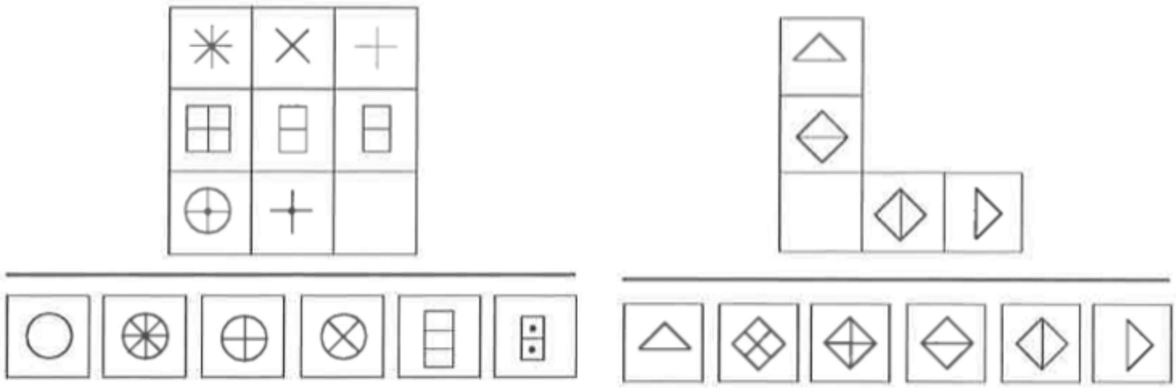


Figure 8. Examples of the Test of Nonverbal Intelligence (TONI- 2; Brown et al., 1990).

Table 2. Participant characteristics and test scores of the deaf adult readers of English

	Mean (SD)	**Range**
Age (Yrs, mths.)	36,9 (10.7)	(23.5-53.1)
Reading Comprehension (% correct)	68.7% (17.7)	(33.3%-90.5%)
Vocabulary Test (% correct)	82 % (15.4)	(51.2%-98.6%)
Phonological Processing (Rhyme task, % correct)	73% (17.5)	(51%-98%)
Speechreading Ability Test (% correct)	91.2% (7.5)	(74.2%-100%)
Fingerspelling Test (% correct)	86.7% (18.9)	(30%-100%)
NVIQ (Standardised score)	113.57 (9.09)	(100-139)

In order to better describe the sample of participants, correlations between the off-line measures were calculated (see Table 3). Significant correlations were found between: Vocabulary and Reading Comprehension (see Figure 9), Phonological processing (Rhyme judgement task) and Speechreading ability (see Figure 10), NVIQ and Reading Comprehension (see Figure 11) and NVIQ and Vocabulary (see Figure 12).

Table 3. Correlations between offline behavioural measures in deaf adult readers of English.

	Vocabulary Test	Phonological Processing	Speechreading Ability Test	Fingerspelling Test	NVIQ
Reading Comprehension	.94***	-.18	.48	-.23	.63**
Vocabulary Test		.44	.46	-.12	.58*
Phonological Processing (Rhyme task)			.55*	-.05	-.28
Speechreading Ability Test				.04	-.17
Fingerspelling Test					-.05

* $p < .05$, ** $p < .01$, *** $p < .001$

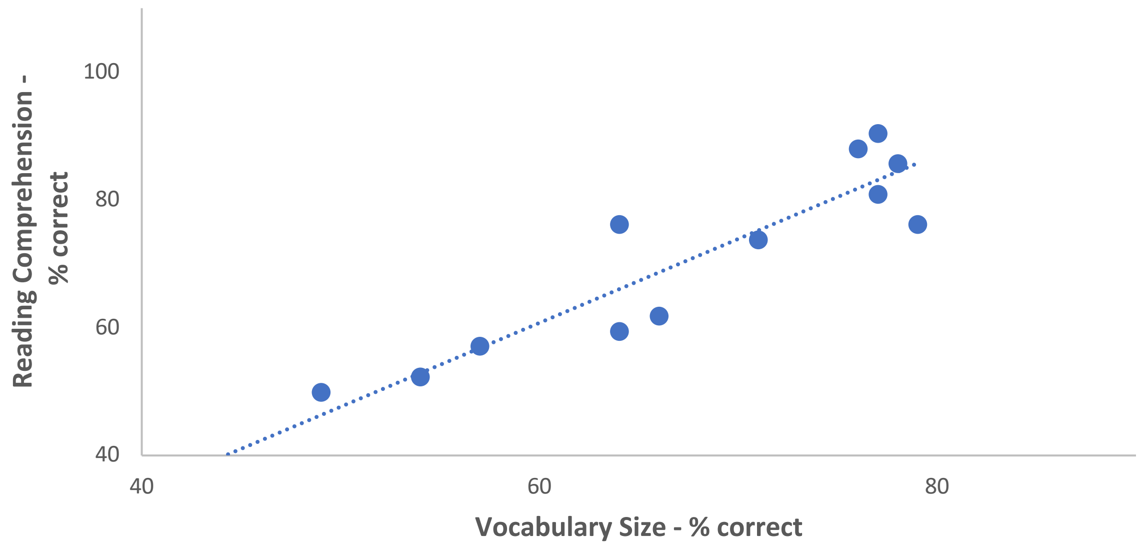


Figure 9. Correlation between Vocabulary Size (x-axis) and Reading Comprehension (y-axis) in deaf adult readers of English.

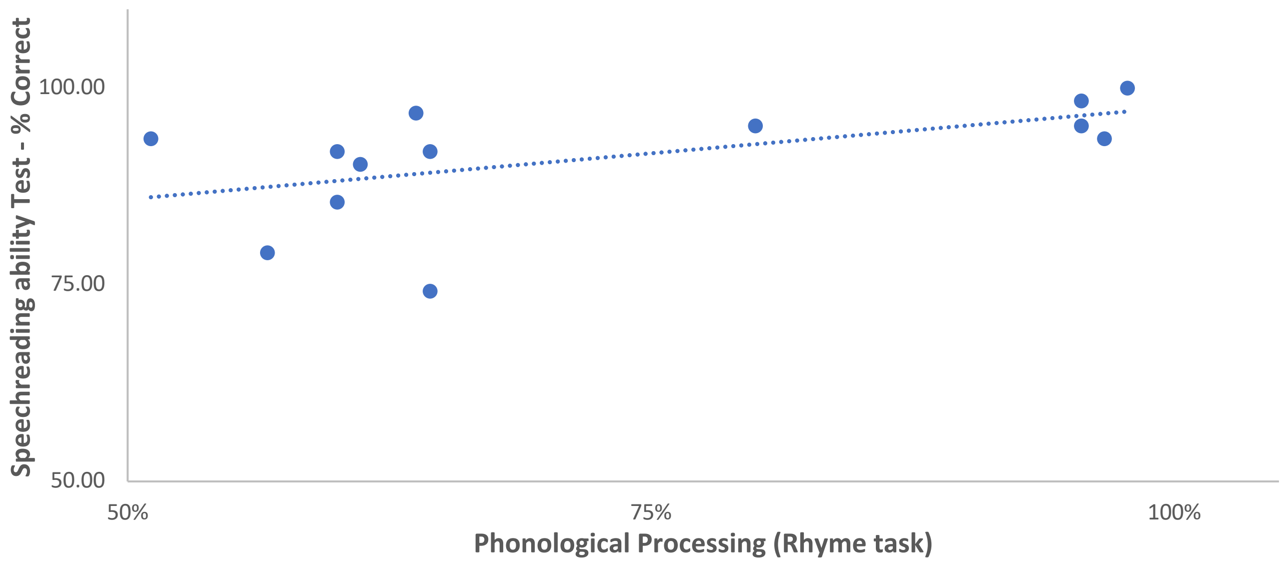


Figure 10. Correlation between Phonological Processing (Rhyme task, x-axis), and Speechreading (y-axis) in deaf adult readers of English*.*

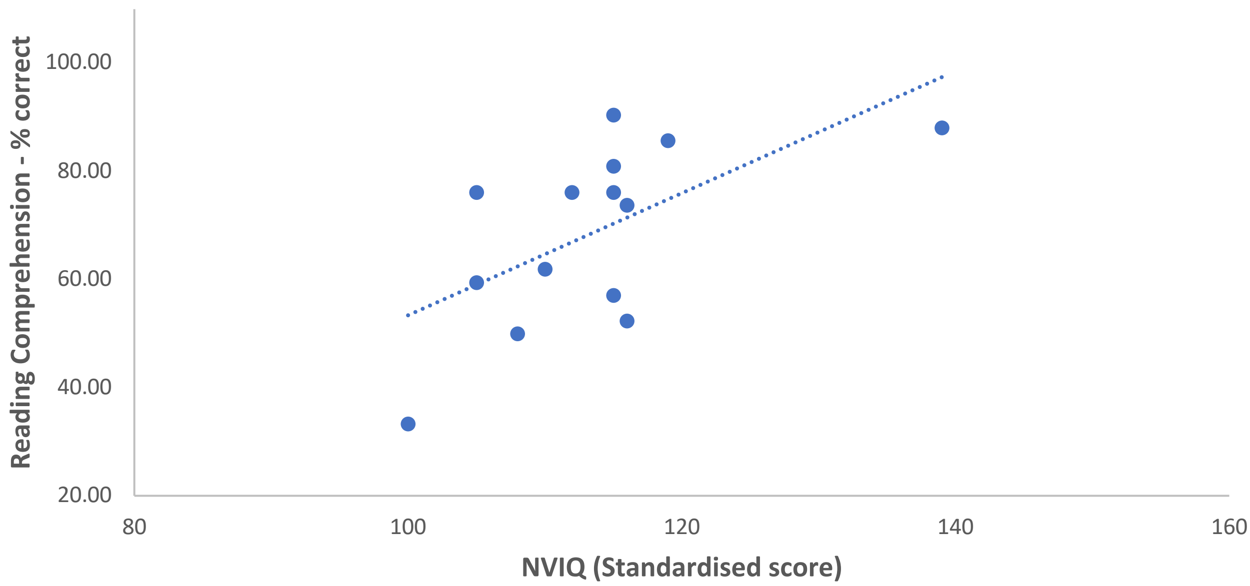


Figure 11. Correlation between NVIQ (x-axis) and Reading Comprehension (y-axis) in deaf adult readers of English.

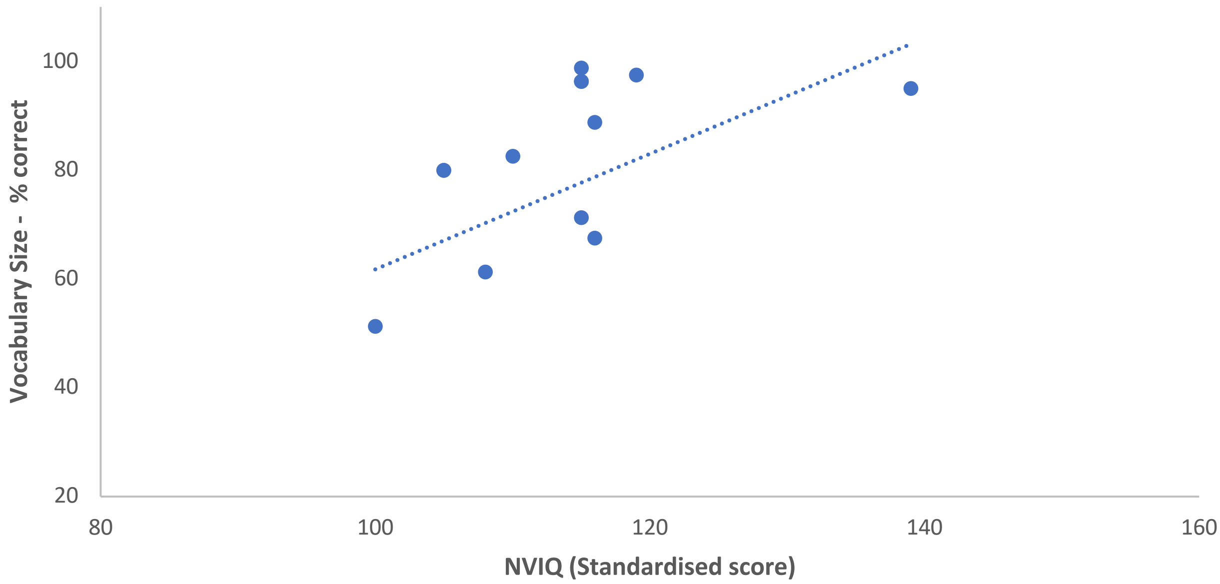


Figure 12. Correlation between NVIQ (x-axis), and Vocabulary Size (y-axis) in deaf adult readers of English.

6.1.1.1.3. **Materials**

Word targets

A total of 160 words were selected from stimuli used in previous phonological priming experiments by Rastle and Brysbaert (2006) (88 items), Blythe et al, (2017) (24 items), Lukatela et al., (1998) (12 items), and Lukatela & Turvey (2000) (7 items); see Appendix C for full list.

The word length was 4-6 letters (M = 4.4, SD = 0.79). The mean of word frequency per million in the N-watch database (Davis, 2005) was 115.77 (range: 1.79 - 6981.29, SD = 560.33) and the orthographic neighborhood size was M = 7.30, SD= 0.79 (range= 0-22) (Davis, 2005). Target words had between three phonemes (e.g. cheese, pronunciation: chēz, /t͡ʃiːz/) and five phonemes (e.g. window, win•dow, pronunciation: /ˈwɪndəʊ/), (Mean number of phonemes = 3.47, SD = .59). Each target word could be preceded by one of the following types of prime, (see some examples in Table 4):

1) Itself (repetition priming condition, e.g., cheese – *cheese*).

2) An unrelated pseudoword - which did not have any phonological nor orthographic overlap with the target. The unrelated primes had exactly the same length as their corresponding targets, and the same orthographic neighborhood size (0-15 neighbors, M = 3.26, SD = 2.96, e.g., cheese - *scouil*).

3) A pseudohomophone - sounds same as the target but could differ in one or more graphemes from the target. The pseudohomophone primes were on average longer than the targets (mean number of letters 4.8 vs. 4.4 respectively; $t(159) = -5.73$, $p < .001$), orthographic neighborhood (range= 0-18). Type bigram frequency (from N-watch, Davis, 2005) did not significantly differ from the targets (27.5 vs. 30.1 respectively, $t(159) = 0.95$, $p = .343$) (e.g., cheese -cheeze).

4) An orthographic control pseudoword priming condition; the orthographic control primes had the same length as their corresponding pseudohomophone primes (therefore they are on average longer than the target words). They also had the same orthographic overlap with the target words as the pseudohomophones, orthographic neighborhood (range= 0-20) and type bigram frequency (from N-watch, Davis, 2005) did not significantly differ from the targets (30.6 vs. 30.1 respectively, $t(159) = -0.24$, $p = .810$). Importantly, the type of bigram frequency did not differ between pseudohomophone and orthographic control primes (27.6 vs. 30.6 respectively, $t(159) = -1.25$, $p = .213$, e.g., cheese – cheede). All pseudoword primes were orthographically legal and pronounceable.

Table 4. Examples of word targets with their prime conditions (pseudohomophone, orthographic control, repetition and unrelated).

No. of shared graphemes	**Target**	Pseudohomophone	Orthographic control	Repetition	Unrelated
2	**SET**	cet	fet	set	mut
1	**PHASE**	faze	yade	phase	gnond
0	**USE**	yuice	douke	use	ach

Pseudoword targets

A total of 160 pseudowords were used in this experiment. Ninety-four pseudowords targets were obtained from Rastle and Brysbaert (2006), and 66 pseudoword targets were generated using Wuggy (Keuleers & Brysbaert, 2010) as they were not listed in the original articles. The total of 160 pseudoword targets did not differ in length to target words, (M = 4.36 vs 4.38, range = 3-6, $t(159) = 0.23$, $p = .817$). The neighborhood size was also similar (words: M = 7.3, range = 0-22, pseudowords: M = 6.5, range = 0-20, $t(159) = -1.50$, $p = .134$).

Pseudoword targets could be preceded by themselves, an unrelated pseudoword a pseudohomophone or an orthographic control. There were only 80 pseudohomophone and 80 orthographic control primes for the pseudowords. Therefore, half of the pseudowords targets were preceded by a pseudohomophone prime and half by an orthographic control prime. See list of the stimuli in Appendix C.

6.1.1.1.4. **Procedure**

Participants were tested individually in a quiet room at the University College London, Deafness Cognition and Language Centre (DCAL). A MacBook (Retina, 12-inch, Early 2015) was used to display the stimuli. All stimuli were presented in a high-resolution monitor (2304x1440) that was placed slightly below eye level, 85-90cm in front of the participant. PsychoPy (Peirce, 2007) software written in Python was used to present the stimuli and to save the outputs of the experiment. Stimuli were presented in the centre of the screen in white Courier New font with a dark grey background. Figure 10 shows the sequence of events in each trial.

First, the participant saw a pattern mask (a series of #s matched with the length of the target) for 500ms, followed by a lowercase target stimulus was presented in 8-pt Courier New font for 33.3ms. Then, a lower-case prime in 12-pt Courier New font was displayed for 50ms, a blank screen was presented for 50ms and finally, the target (either a word or pseudoword) was presented in 12-pt Courier New until participant's response or a maximum of 2500ms. Then a blank screen of random duration (between 700 and 1000ms) ended the trial. Participants were asked to respond as quickly and as accurately as possible if the target stimulus was a word or not. They were asked to press one key for “Yes” and another key for “No”. The hand used to respond was counterbalanced across participants. RTs were measured from target onset until participant's response. Participants were randomly assigned to one of the four counterbalanced lists. The sequence of the stimuli was randomized for each participant. Before the experiment began participants completed sixteen practice trials with stimuli not used in the experimental trials. The experiment lasted 10 minutes.

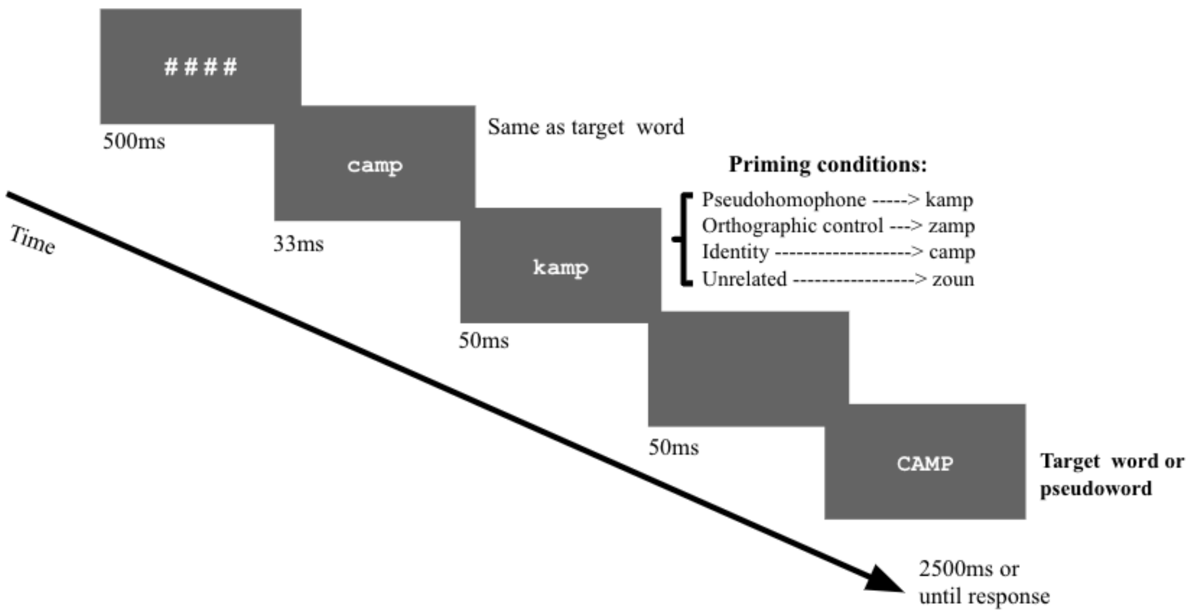


Figure 13. Description of events in a Sandwich Masked Priming trial and experimental conditions for adult readers of English.

6.1.1.2. Results – deaf adult readers of English

Accuracy for all items (n=160) was above 78.6% (Mean = 97.5%, SD = 4.9). All the items were included in the analyses. Separate paired-samples *t*-tests were performed contrasting the two conditions of interest for both the identity and the phonological priming effects. These *t*-tests were conducted over the subjects (t_1) and item (t_2) scores per condition. The RT analysis was performed only on correct trials of word targets. In order to evaluate all four conditions in contrast to each other, further analyses using repeated measures ANOVA were performed and included in Appendix D. These results confirmed the pattern of the findings reported here.

6.1.1.2.1. Lexicality effect, Repetition and Phonological masked priming effects

Lexicality effect - Separate paired-samples *t*-tests for the RTs and the accuracy data showed that responses to words were significantly faster (752.58ms vs 970.44ms); $t_1(13) = -5.98$, $p < .001$; $t_2(318) = -14.78$, $p < .001$, and more accurate (98% vs 88%); $t_1(13) = 3.72$, $p = .003$; $t_2(318) = 7.04$, $p < .001$, than responses to pseudowords.

Repetition masked priming effect - Separate paired-samples t-tests for the RTs and the accuracy data showed that responses were faster in the identity than in the unrelated condition (714.04ms vs. 768.25ms); $t_1(13) = -4.95$, $p < .001$; $t_2(159) = -4.28$, $p < .001$. There was no significant difference in accuracy (98% vs 97%); $t_1(13) = .82$, $p = .425$; $t_2(159) = .47$, $p = .634$ (see Table 5).

Phonological masked priming effect - To test the effect of masked phonological priming, paired-samples *t*-tests including the pseudohomophone and the orthographic control prime conditions were performed separately for the RTs and the accuracy data (see Table 5 and Figures 14 and 15).

Analysis on the RTs showed that participants were faster to respond to targets preceded by pseudohomophone primes than preceded orthographic control primes in the analysis by subject; (751.70ms vs 776.35ms); $t_1(13) = -2.18$, $p = .048$; $t_2(159) = -1.39$, $p = .166$.

Analysis on the accuracy data showed that participants were more accurate for the pseudohomophone than for the orthographic control condition (98% vs. 96% correct); $t_1(13) = 2.47$, $p = .028$; $t_2(159) = -1.39$, $p = .055$.

Table 5. Mean lexical decision times (RTs in ms, upper quadrants), and percentage accuracy (lower quadrants) for each experimental condition: Identity and Unrelated primes (left), and Pseudohomophone and Orthographic control primes (right), in deaf adult reader of English.

	Repetition Effect	**Phonological Effect**	
	RT	RT	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
Identity primes	714.04 (217.89)	751.69 (202.77)	Pseudohomophone primes
Unrelated primes	768.24 (206.57)	776.35 (216.11)	Orthographic control primes
difference	**-54.21*** **	**-24.65***	**difference**
	Accuracy	Accuracy	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
Identity primes	98% (2.3)	98% (2.2)	Pseudohomophone primes
Unrelated primes	97% (2.7)	96% (4.1)	Orthographic control primes
difference	**1%**	**2%**	**difference**

* $p < .05$, ** $p < .01$, *** $p < .001$

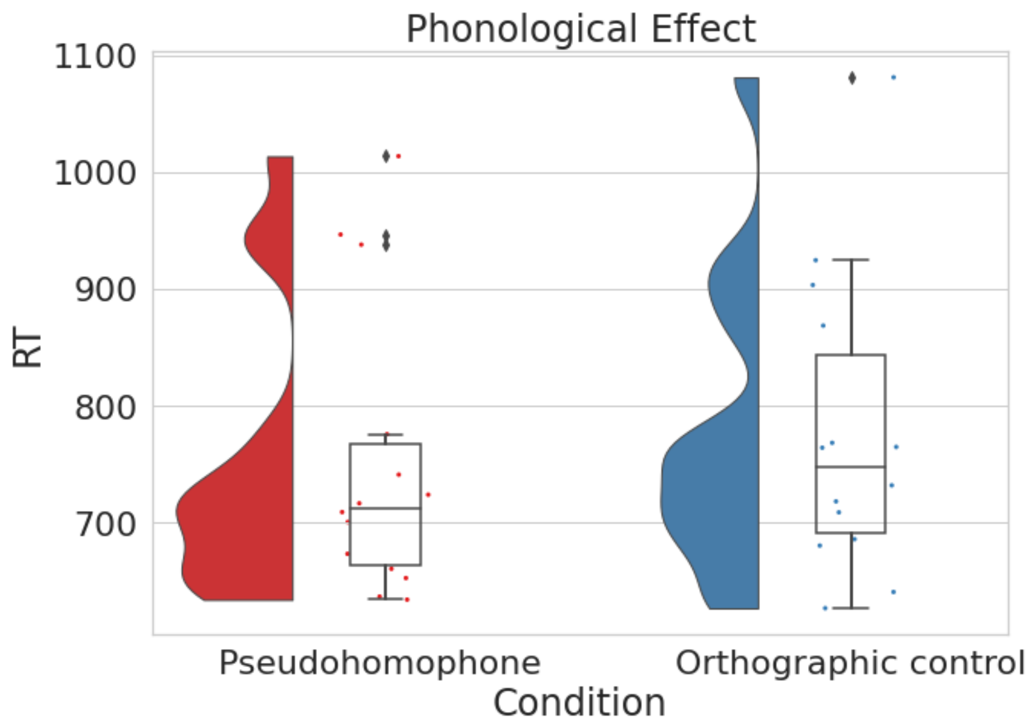


Figure 14. Response times (RT) for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in deaf adult readers of English.

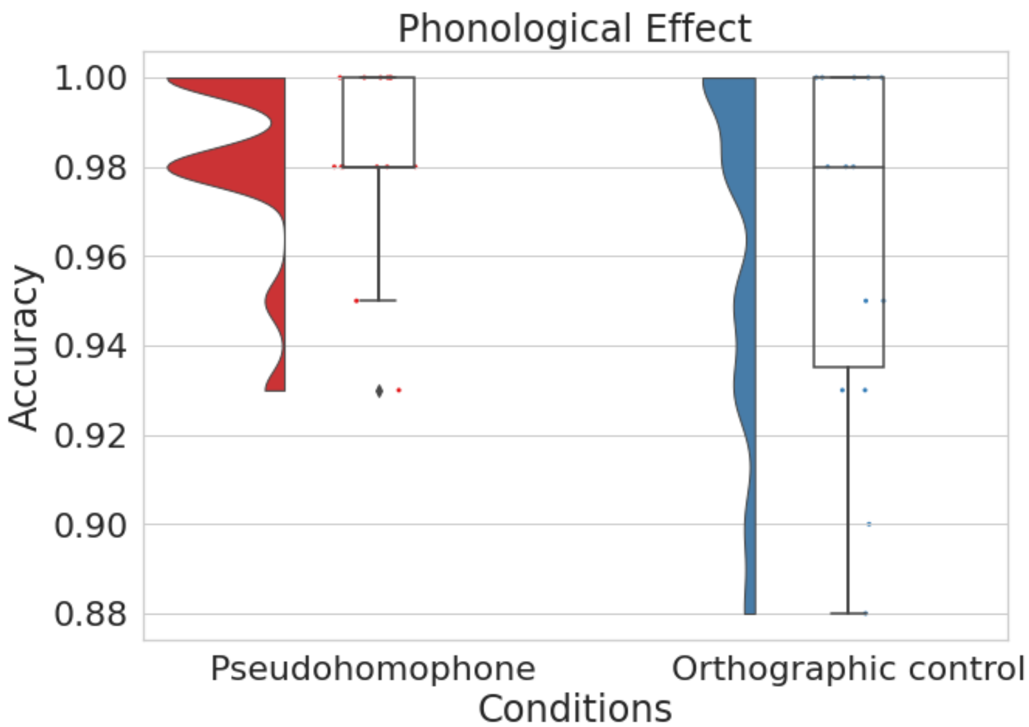


Figure 15. Accuracy of correct responses for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in deaf adult readers of English.

Correlations between offline behavioural measures to masked priming effects

Correlations between the size of phonological priming effects and offline behavioural measures are shown in Table 6. The masked phonological priming effects was measured as the difference in RTs and accuracy between the pseudohomophone and orthographic control conditions. A negative correlation was found between the size of the masked phonological priming effect in accuracy and the vocabulary test (See Figure 16). The larger the vocabulary, the smaller the size of the phonological effect (the difference in errors between pseudohomophones and orthographic control). This suggests that deaf adult readers of English with a large vocabulary size make less use of phonology during SWR than readers with a smaller vocabulary.

Table 6. Correlations with offline behavioural measures and the size of the masked phonological priming effect in RT (left) and accuracy (right), in deaf adult readers of English.

Offline measures		Size of the masked phonological priming effect in:	
		RT	Accuracy
Sentence Reading. (% correct)	r	.26	-.50
	p	.361	.067(+)
Speechreading Ability Test (% correct)	r	.37	-.55
	p	.215	.054(+)
Vocabulary Test (# correct answers; max = 80)	r	.25	-.58*
	p	.420	.036
Fingerspelling Ability Test (% correct)	r	.36	.07
	p	.245	.819
Rhyme judgement task (% correct)	r	-.02	.25
	p	.952	.405

*(+) p < .07, * p < .05, ** p < .01, *** p < .001*

Note . Size of the masked phonological priming effect (in RT and Accuracy) = Phonological - Orthographic control condition.

After Bonferroni correction no correlations were significant.

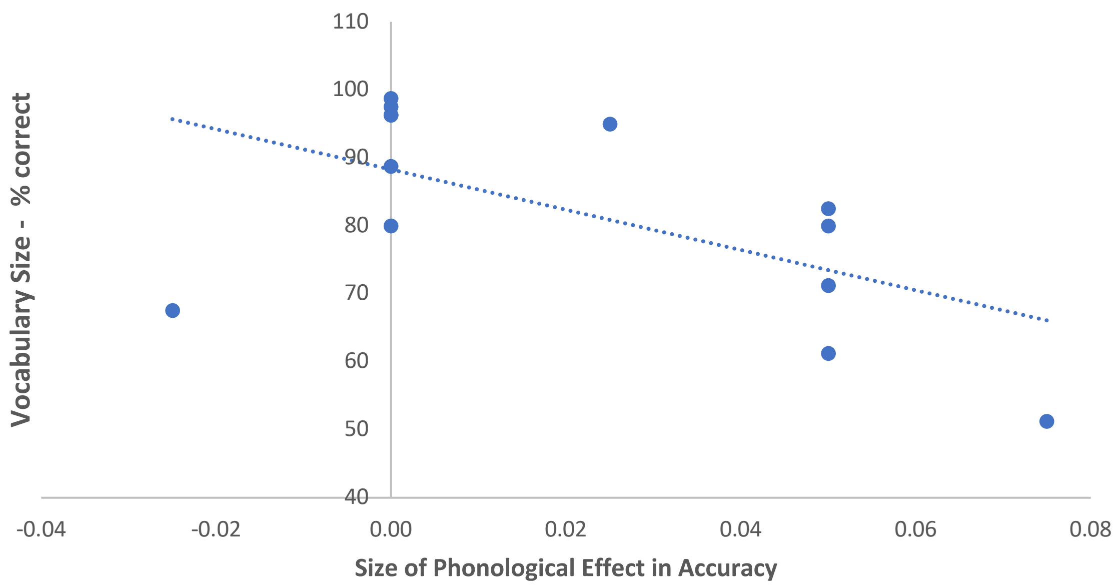


Figure 16. Correlation between and the Size of the masked Phonological Priming Effect (x-axis) in accuracy, and Vocabulary Size (y-axis) in deaf adult readers of English.

6.1.2. Adult deaf readers of Spanish

Given the transparency of written Spanish, in contrast to written English, here we examine the role of phonological processing in deaf adult readers of Spanish. The same sandwich masked phonological priming paradigm is used as in Experiment 1. The same experimental design used for adult deaf readers of English (Experiment 1, section 6.1.1.) was used here. In order to further investigate whether deaf readers use phonological codes automatically to recognise words, we tested adult and adolescent readers of Spanish, a language with a shallower orthography than English. As before, we investigated whether a larger phonological priming effect was corelated to reading, speechreading and fingerspelling skills in both adult and developing readers.

6.1.2.1. Methods

6.1.2.1.1. Participants

Sixteen deaf adults (9 female) participated in this Experiment no. 2. All participants were profoundly or severely deaf from birth. Their ages ranged from 21.7 to 61.4 years (M = 31.18, SD = 9.73). Five participants were native signers of Mexican Sign Language (*Lengua de Señas Mexicana:* 'LSM'), one participant was an early signer (AoA between 3 and 9 years old), and ten participants learnt LSM after the age of 9. Ten participants were fluent signers of LSM (self-ratings 6-7, in a 1-7 Likert scale) and used LSM as their preferred means of communication in their daily lives. Four participants rated their LSM proficiency at 4 and reported using LSM with friends and Spanish with their families. One participant rated her LSM proficiency at 2 and reported using Spanish as her preferred language. This study was approved by the University College London Research Ethics Committee (Project ID Number 10991/001). Instructions were given in LSM) and in written Spanish. Participants were asked to provide written consent at the beginning of the sessions, and they were told that they could withdraw at any time of the session if they would like to.

6.1.2.1.2. Offline behavioural measures

The reading skills were measured with a reading comprehension test ('Prueba de Lectura y Lenguaje Escrito', PLLE; Hammill et al., 1982) and a sentence reading test

(‘Test Colectivo de Eficacia Lectora’ TECLE; Carrillo and Marin, 1997). These test different aspects of reading. Whilst the TECLE requires the ability to select a word that fits in the sentence among three other distractors, the PLLE test provides a measure of a more complex semantic and syntactic reading comprehension. The vocabulary size of the participants was measured with the WISC-IV vocabulary subtest. The ‘Speechreading Ability Test’ and the ‘Fingerspelling Ability Test’ were adapted to Spanish from the English version (See section above, ‘6.1.1.1.2.). The ‘Phonological processing task’ was a syllable counting task. The characteristics of each of these tests are described below. Participants also completed TONI- 2 (Brown et al., 1990) non-verbal IQ test (see above section 6.1.1.1 Methods). All adult deaf readers of Spanish had non-verbal IQ over 85 and none of them reported other disorders or learning disabilities.

Reading comprehension

Reading comprehension was measured using the “Paragraphs comprehension” subtest of the “Prueba de Lectura y Lenguaje Escrito” (PLLE; Hammill et al., 1982) which is an adapted to Spanish version of the Test of Reading Comprehension (TORC; Brown, Hammill & Wiederholt, 1978). Participants were asked to read a total of eight short stories. After each story, they were required to answer five comprehension questions by selecting the best of four options. The reading comprehension test lasted from 15-20 minutes. The percentage of accurate responses was reported (M = 68%, SD = 15.1, see Table 7). The average percentage of correct responses was used for the correlations (See Table 8).

Sentence reading

A standardised Spanish test ("Test Colectivo de Eficacia Lectora" TECLE; Carrillo and Marin, 1997) was used to measure reading ability at the sentence level. This test has been used in studies with hearing (Abusamra et al., 2010; Bravo et al., 2004; Carrillo et al., 2011; Cuadro and Marín, 2007; Ferreres et al., 2011), and deaf readers of Spanish (Domínguez & Alegria, 2010; Gutierrez-Sigut et al. 2017). The TECLE contains 64 incomplete sentences of increasing syntactic, semantic and orthographic complexity. The participant's task is to select one of the four options: 1) the correct word, 2) a pseudoword phonologically similar to the correct, 3) a pseudoword orthographically similar to the correct and, 4) a semantically incorrect word (e.g. in Spanish: '*Tu pelota es de color____: rogo, roco, robo, rojo*', in English: The colour of your ball is____: ret, reb, ref, red). The scores are reported in percentage accuracy (M = 89%, SD = 10.4, see Table 7). Participants were asked to respond as quickly as possible, as the test had a total duration of 5 minutes.

Vocabulary Test

We used the vocabulary subtest of the WISC-IV (Wechsler, 2004) standardized for Mexican, to measure vocabulary size in deaf people. This test measures the level of knowledge of words and their ability to describe the meaning of the words. The task requires the participant to produce either in Sign or Spoken Language as accurately as possible the meaning of a series of words. Of the 36 items, 4 are presented in pictures and 32 in written Spanish. The task difficulty increases throughout the test. The WISC-IV has been previously used with deaf and hard of hearing participants (Krouse & Braden, 2011). The instructions of the test can be given in sign or spoken language and, participants can also give their responses in either modality, (e.g., sign or spoken language, see Kyle et al., 2017), making this test more appropriate to use with deaf participants. Of the 16 participants (female = 9), 12 answered in LSM, 3 in sign supported Spanish (i.e., syntax from spoken Spanish while simultaneously signing) and one in Spanish. The vocabulary test lasted from 5-10 minutes. The scores are reported in percentage accuracy (M = 71%, SD = 18.3, see Table 7).

Phonological processing task (syllable counting)

Participants completed a syllable counting task on a sequence of highly consistent and highly inconsistent words on their phonological and orthographic structure (see Gutiérrez-Sigut et al., 2018 for further details). The consistent words were a) 5 letter, 2 syllable words (e.g. *gra.do*, grade) or b) 7 letter, 3 syllable words (e.g. *mi.nu.tos*, minutes). The inconsistent words: a) 5 letter, 3 syllable (e.g. *a.mi.go*, friend) or b) 7 letter , 2 syllable words (e.g. *cien.cia,* science). An index was computed of the degree to which orthographic or visual factors (i.e., word length), influenced the participant's response during the online syllabification. The index was calculated and reported as follows: the percentage of accurate responses for consistent words minus percentage of inconsistent words (M = 17, SD = 15.44). The higher the number, the more biased the processing of the visual characteristics of the words (i.e., higher accuracy for visually consistent words).

Speechreading Ability Test

The Everyday questions' extension of the "Test of Child Speechreading" (ToCS, Kyle et al., 2013) was adapted to Spanish. The same 12 questions were adapted from English to Spanish, we tried to keep a similar length for each question, and the exact meaning (See the everyday questions of the ToCS in English and Spanish, in Appendix no. E). The model was a Mexican native speaker, during the recording the model was asked to speak normally. Participants watched silent videos (n =12) of a person asking everyday questions (e.g., *What is your name?* In Spanish: *¿Cuál es tu nombre?).* The characteristics of the test and the scoring are described in section (6.1.1.1.2. Offline behavioural measures – Speechreading Ability Test). Of the16 participants (female = 9), 12 answered in LSM, 3 in sign supported Spanish (i.e., syntax from spoken Spanish while simultaneously signing) and one in Spanish. The percentage of accurate responses was reported (M = 64%, SD = 26.1, see Table 7).

Fingerspelling Ability test

The fingerspelling ability test in Spanish words with LSM alphabet, followed the same characteristics (e.g. lexical frequency, and length) of the original version in English with the BSL alphabet (see 6.1.1.1.2. Offline behavioural measures – Fingerspelling Ability test). Thirty words were selected from the Mexican lexical database "Lexmex" (Silva-Pereyra et al., 2014). The words were presented in a short clip by a skilled LSM signer, their length was increasing, and their frequency was decreasing; making them longer and less common throughout the test (see list of words in the Appendix B). The aim of the test was to measure the participants' fingerspelling receptive skills. Participants saw a video of a fingerspelled word, then a black blank screen appeared on the screen indicating a pause. During this interval, participants were requested to reproduce either in sign or spoken language the fingerspelled word (total words = 30). The scores were reported in percentage accuracy (M = 86%, SD = 20.9, See Table 7). The test lasted approximately between 5 to 10 minutes maximum.

Table 7. Participants' characteristics and test scores of the deaf adult readers of Spanish.

	Mean (SD)	**Range**
Age (Yrs, mths.)	31,2 (9.7)	(21,7-61,4)
Reading Comprehension (% correct)	68% (15.1)	(50%-87.5%)
Sentence Reading (% correct)	89% (10.4)	(68.8%-100%)
Vocabulary Test (% correct)	71% (18.3)	(45.6%-98.5%)
Phonological Processing (visual bias index)	17 (15.44)	(-5- 44)
Speechreading Ability Test (% correct)	64% (26.1)	(17.5%-98.3%)
Fingerspelling Test (% correct)	86% (20.9)	(30%-100%)
NVIQ (Standardised score)	110.43 (10.4)	(93-125)

A correlation analyses was run among the offline behavioural measures, in order to better describe the sample of participants, correlations between the off-line measures were calculated (see Table 8). All the significant correlations found between the behavioural measures are shown in the following Figures: 17-23. Significant correlations were found between, reading and vocabulary (see Figure 17), and reading and speechreading ability (see Figure 18).

Table 8. Correlations between offline behavioural measures in deaf adult readers of Spanish.

	Reading Comprehension	Vocabulary Test	Phonological Processing (visual bias index)	Speechreading Ability Test	Fingerspelling Test	NVIQ
Sentence Reading	.64*	.72**	-.54*	.64**	.25	-.03
Reading Comprehension		.69**	-.48	.75**	.37	.05
Vocabulary Test			-.71**	.67**	.53(+)	-.18
Phonological Processing				-54*	-.62*	-.23
Speechreading Ability Test					.43	-.20
Fingerspelling Test						.31

*(+) p < .06, *p < .05, **p < .01, *** p < .001*

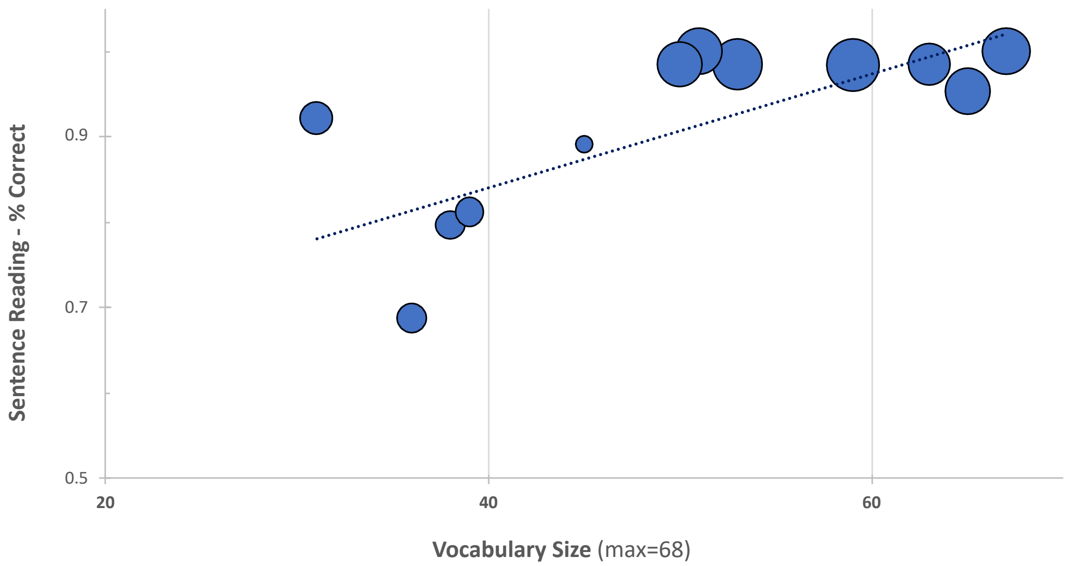


Figure 17. Correlation between Vocabulary Size (x-axis), Sentence Reading (y-axis), and Reading comprehension (bubble width), in deaf adult readers of Spanish.

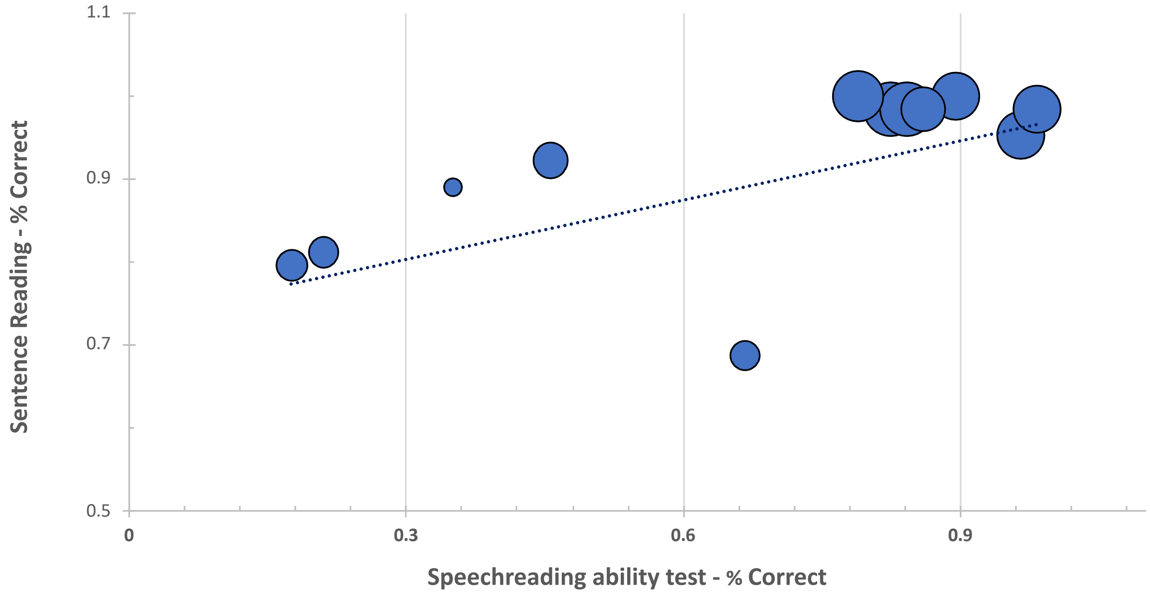


Figure 18. Correlation between Speechreading Ability Task (x-axis), Sentence Reading (y-axis), and Reading comprehension (bubble width), in deaf adult readers of Spanish.

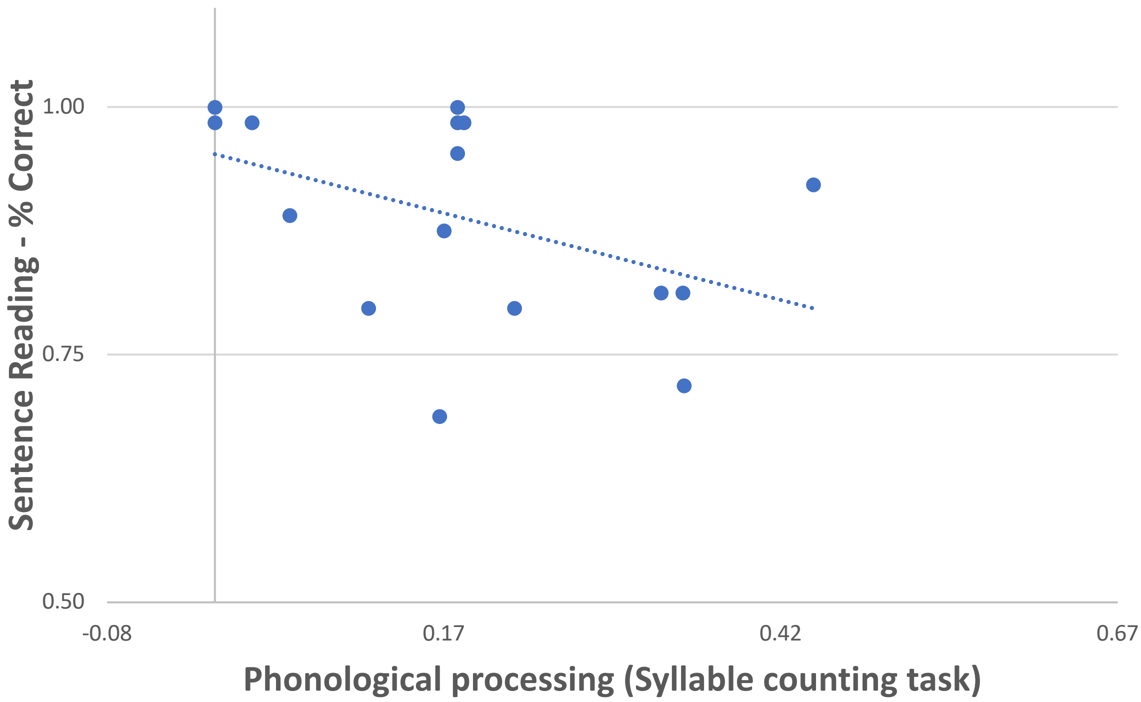


Figure 19. Correlation between Phonological processing (Syllable counting, x-axis) and Sentence Reading (y-axis) in deaf adult readers of Spanish.

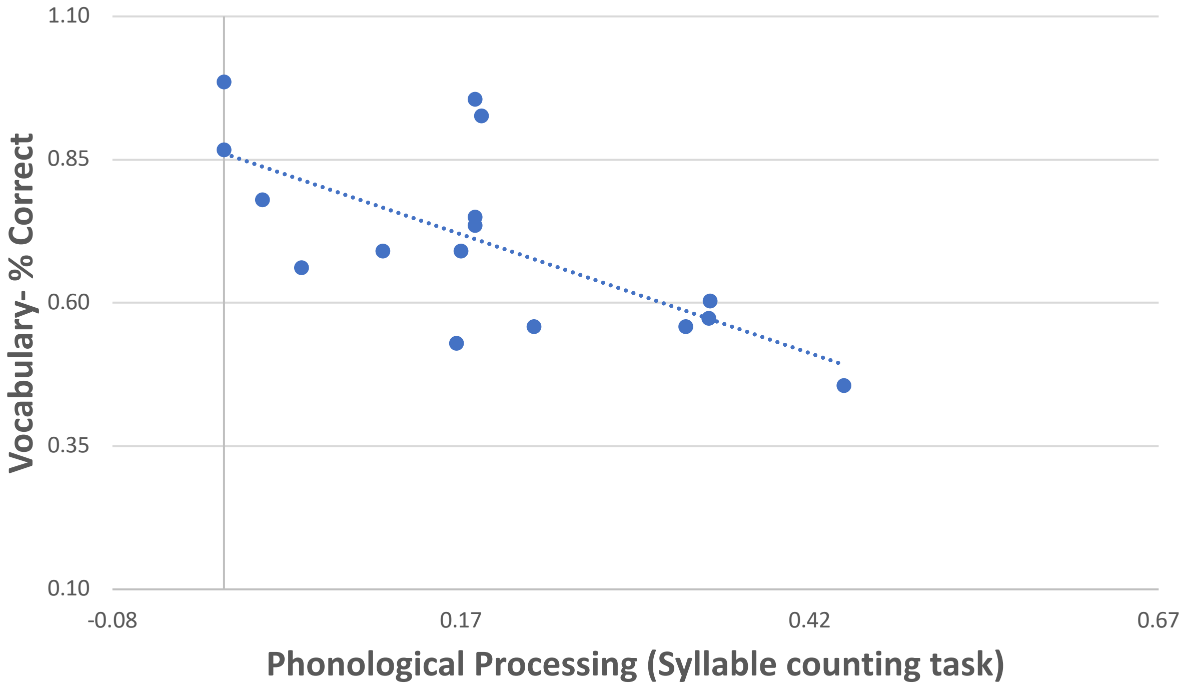


Figure 20. Correlation between Phonological processing (Syllable counting, x-axis) and Vocabulary (y-axis) in deaf adult readers of Spanish.

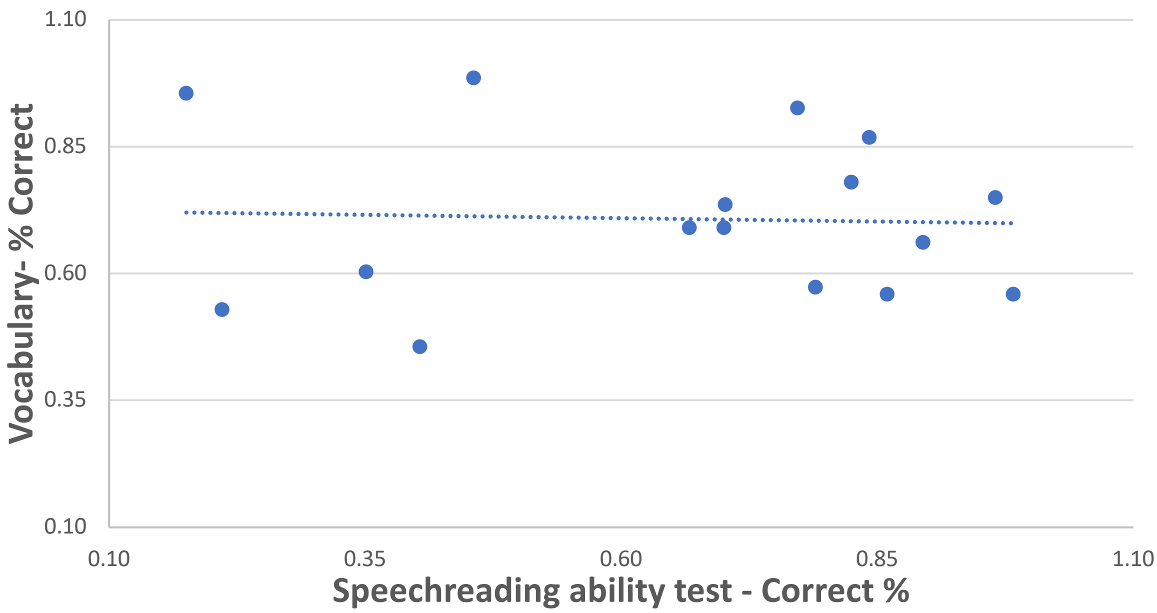


Figure 21.Correlation between Speechreading ability test (x-axis) and Vocabulary (y-axis) in deaf adult readers of Spanish.

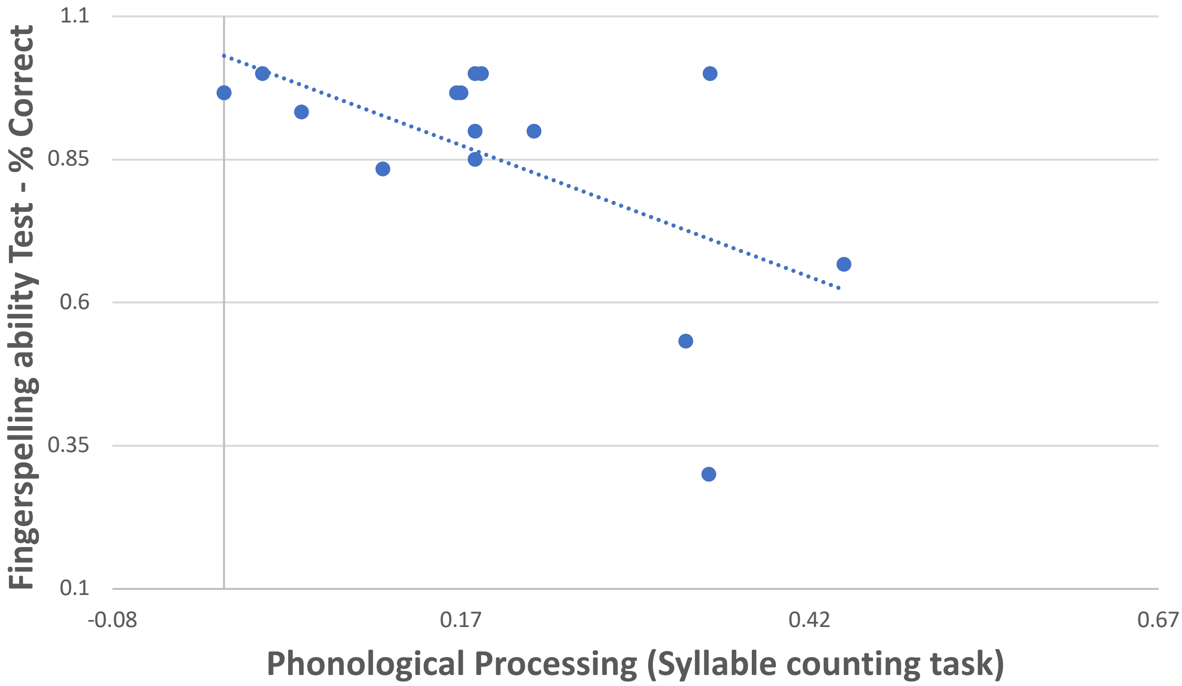


Figure 22. Correlation between Phonological processing (Syllable counting, x-axis) and Fingerspelling (y-axis) in deaf adult readers of Spanish.

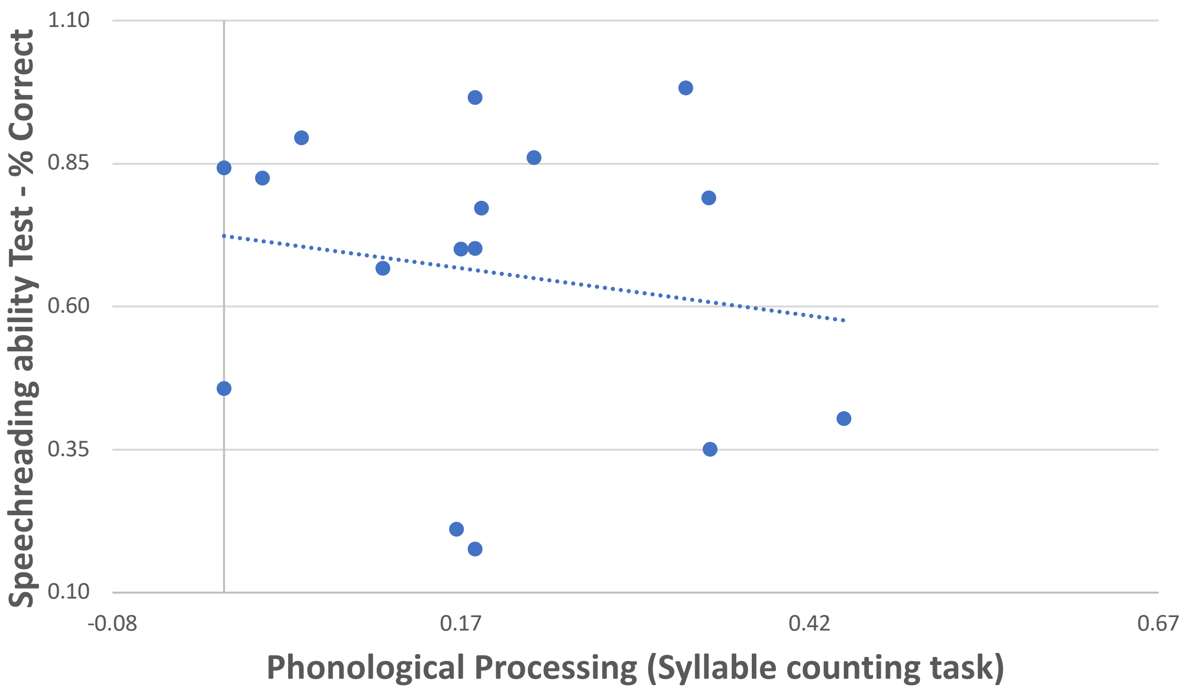


Figure 23. Correlation between Phonological processing (Syllable counting, x-axis) and Speechreading (y-axis) in deaf adult readers of Spanish.

6.1.2.1.3. **Materials**

One hundred and sixty words and 160 matched pseudowords were used in this experiment. The stimuli were used in a similar experiment with deaf adults (Gutierrez-Sigut et al., 2017) and hearing children (mean age = 9.94, SD = 0.41; Comesaña et al., 2016). The characteristics of the words (length, frequency, syllable structure) were found in the Mexican lexical database “Lexmex” (Silva-Pereyra et al., 2014). Only two words were replaced due to extremely low frequency in Mexican Spanish; catarro, and bañador were replaced by: capilla and balazos. The mean of word frequency per million in the Lexmex database was 52 (range: 0.40–744.51, SD = 101.43). Each word and pseudoword was between four and seven letters long (M = 5.51, SD = 1.1). None of the pseudowords were replaced.

The target words were preceded by one of four possible primes:

1) The same as the target, (e.g., copa-COPA, identity condition);

2) a pseudoword in which the first letter was replaced by another letter with the same sound (e.g., kopa-COPA, pseudohomophone condition),

3) a pseudoword in which the first letter was replaced by a letter matched in shape (ascending, descending or neutral) to the one used in the pseudohomophone condition (e.g., lopa- COPA, orthographic control condition), and,

4) a pseudoword unrelated to the target (e.g., bugo-COPA, unrelated condition).

The manipulation of the prime-target relationship was the same for words and pseudowords. The set of stimuli can be found in Appendix F. Four counterbalanced lists of materials were constructed in a Latin-square type. Therefore, each target appeared once in each list, but its prime was different across the four lists. For example, if a target word was preceded by the identity prime condition in “List 1”, then in “List 2” the same target word was preceded by the pseudohomophone prime condition, in “List 3” by the orthographic prime condition, and finally in “List 4” by the unrelated prime condition.

The main goal of this experiment was to investigate the phonological processing of deaf readers. Therefore, the main comparison was between pseudohomophone prime and orthographic control conditions. However, the identity vs unrelated conditions were also compared, in order to have a more detailed view of the phonological effect. The analysis only considers the target words, this is because pseudowords usually show extremely small masked priming effects.

6.1.2.1.4. **Procedure**

Participants were tested individually in a quiet room at school. A MacBook (Retina, 12-inch, Early 2015) was used to display the stimuli using PsychoPy (Peirce, 2007), software written in Python which was used to present the stimuli and to save the outputs of the experiment. The procedure followed was the same as in Experiment 1. Figure 24 shows the sequence of events in each trial.

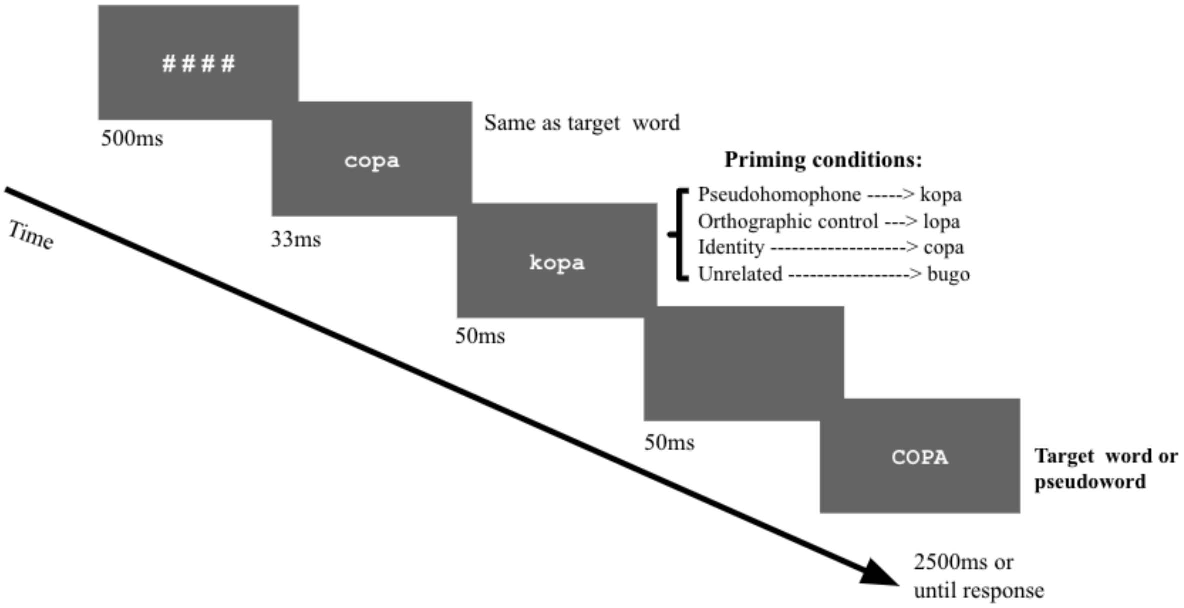


Figure 24. Depiction of events in a Sandwich Masked Priming trial and experimental conditions for adult readers of Spanish.

6.1.2.2. Results - deaf adult readers of Spanish

Responses to items were considered above chance level when their accuracy was >58% and those responses were included in the analysis. This threshold was used because it is slightly above chance (45-55%) but low enough to not penalise or just exclude less skilled readers. This approach has been used traditionally in in previous studies (see MacSweeney et al., 2013) with deaf readers, and it was decided use it in all the experiments of this thesis. In the results of the group of deaf readers of Spanish, six target words were excluded from the analysis as they had less than 58% accuracy overall (See in Appendix F, the list of the stimuli included and excluded from the analyses). The RT analysis was performed only on correct trials of word targets. As in Experiment 1, response times (RTs) and accuracy data were submitted to separate paired-samples t-tests contrasting the two conditions of interest for both the identity and the phonological priming effects. These *t*-tests were conducted over the subjects (t_1) and items (t_2) scores. Additionally, in order to evaluate all four conditions in contrast to each other, further analyses using repeated measures ANOVA were performed and included in Appendix D. These results confirmed the pattern of the findings reported here. The mean lexical decision times and percentage of correct responses per condition are displayed in Table 9.

6.1.2.2.1. Lexicality effect, Repetition and Phonological masked priming effects

Lexicality effect - Responses to target words were faster than for pseudowords targets (805.85ms vs 1003.04ms); $t_1(15) = -2.75$, $p = .015$; $t_2(306) = -12.67$, $p < .001$. There was only a significant difference in accuracy between words and pseudowords in the analyses by-item; (94% vs 88%) $t_1(15) = 1.38$, $p = .189$; $t_2(306) = 5.03$, $p < .001$.

Repetition masked priming effects - Paired-samples *t*-tests showed that the response times were faster in the identity than in the unrelated condition (777.32ms vs. 824.67ms), $t_1(15) = -2.87$, $p = .012$; $t_2(153) = -2.93$, $p = .004$; and that participants were more accurate for the identity than for the unrelated control condition (94.66% vs. 92.01% correct; $t_1(15) = 2.62$, $p = .019$, no difference in the analyses by-item $t_2(153) = 1.41$, $p = .158$.

<u>*Phonological masked priming effects*</u> - To test for the effect of masked phonological priming we performed a paired samples t-test contrasting the pseudohomophone and orthographic control prime conditions (see Table 9).

There was no significant difference in RTs (813.49ms vs 807.93ms); $t_1(15) = 0.29$, $p = .778$; $t_2(153) = 3.64$, $p = .716$; nor in accuracy (93.35% vs. 94.15% correct), $t_1(15) = -0.64$, $p = .532$; $t_2(153) = -.69$, $p = .494$.

Table 9. Mean lexical decision times (RTs in ms, upper quadrants), and percentage accuracy (lower quadrants) for each experimental condition: Identity and Unrelated primes (left), and Pseudohomophone and Orthographic control primes (right), in deaf adult readers of Spanish.

	Repetition Effect	**Phonological Effect**	
	RT	RT	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
Identity primes	777.32 (170.36)	813.49 (209.56)	Pseudohomophone primes
Unrelated primes	824.67 (160.17)	807.92 (167.75)	Orthographic control primes
difference	**-47.35***	**5.56**	**difference**
	Accuracy	Accuracy	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
Identity primes	95% (6.2)	93% (6.9)	Pseudohomophone primes
Unrelated primes	92% (8.5)	94% (6.8)	Orthographic control primes
difference	**3%***	**-1%**	**difference**

* $p < .05$, ** $p < .01$, *** $p < .001$

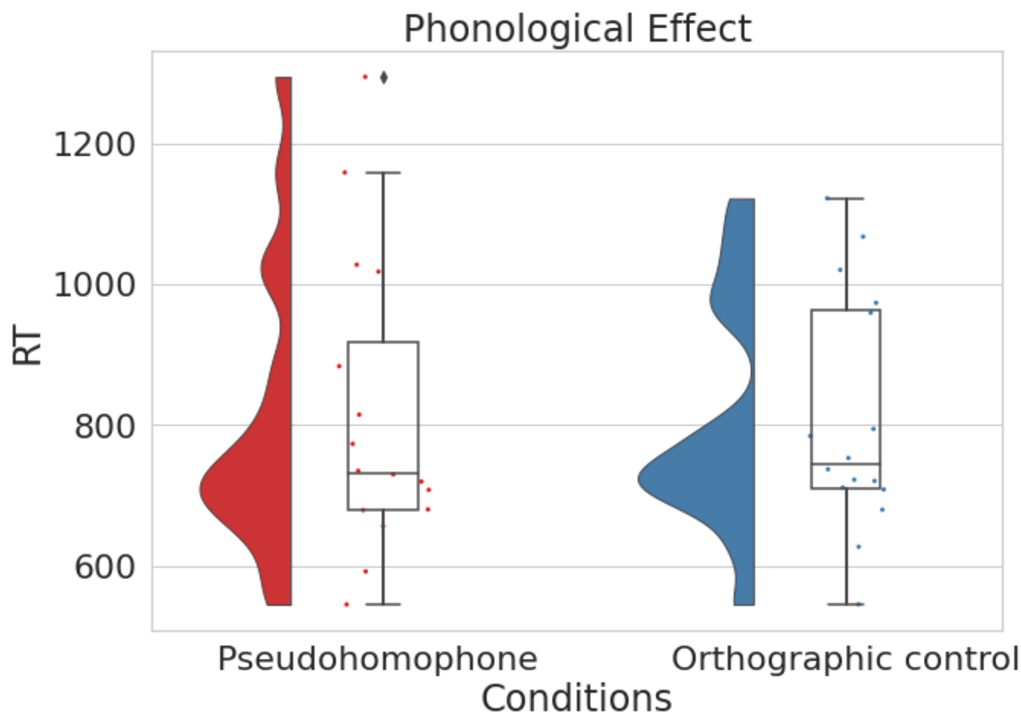


Figure 25. Response times (RT) for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in deaf adult readers of Spanish.

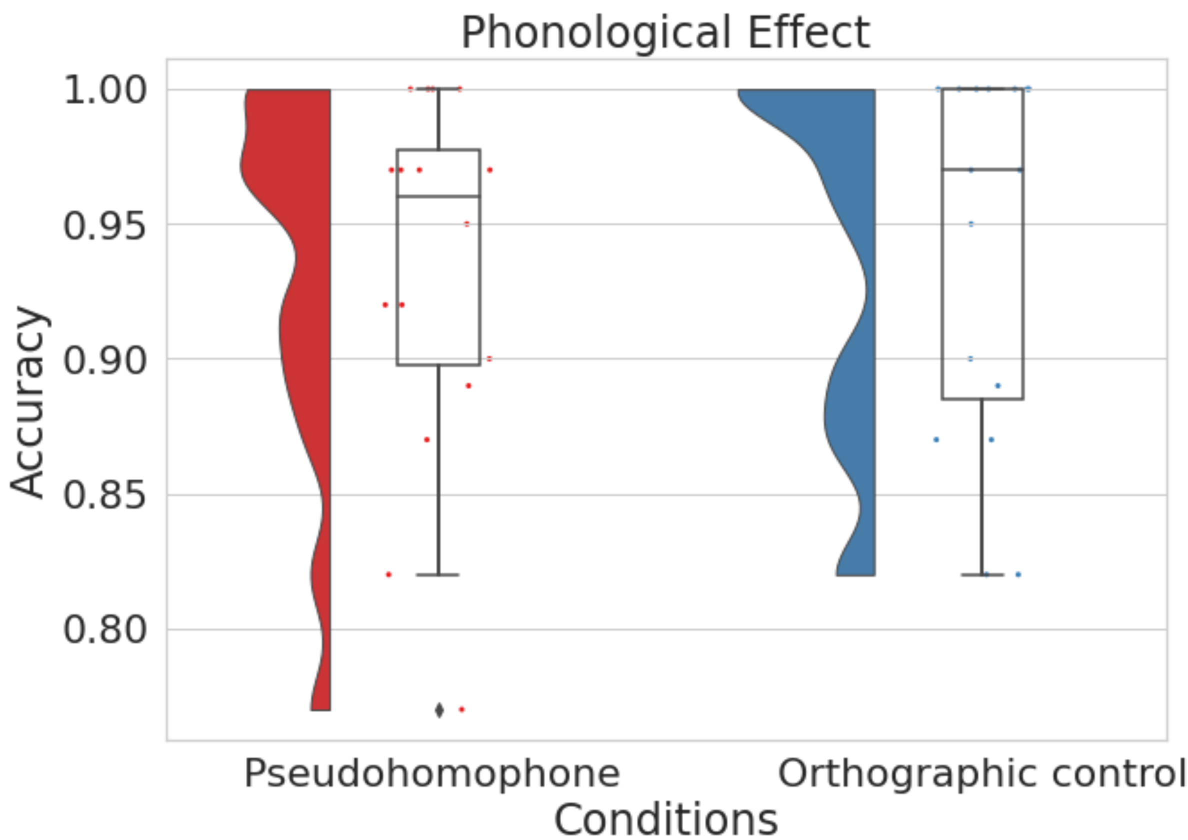


Figure 26. Accuracy of correct responses for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in deaf adult readers of Spanish.

Correlations between offline behavioural measures to masked priming effects

Correlations between the size of the masked phonological priming effects (i.e., difference in RTs between the pseudohomophone and orthographic control condition) and the performance in offline behavioural measures: a) sentence reading, b) reading comprehension, c) speechreading ability and d) vocabulary test, are shown in Table 10. A negative correlation was found between the size of the masked phonological priming effect in RT and fingerspelling (See Figure 27). As this correlation involves RTs (smaller numbers = faster responses) this pattern suggests that better fingerspelling abilities were associated with larger phonological effect on RTs. That is, readers with better fingerspelling abilities seem to use phonology to a greater extent during SWR than those with poorer fingerspelling skills.

Table 10. Correlations with offline behavioural measures and the size of the masked phonological priming effect in RT (left) and accuracy (right), in deaf adult readers of Spanish.

Offline measures		Size of the masked phonological priming effect in:	
		RT	Accuracy
Sentence Reading. (% correct)	r	-.32	-.32
	p	.223	.222
Reading Comprehension (% correct)	r	-.13	-.54
	p	.673	.055(+)
Speechreading Ability Test (% correct)	r	-.27	-0.37
	p	.307	.160
Vocabulary Test (# correct answers; max = 68)	r	-.42	-.50
	p	.135	.067(+)
Fingerspelling Ability Test (% correct)	r	-.66	.08
	p	.008**	.774
Phonological Processing (visual bias index)	r	.25	.40
	p	.383	.153

*(+) p < .07, * p < .05, ** p < .01, *** p < .001*

Note . Size of the masked phonological priming effect (in RT and Accuracy) = Phonological - Orthographic control condition.

After Bonferroni correction no correlations were significant.

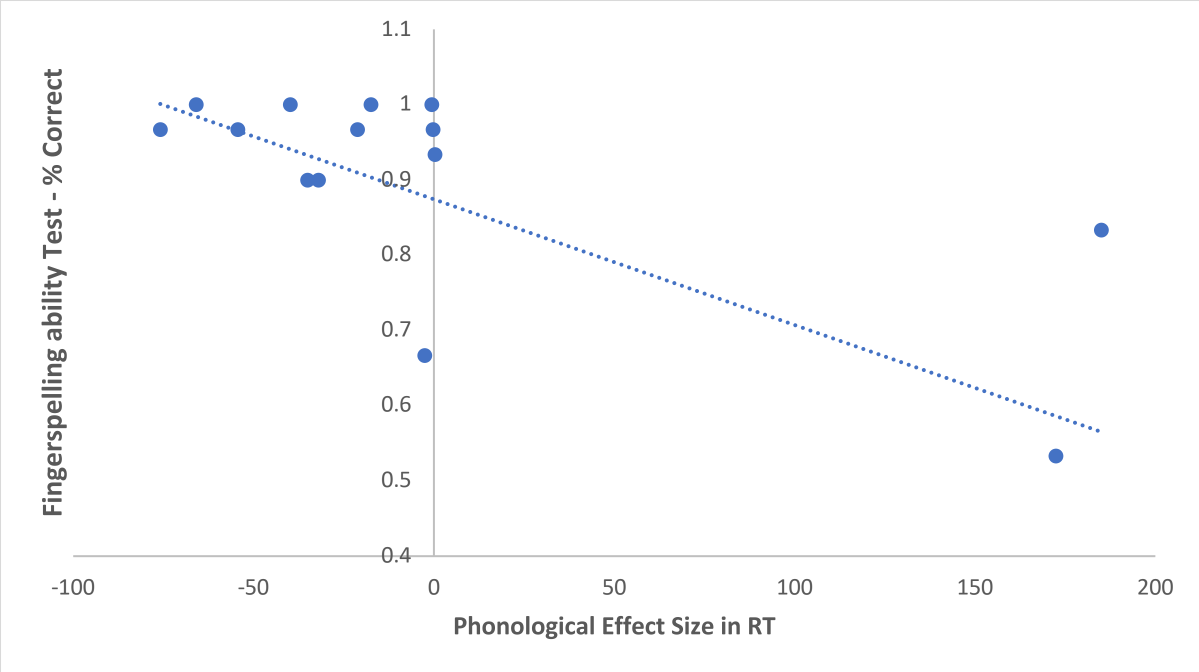


Figure 27. Correlation between the Size of the masked Phonological Priming Effect in RT (x-axis), and Fingerspelling ability Test (y-axis) in deaf adult readers of English.

6.1.3. Young deaf readers of Spanish

It has been shown that developing readers might be more sensitive to phonological information than skilled readers, who might have built stronger direct access to a large number of words (Castles, Rastle and Nation; 2018). Since deaf young readers have different experiences than hearing readers in accessing to phonology, here it was investigated whether young deaf readers of Spanish use phonological information from the pseudohomophone prime condition compared to the prime orthographic control when recognising target words. The research questions and experimental design were the same as the ones used for adult deaf readers of English and Spanish, (see above sections: 6.1.1. and 6.1.2).

6.1.3.1. Methods

6.1.3.1.1. Participants

Sixty-one (25 female) congenitally deaf participants were recruited. All participants were profoundly or severely deaf from birth, did not report history of neurological or psychiatric impairments, and had normal or corrected to normal vision. The data from 6 participants were discarded, because they did not meet the inclusion criteria (non-verbal IQ below 85 and score categorized as deficient reading at the reading comprehension test). Of the remaining 55 participants (20 female, Age mean = 16.5, SD = 2.8), ten were native signers of Mexican Sign Language (*Lengua de Señas Mexicana:* 'LSM'). Thirty-seven had learned LSM from teachers and friends before the age of 9, and nine learned LSM between 12 and 15 years old. Participants rated their MSL skills (Likert scale from 1 to 7). Twenty-one participants considered themselves skilled signers (self-ratings = 6-7), twenty-eight medium skilled (self-ratings = 4-5) and seven with poor sign skills (self-ratings < 4). Thirty-four participants were in secondary school (i.e. year 7 to 9, year one starts at 6 years old) and twenty-two participants were in high school (i.e. year 10 to 12). All participants reported to have always attended mainstream schools and all of them received literacy training on a phonological (i.e., syllabic) method. This study was approved by the University College London Research Ethics Committee (Project ID Number 10991/001). Parental consent was obtained for participants younger than 18 years old. Participants older 18 years old they were asked to provide written consent at the beginning of the sessions. Instructions were given in LSM and in written Spanish.

6.1.3.1.2. **Offline behavioural measures**

The offline behavioural measures were the same as the ones used with the adult deaf readers of Spanish. Therefore, the young deaf readers were tested on: Reading comprehension, Sentence reading, Vocabulary, Speechreading, Fingerspelling and Phonological processing. The description of the offline behavioural tests can be found in section: '6.1.2.1.2 Offline behavioural measures. See participant's performance Table 11. In Table 12 and Figures 28 - 35 a pattern of correlations between these offline behavioural measures is showed.

Table 11. Participants' characteristics and test scores of the young deaf readers of Spanish.

	Mean (SD)	**Range**
Age (Yrs, mths.)	16,5 (2.8)	(11,6-21,7)
Reading Comprehension (% correct)	42% (18.9)	(10%-82.50%)
Sentence Reading (% correct)	62% (19)	(17%-100%)
Vocabulary Test (% correct)	45% (14)	(18%-78%)
Phonological Processing (visual bias index)	22 (21)	(-44.4 - 50)
Speechreading Ability Test (% correct)	20% (20.8)	(2%-86%)
Fingerspelling Test (% correct)	75% (18.4)	(33%-100%)
NVIQ (Standardised score)	116.58 (13.6)	(88-144)

Table 12. Correlations between offline behavioural measures in young deaf readers of Spanish.

	Reading Comprehension	Vocabulary Test	Phonological Processing (visual bias index)	Speechreading Ability Test	Fingerspelling Test	NVIQ
Sentence Reading	.69***	.69***	.12	.59***	.73***	.31*
Reading Comprehension		.67***	.02	.58***	.74***	.45***
Vocabulary Test			.06	.63***	.51***	.43***
Phonological Processing				-.08	.14	.19
Speechreading Ability Test					.51***	.20
Fingerspelling Test						.39**

p* < .05, ***p* < .01, * *p* < .001*

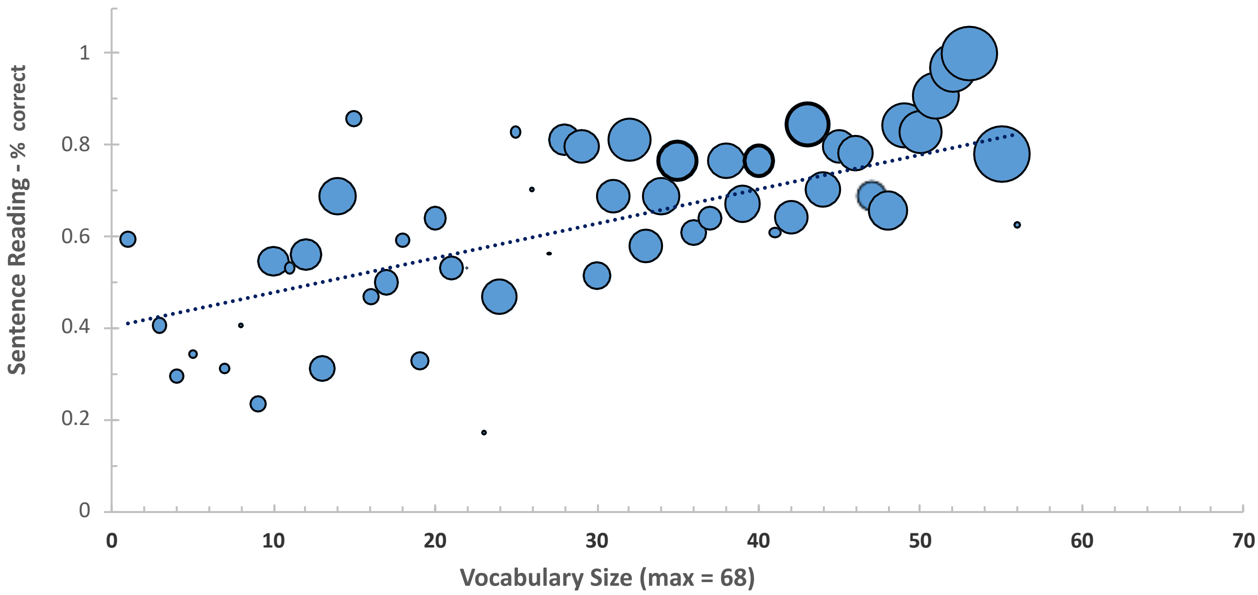


Figure 28. Correlation between Vocabulary Size (x-axis), Sentence Reading (y-axis), and Reading comprehension (bubble width), in young deaf readers of Spanish.

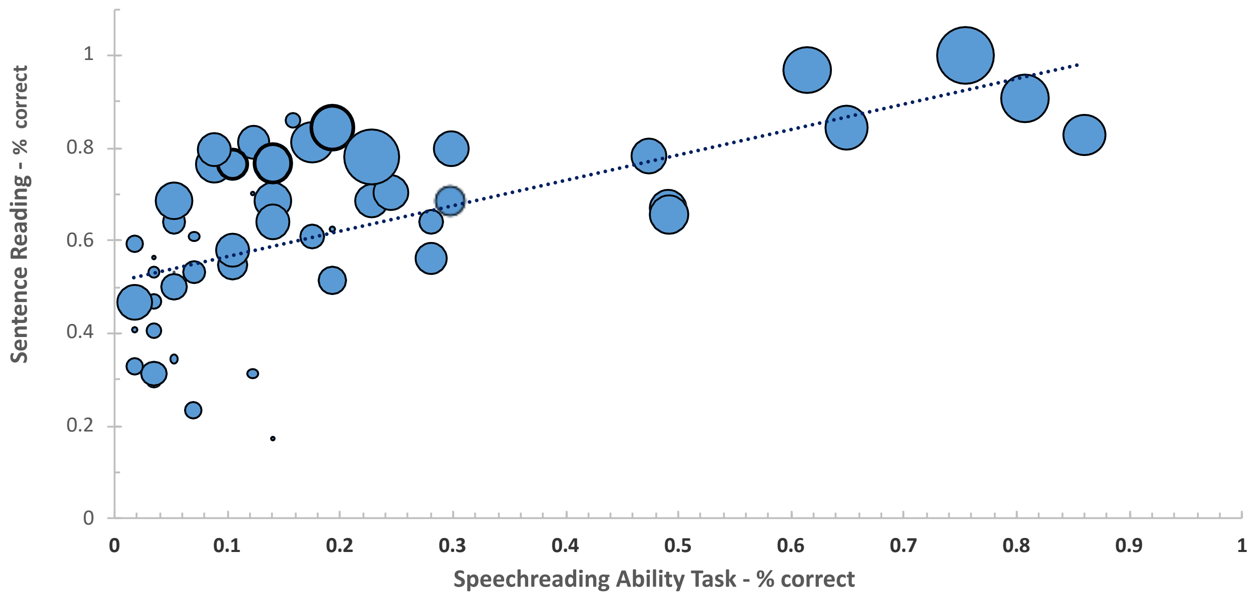


Figure 29. Correlation between Speechreading Ability Task (x-axis), Sentence Reading (y-axis), and Reading comprehension (bubble width), in young deaf readers of Spanish.

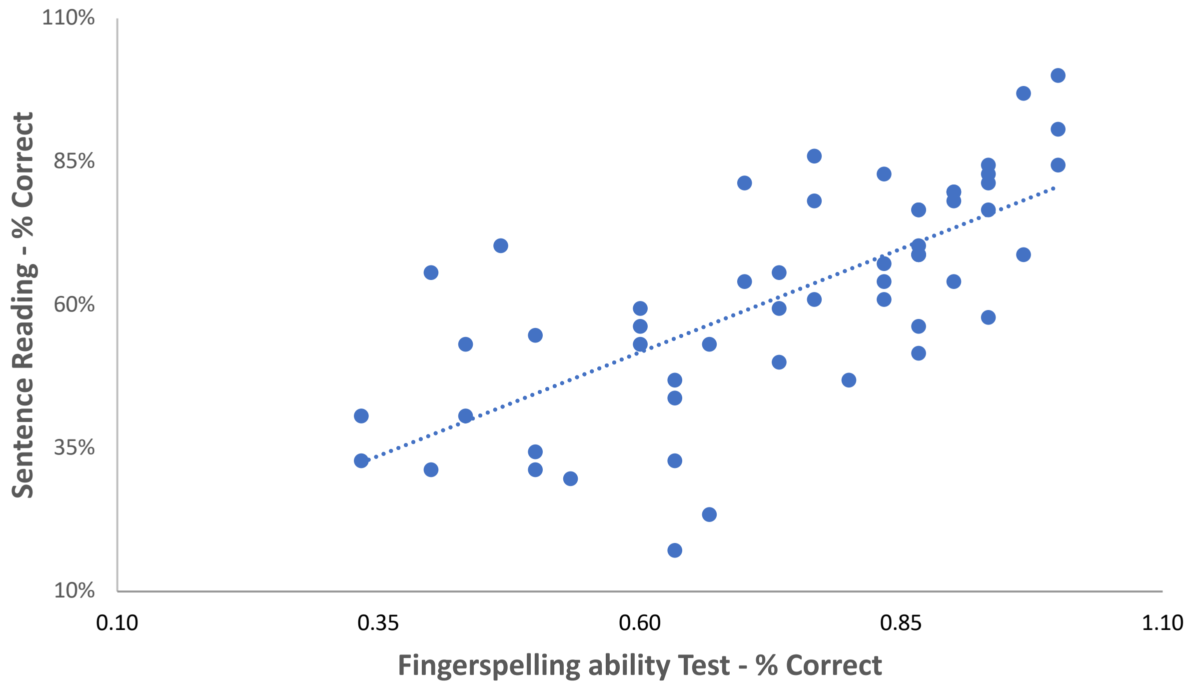


Figure 30. Correlation between Fingerspelling ability Test (x-axis) and Sentence Reading (y-axis) in young deaf readers of Spanish.

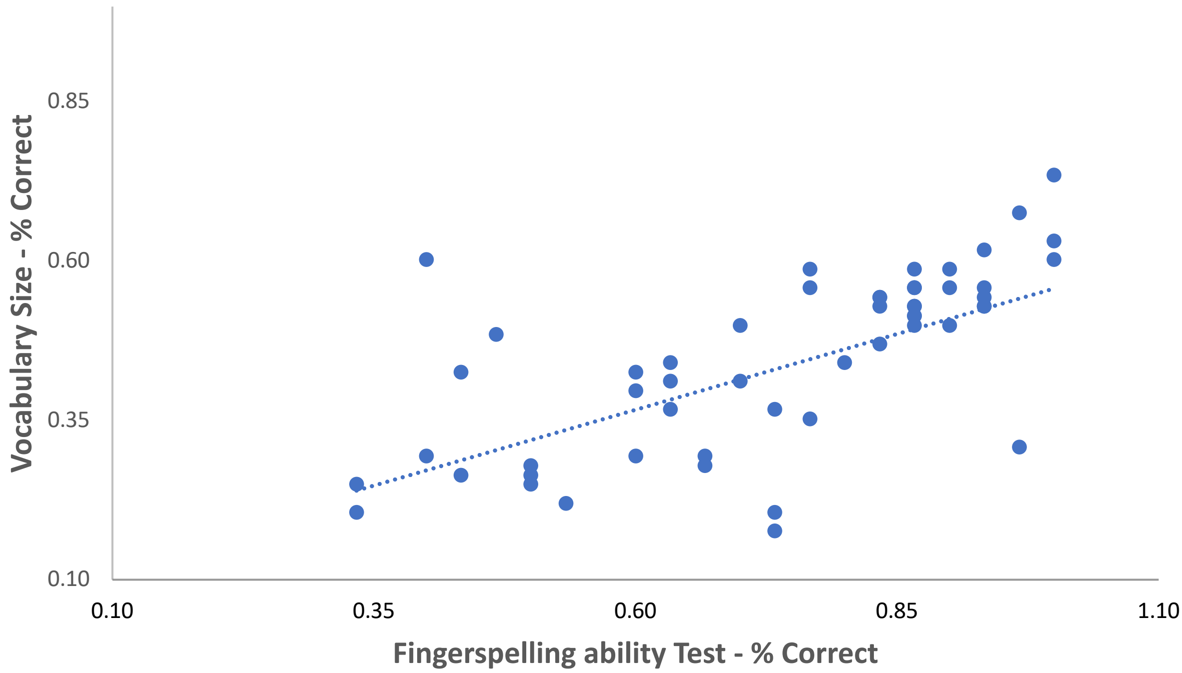


Figure 31. Correlation between Fingerspelling ability Test (x-axis) and Vocabulary Size (y-axis) in young deaf readers of Spanish.

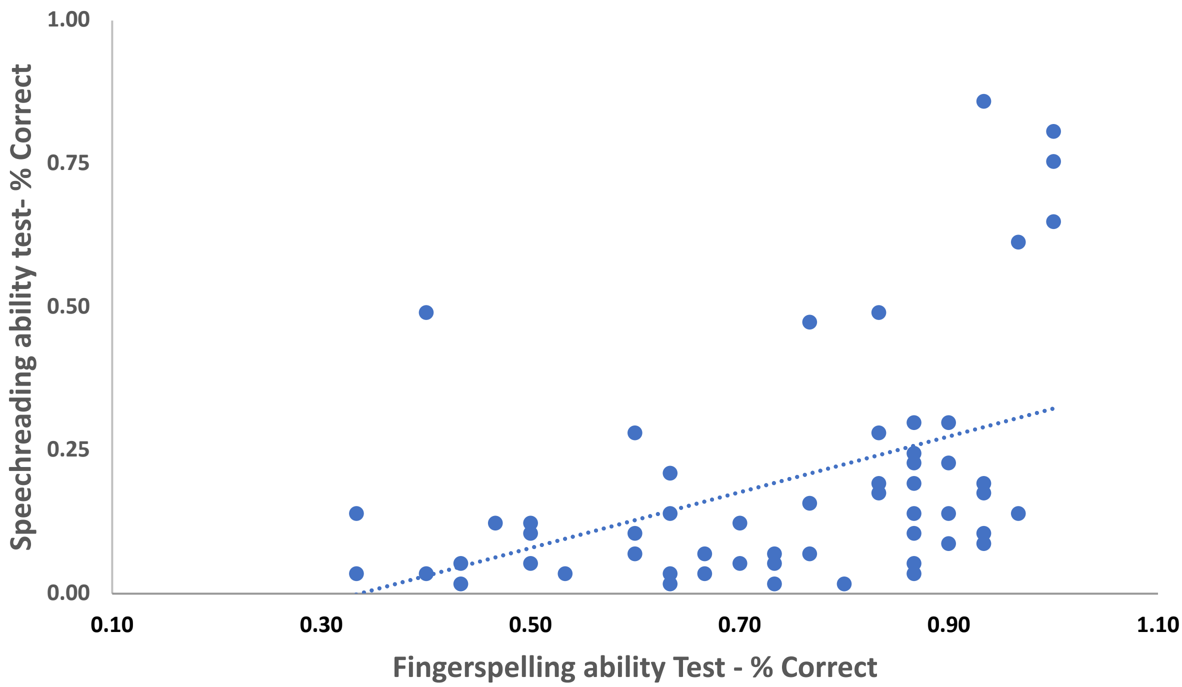


Figure 32. Correlation between Fingerspelling ability Test (x-axis) and Speechreading ability test Size (y-axis) in young deaf readers of Spanish.

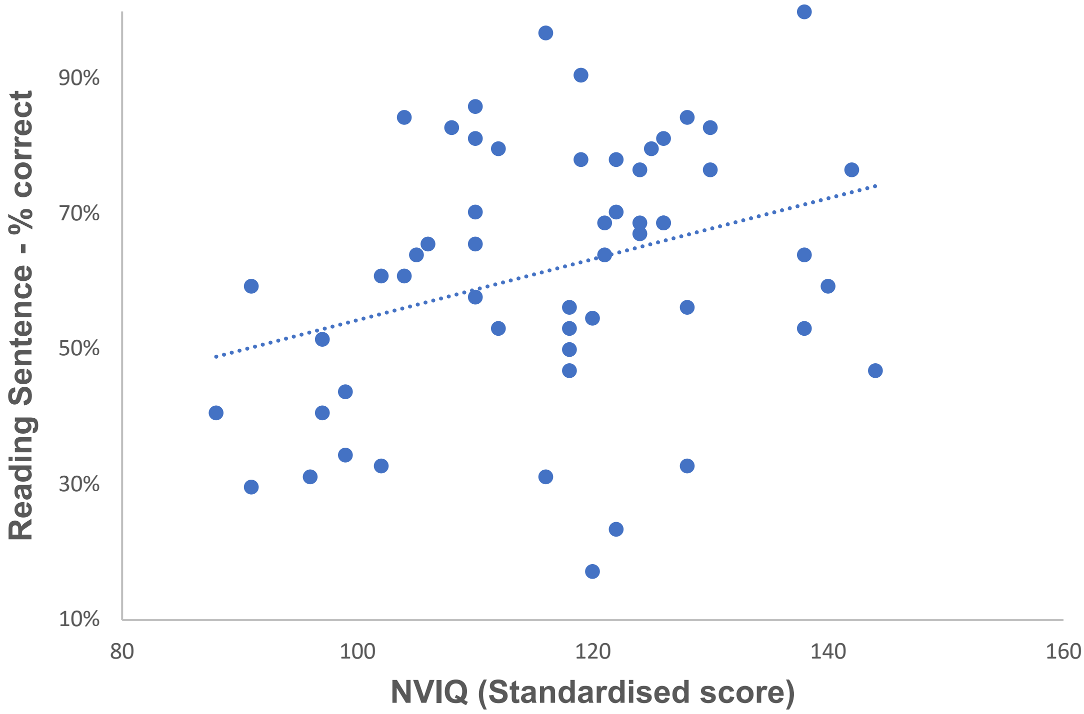


Figure 33. Correlation between NVIQ (x-axis) and Sentence Reading (y-axis) in young deaf readers of Spanish.

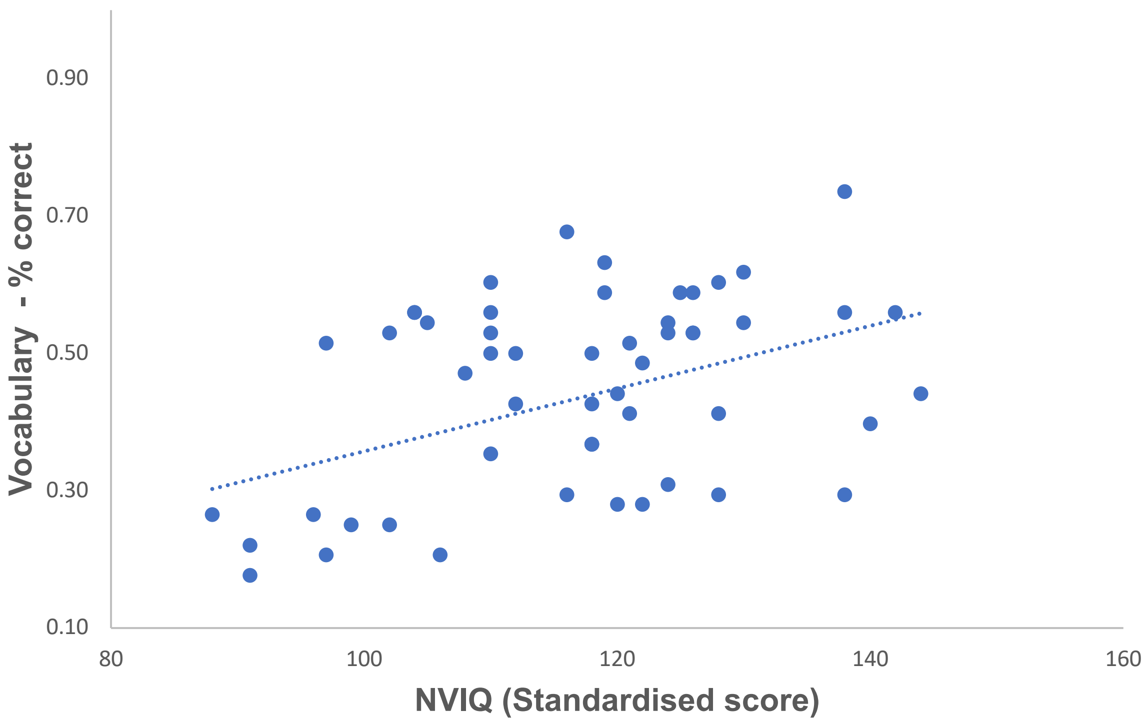


Figure 34. Correlation between NVIQ (x-axis) and Vocabulary (y-axis) in young deaf readers of Spanish.

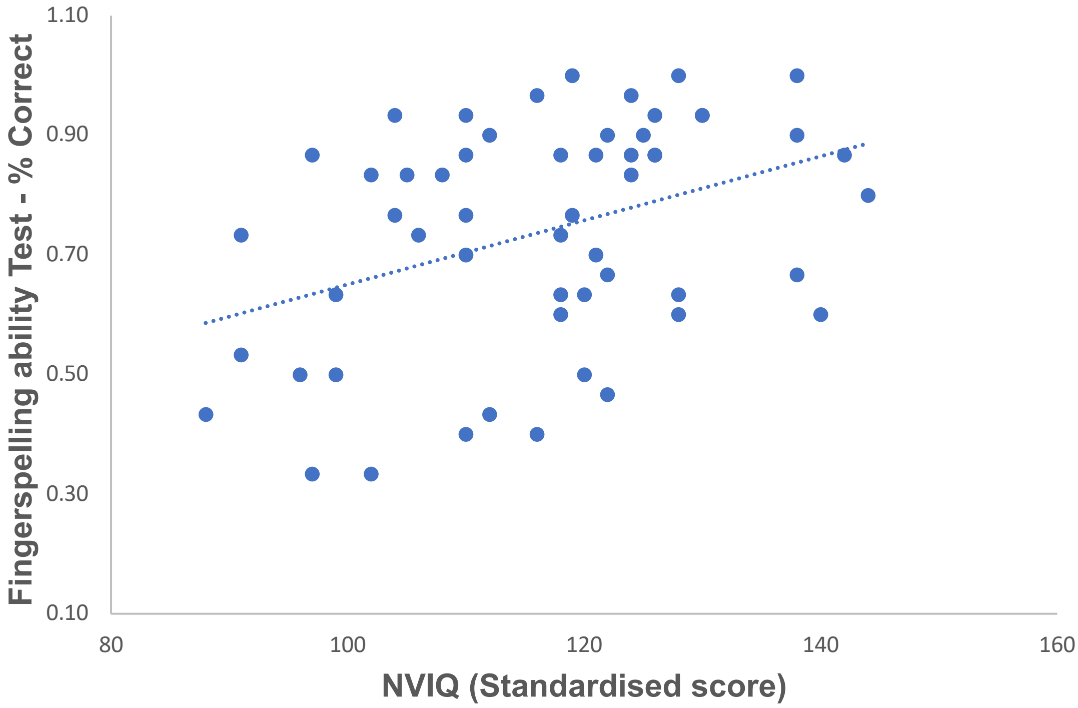


Figure 35. Correlation between NVIQ (x-axis) and Fingerspelling ability Test (y-axis) in young deaf readers of Spanish.

6.1.3.1.3. Materials

The same materials used with adult deaf readers of Spanish were used here with young deaf reads of Spanish. See section '6.1.2.1.3. Materials'.

6.1.3.1.4. Procedure

Same procedure followed as with adult deaf readers of English and Spanish. See section: '6.1.1.1.4. Procedure'.

6.1.3.2. Results - Young deaf readers of Spanish

A hundred and nine words were included in the analyses after removing the words that had less than 58% accuracy (See Appendix F). The same statistical analyses performed in the adult deaf readers studies were performed here (see section 6.1.2). The RT analysis was performed only on correct trials of word targets. Additionally, further analyses using repeated measures ANOVA were performed and included in Appendix D. These results confirmed the pattern of the findings reported here. The mean lexical decision times and percentage of correct responses per condition are displayed in Table 13.

6.1.3.2.1. Lexicality effect, Repetition and Phonological masked priming effects

Lexicality effect - Responses to words were faster than to pseudowords (946.96ms vs 1069.73ms); $t_1(54) = -4.36$, $p < .001$; $t_2(216) = -12.40$, $p < .001$. In the accuracy analyses, there was only a significant difference in the analyses by-item; (75% vs 69%) $t_1(54) = 1.49$, $p = .141$; $t_2(216) = 6.26$, $p < .001$.

Repetition masked priming effects - Paired-samples *t*-tests showed that responses were faster in the identity than in the unrelated condition (932.9ms vs. 986.69ms); $t_1(54) = -2.63$, $p = .011$; $t_2(108) = -3.96$, $p < .001$. No difference was shown in the accuracy data (77% vs. 75%), $t_1(54) = 1.97$, $p = .055$; $t_2(108) = 1.26$, $p = .211$.

Phonological masked priming effects - To test for the effect of masked phonological priming we contrasted the pseudohomophone and orthographic control prime conditions (see Table 13). The paired-samples *t*-tests in the by-subject analyses showed that participants were faster to respond in the pseudohomophone condition than in the orthographic control condition (919.1ms vs 949ms), $t_1(54) = -2.62$, $p = .049$; but no difference was shown in the by-item analyses; $t_2(108) = -1.02$, $p = .309$. No significant difference was found for accuracy (75% vs. 74%), $t_1\ (54) = .98$, $p = .332$; $t_2(108) = 1.03$, $p = .304$.

Table 13. Mean lexical decision times (RTs in ms, upper quadrants), and percentage accuracy (lower quadrants) for each experimental condition: Identity and Unrelated primes (left), and Pseudohomophone and Orthographic control primes (right), in young deaf readers of Spanish.

	Repetition Effect	**Phonological Effect**	
	RT	RT	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
Identity primes	932.93 (274.03)	919.16 (229.68)	Pseudohomophone primes
Unrelated primes	986.69 (255.12)	949.07 (274.47)	Orthographic control primes
difference	**-53.76****	**-29.92***	**difference**
	Accuracy	Accuracy	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
Identity primes	77% (19.5%)	75% (21.9%)	Pseudohomophone primes
Unrelated primes	75% (20.4%)	74% (21.5%)	Orthographic control primes
difference	**2%(+)**	**1%**	**difference**

(+) $p = .055$, * $p < .05$, ** $p < .01$, *** $p < .001$

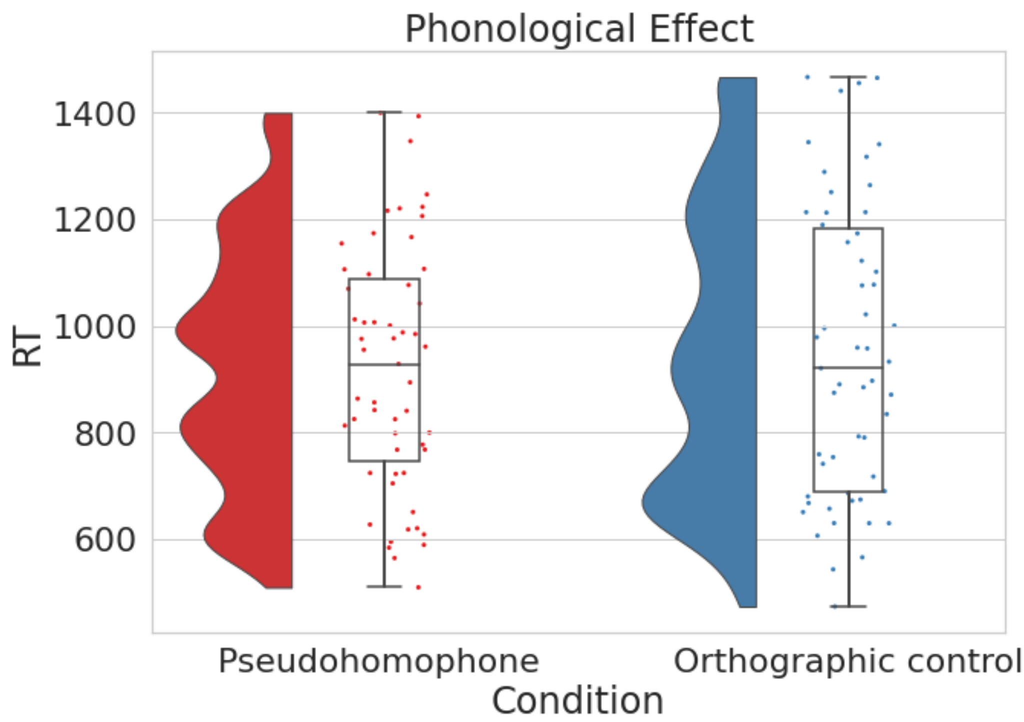


Figure 36. Response times (RT) for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in young deaf readers of Spanish.

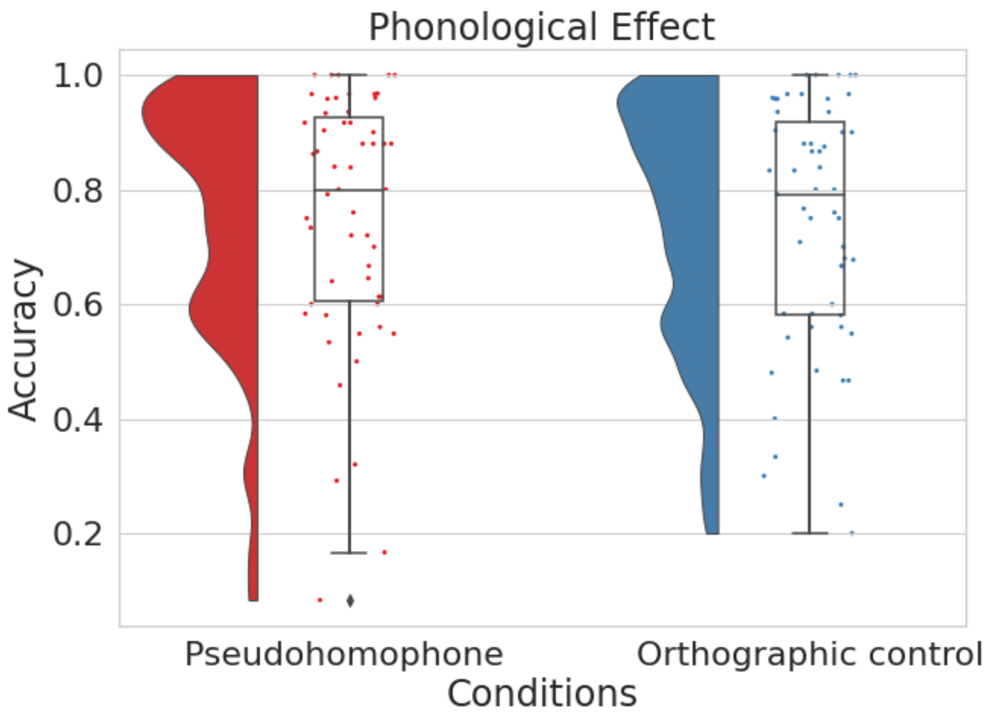


Figure 37. Accuracy of correct responses for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in young deaf readers of Spanish.

Besides being one of the main predictors of reading ability in deaf children (Kyle & Harris, (2010), Harris et al., (2017), and in deaf adults (Moreno-Perez et al., 2015; Dominguez et al; 2014, Wauters et al., 2021), vocabulary size has been linked to phonological awareness in deaf young readers. Furthermore, using the same sandwich masked priming paradigm that we use in the present study, Gutierrez-Sigut et al, (2018) found that adult deaf readers with smaller vocabulary size (i.e., word knowledge) had larger phonological effects. Here a split-half analysis was performed in order to investigate whether the phonological and repetition priming effects persist in young readers with small and large vocabulary. Specifically, the median of the group (50%) in the vocabulary test was used to split the group in two: Small vocabulary (n= 29, Vocabulary Mean score = 35%, SD = 10) and Large vocabulary (n=26, Vocabulary Mean score = 57%, SD = 5). The same analyses described above for the whole group were performed for each group separately (see Table 14 for Small Vocabulary group and Table 15 for Large Vocabulary group).

Small vocabulary group

Lexicality effect - Responses to target words were faster than for pseudowords targets only in the by-item analyses, (1062.03ms vs 1116.17ms); $t_1(28) = -1.58$, $p = .126$; $t_2(216) = -3.32$, $p < .001$. No significant difference was found for accuracy between words and pseudowords (66% vs 63%); $t_1(28) = .51$, $p = .612$; $t_2(216) = .88$, $p = .383$.

Repetition masked priming effects - There was no repetition priming effect for this group in RTs (1078.96ms vs 1096.72ms; t_1 (28) = -0.49, p = .625; t_2(108) = 1.01, p = .316), nor in accuracy (68% vs 65%); t_1(28) = 1.37, p = .181; t_2(108) = 1.25, p = .215 (see Table 14).

Phonological masked priming effects - Responses were significantly faster for the pseudohomophone than the orthographic control prime condition in the by-subject analyses, (1009.45ms vs 1062.99ms); t_1(28) = -2.27, p = .031), but not in the analyses by-item, t_2(108) = -1.52, p = .131. There were no significant differences in accuracy; (68% vs 65%), t_1(28) = 1.43, p = .165; t_2(108) = .92, p = .361 (see Table 14).

Large vocabulary group

Lexicality effect - Responses to target words were faster than for pseudowords targets, (818.62ms vs 1017.96ms); t_1(25) = -4.82, $p < .001$; t_2(216) = -12.33, $p < .001$. There was only a significant difference in accuracy between words and pseudowords in the analyses by-item, (85% vs 75%), t_1(25) = 1.92, p = .067; t_2(216) = 9.49, $p < .001$.

Repetition masked priming effects - Responses were faster for the identity than for the unrelated prime condition (770.06ms vs 863.96ms); t_1(25) = -7.06, $p < .001$; t_2(108) = -5.23, $p < .001$. There were no differences in accuracy (88% vs 86%), t_1(25) = 1.48, p = .152; t_2(108) = 1.49, p = .139 (see Table 15).

Phonological masked priming effects - There were no differences between the pseudohomophone and the orthographic control condition in RTs (818.44ms vs 822.01ms), $t_1(25) = -0.22$, $p = .827$; $t_2(108) = -.89$, $p = .375$, nor in accuracy (83% vs 84%), $t_1(25) = -.35$, $p = .731$; $t_2(108) = .23$, $p = .816$ (see Table 15).

Table 14. Mean lexical decision times (RTs in ms, upper quadrants), and percentage accuracy (lower quadrants) for each experimental condition: Identity and Unrelated primes (left), and Pseudohomophone and Orthographic control primes (right), in young deaf readers of Spanish with Small Vocabulary Size.

	Repetition Effect	**Phonological Effect**	
Type of prime	RT Mean (SD)	RT Mean (SD)	Type of prime
Identity primes	1078.96 (225.88)	1009.45 (197.78)	Pseudohomophone primes
Unrelated primes	1096.72 (219.55)	1062.99 (249.95)	Orthographic control primes
difference	**-17.76**	**-53.54***	**difference**
Type of prime	Accuracy Mean (SD)	Accuracy Mean (SD)	Type of prime
Identity primes	68% (20.3%)	68% (21.9%)	Pseudohomophone primes
Unrelated primes	65% (20.4%)	65% (21.9%)	Orthographic control primes
difference	**3%**	**3%**	**difference**

* $p < .05$, ** $p < .01$, *** $p < .001$

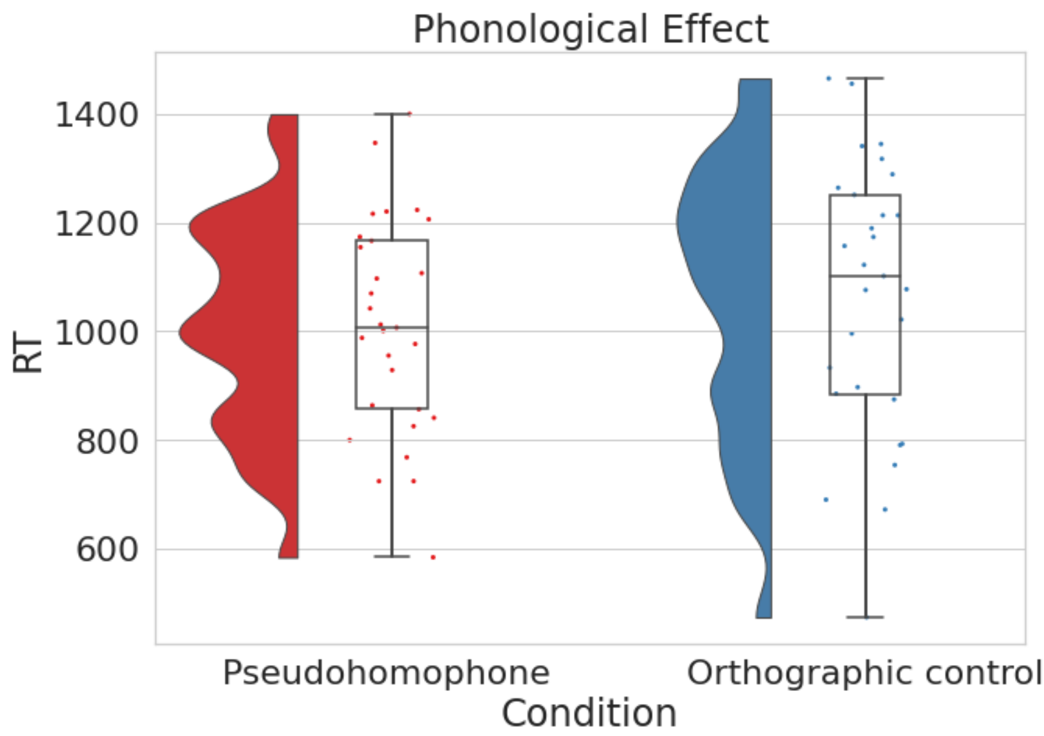


Figure 38. Response times (RT) for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in young deaf readers of Spanish with Small Vocabulary Size.

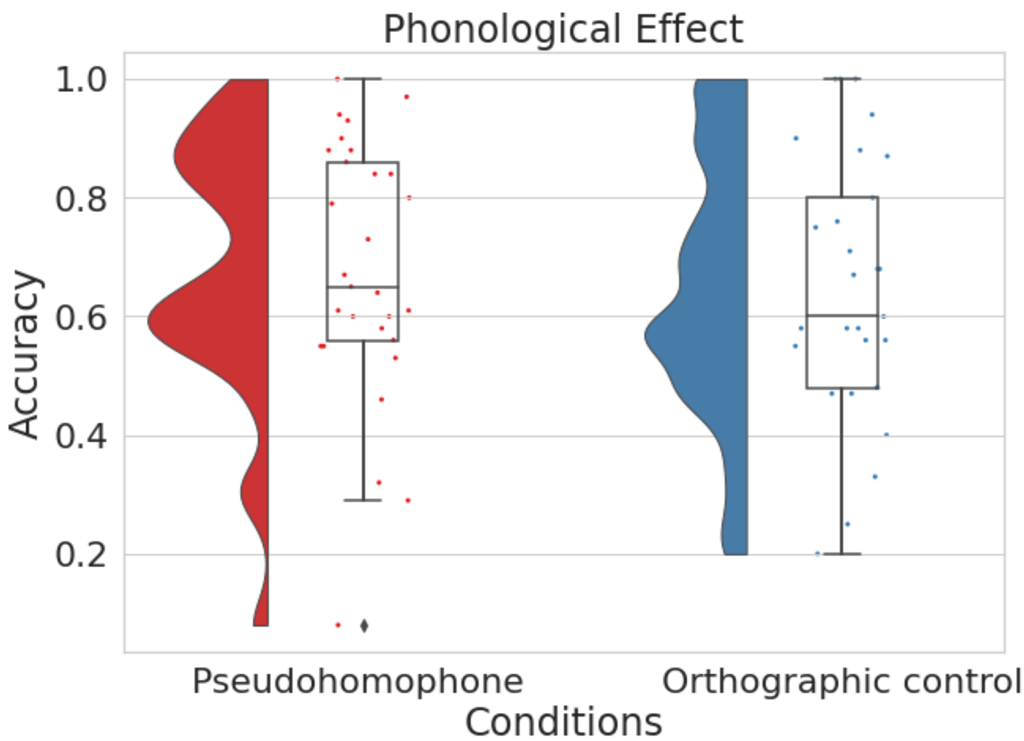


Figure 39. Accuracy of correct responses for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in young deaf readers of Spanish with Small Vocabulary Size.

Table 15. Mean lexical decision times (RTs in ms, upper quadrants), and percentage accuracy (lower quadrants) for each experimental condition: Identity and Unrelated primes (left), and Pseudohomophone and Orthographic control primes (right), in young deaf readers of Spanish with Large Vocabulary Size.

	Repetition Effect	**Phonological Effect**	
	RT	RT	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
Identity primes	770.06 (229.62)	818.45 (223.91)	Pseudohomophone primes
Unrelated primes	863.96 (238.52)	822.01 (246.79)	Orthographic control primes
difference	**-93.91****	**-3.57**	**difference**
	Accuracy	Accuracy	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
Identity primes	88% (11.7)	84% (19.1)	Pseudohomophone primes
Unrelated primes	86% (14.1)	84% (15.7)	Orthographic control primes
difference	**2%**	**1%**	**difference**

* $p < .05$, ** $p < .01$, *** $p < .001$

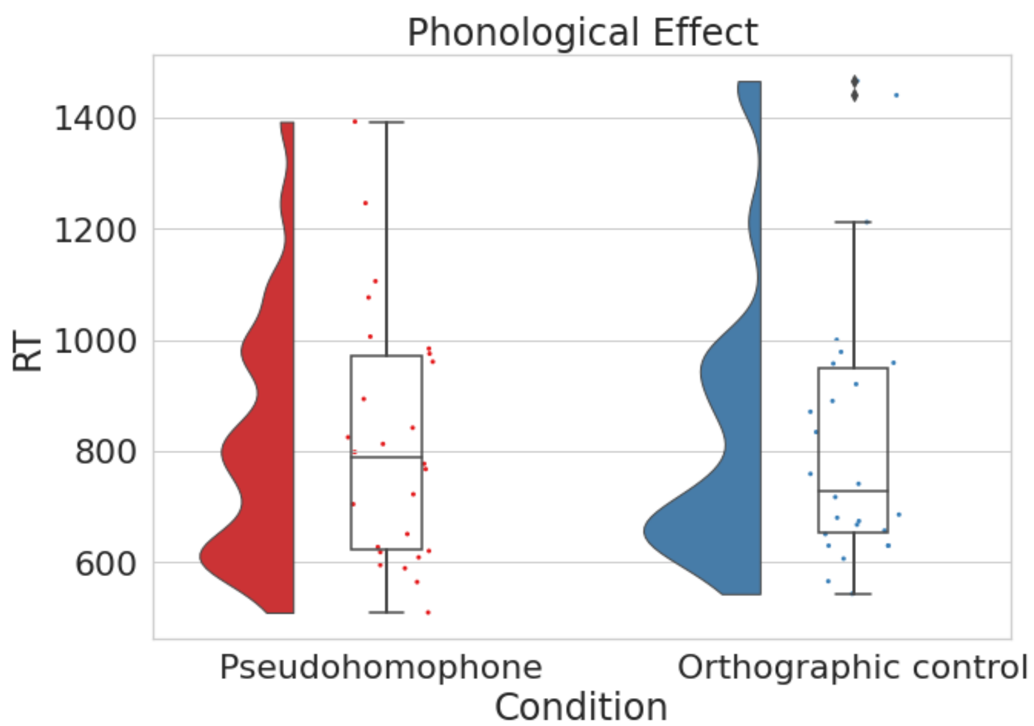


Figure 40. Response times (RT) for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in young deaf readers of Spanish with Large Vocabulary Size.

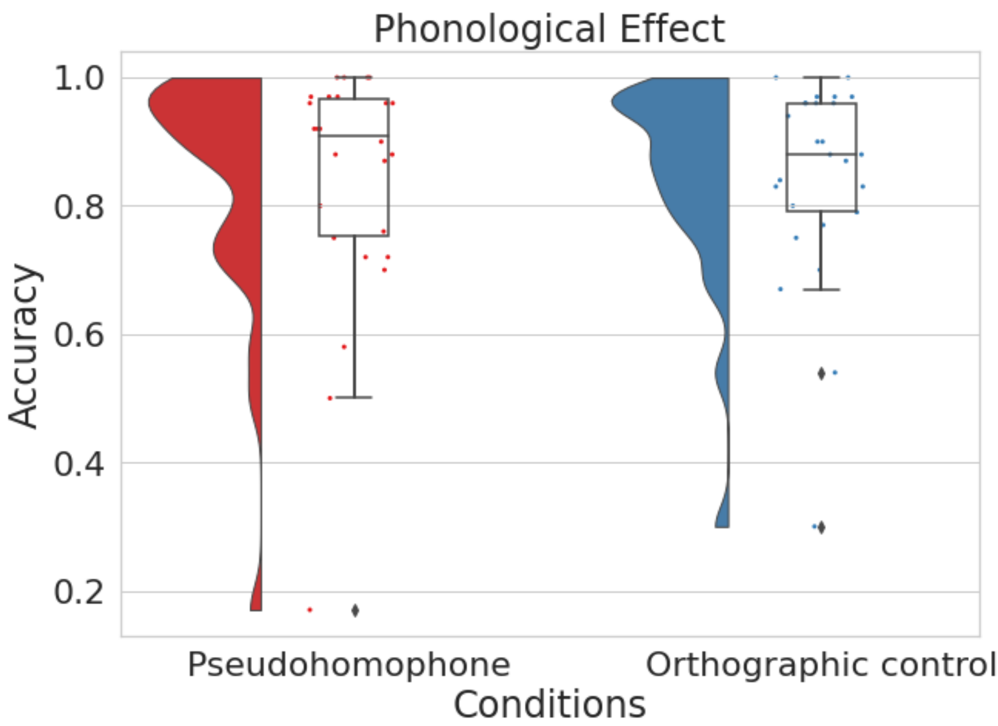


Figure 41. Accuracy of correct responses for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in young deaf readers of Spanish with Large Vocabulary Size.

There were no significant correlations between the size of the phonological priming effect for the whole group of young readers and the offline behavioural measures (sentence reading, reading comprehension, and speechreading ability), all *p*s > .2, (See Table 16). The same correlation analyses were performed in the two groups: Small Vocabulary Size (see Table 17), and Large Vocabulary Size (see Table 18).

Table 16. Correlations with offline behavioural measures and the size of the masked phonological priming effect in RT (left) and accuracy (right), in young deaf readers of Spanish.

Offline measures		Size of the masked phonological priming effect in:	
		RT	Accuracy
Sentence Reading (% correct)	r	.03	.10
	p	.824	.472
Reading Comprehension (% correct)	r	.17	.11
	p	.227	.421
Speechreading Ability Test (% correct)	r	.14	.06
	p	.319	.651
Vocabulary Test (# correct answers; max = 68)	r	.02	-.10
	p	.879	.496
Fingerspelling Ability Test (% correct)	r	.09	.11
	p	.537	.435
Phonological Processing (visual bias index)	r	-.03	.02
	p	.831	.875

* $p < .05$, ** $p < .01$, *** $p < .001$

Note . Size of the masked phonological priming effect (in RT and Accuracy) = Phonological - Orthographic control condition.

After Bonferroni correction no correlations were significant.

Table 17. Correlations with offline behavioural measures and the size of the masked phonological priming effect in RT (left) and accuracy (right), in young deaf readers of Spanish with Small Vocabulary Size.

Offline measures		Size of the masked phonological priming effect in:	
		RT	Accuracy
Sentence Reading (% correct)	r	.10	.16
	p	.601	.402
Reading Comprehension (% correct)	r	.01	-.02
	p	.969	.934
Speechreading Ability Test (% correct)	r	.09	.31
	p	.643	.102
Vocabulary Test (# correct answers; max = 68)	r	-.34	.01
	p	.074(+)	.971
Fingerspelling Ability Test (% correct)	r	-.15	.38
	p	.488	.059(+)
Phonological Processing (visual bias index)	r	-.04	.16
	p	.845	.405

*(+) p < .074, * p < .05, ** p < .01, *** p < .001*

Note. Size of the masked phonological priming effect (in RT and Accuracy) = Phonological - Orthographic control condition.
After Bonferroni correction no correlations were significant.

Table 18. Correlations with offline behavioural measures and the size of the masked phonological priming effect in RT (left) and accuracy (right), in young deaf readers of Spanish with Large Vocabulary Size.

Offline measures		Size of the masked phonological priming effect in:	
		RT	Accuracy
Sentence Reading (% correct)	r	-.03	.23
	p	.900	.264
Reading Comprehension (% correct)	r	-.05	.37
	p	.818	.061(+)
Speechreading Ability Test (% correct)	r	-.02	.21
	p	.944	.294
Vocabulary Test (# correct answers; max = 68)	r	.02	.17
	p	.942	.422
Fingerspelling Ability Test (% correct)	r	-.076	.30
	p	.694	.109
Phonological Processing (visual bias index)	r	-.02	-.23
	p	.910	.259

*(+) $p < .061$, * $p < .05$, ** $p < .01$, *** $p < .001$*

Note. Size of the masked phonological priming effect (in RT and Accuracy) = Phonological - Orthographic control condition.
After Bonferroni correction no correlations were significant.

6.1.4 Discussion

This subsection includes a brief discussion from the results from each experiment in section 6.1. For more detail see the General Discussion in Chapter 8.

Deaf adult readers of English

Deaf adult readers of English showed a Lexicality Effect in both measures, response time and accuracy. They showed this advantage of words over pseudowords by responding faster and better to target words than to pseudowords.

Our results show that there is a clear repetition effect in the latency analyses (i.e. difference in RTs between the identity and unrelated conditions). Since an identical prime provides both orthographic and phonological information to the deaf readers, they seem to benefit most when both sources of information are available to recognise a word. These results are consistent with Gutiérrez-Sigut et al. (2018) and Cripps et al., (2005), where the repetition priming was faciliatory for deaf readers. Even though this was not the main research question of this study, the aim of testing for repetition effect was to assure that the masked priming paradigm was accurate with adult deaf readers. As the results showed, deaf adult readers of English used the information provided by the prime (e.g., phonological, and orthographic) to do the LDT.

The phonological effects found in RTs and in accuracy with our group deaf readers, provide evidence that phonological information can be used by deaf readers from early stages of visual word recognition. This is consistent with Gutiérrez-Sigut et al. (2018), and similar findings with hearing readers (e.g. Ferrand and Grainger, 1992, Perfetti and Bell, 1991, Rastle and Brysbaert, 2006). Our group of deaf readers had a variety of reading range, similar to the group of readers in Gutiérrez-Sigut et al. (2018) study, showing automatic use of phonological codes for visual word recognition.

However, given that this was a relatively small group of participants, further research should be done with a larger N. On the other hand, having found this evidence with a small group, suggests that the masked priming paradigm used to explore the automatic use of phonology codes during visual word recognition in deaf readers seems to be strong in deaf adult readers of English.

This study did not find a correlation between reading skill (Sentence reading test) and size of the phonological effect in RTs nor in accuracy (calculated from the LDT). This was also the case in the Gutierrez-Sigut et al., (2017) study. It is less clear how to interpret this result; however, it may suggest that the processes involved for single word recognition and reading longer texts might vary. There could be a wider variety of strategies used for reading longer texts, where the size of the phonological effects may be only one of several factors involved.

In the case of the correlation between our offline behavioural measures, vocabulary was highly correlated to reading. The 'simple view of reading' (Gough & Tunmer, 1986), proposed that having strong language skills is required for reading ability. Moreover, it has been suggested vocabulary as one of the main predictors of reading ability (Cates, Taxler & Corina, 2021; Dominguez et al; (2014), Kyle & Harris, 2010; Harris, Terlektsi, & Kyle, 2017; Moreno-Perez et al., (2015); Wauters, van Gelder, & Tijsseling, 2021)

Apart from showing the lexicality and repetition priming effects in the same direction that has been found in previous studies, our results show a clear phonological priming effect during word recognition in adult deaf readers of English.

Deaf adult readers of Spanish

Our results show that there is a clear repetition effect in the latency analyses (i.e., difference in RTs between the identity and unrelated conditions). Readers of Spanish also seemed to benefit from both orthographic and phonological codes, provided by the identity prime condition.

The group of deaf adults were skilled readers (Sentence reading test, M=89%, SD=10%), and did not show a facilitation of the phonological prime. This could probably suggest that skilled readers make more use of visual codes and do not need to access to the phonological information to recognise single words. The size of the phonological effect in RT was only correlated to fingerspelling ability.
It would be interesting to replicate this study with a group with a wider range of reading skills, or with another group with lower reading skills to see if they show any

facilitation for the phonological prime during visual word recognition as a function of reading ability.

With regard the correlation between our offline behavioural measures, reading was correlated to vocabulary and speechreading ability, showing once again how language related skills are needed for reading ability. Consistent to Kyle, Campbell and MacSweeney, (2016), speechreading and vocabulary were correlated to reading ability, suggesting the importance of developing these skills which can be used as a tools for deaf readers to achieve reading ability.

In the following experiment we test a group of young readers and explore, whether deaf young readers use phonological codes automatically to recognise words.

Young deaf readers of Spanish

Young deaf readers showed a repetition priming effect in the latency analyses, (i.e. difference in RTs between the identity and unrelated conditions). This is consistent with the repetition priming effect we found in our adult deaf readers of Spanish. However, when this young group was split into ‘Small vocabulary size’ and ‘Large vocabulary size’, the group of ‘Small vocabulary size’ did not show a repetition effect. One possibility is that these young readers did not know a lot of the words and thus read them as nonwords, (e.g., decoding them). Therefore, they did not benefit from the orthographic information as much as the ‘Large vocabulary size’ group did. Phonological effects were found in young deaf readers with smaller vocabulary size, but not in those with larger vocabularies or in adult skilled readers (see section

6.1.2.1). This is consistent with previous findings in hearing developing readers of a more relevant role of phonology during earlier stages of reading development (see Castles at al., 2018 for an extensive review).

Our findings offer insights into prior mixed results with deaf readers of Spanish (See Gutierrez-Sigut et al., 2017; Fariña et al., 2017; Costello et al., 2021). Highlighting the importance of vocabulary (word knowledge) and reading ability.

6.2. Orthographic Processing

In this section we also used a sandwich masked priming to investigate how precisely orthographic information is used automatically during single word recognition by deaf readers. As in the Phonological Processing study (section 6.1) three groups of readers of languages with different orthographic depth (English vs Spanish) and of different ages (adults vs adolescents) were tested. Specifically, data was collected from adult deaf readers of English and, both adult and young deaf readers of Spanish.

The aim of the experiments was to address the following research questions:

1. To what extent do deaf readers of English (Experiment 4) and Spanish (Experiments 5 and 6) use orthographic codes automatically during visual word recognition? It was predicted that deaf readers would show faster RTs and less errors during lexical decision for words preceded by a masked prime which is a pseudoword in which 2 letters had been transposed (e.g., hostipal - hospital) than

when preceded by a pseudoword including a replaced letter (e.g., hosfigal- hospital). This would reflect facilitation due to the transposed letter pseudoword

2. Is a larger orthographic priming effect related with reading, speechreading and fingerspelling skills? It was hypothesized that reading, speechreading and fingerspelling skill should be associated with the size of the orthographic priming effect. The orthographic priming effect was defined as the difference, in either RTs or accuracy, between the transposed letter pseudoword and replaced letter pseudoword control condition.

6.2.1. Deaf adult readers of English

The conditions of interest in this sandwich masked orthographic priming experiment were those where the target was preceded by a transposed letter consonant (TL-C) and by a replaced letter consonant (RL-C) prime. Additionally, and in line with traditional TL experiments (Andrews and Lo, 2012), an unrelated prime condition was included (orthographically and phonologically different to the target).

For the participants to be able to perform a lexical decision task, the experiments included equal number of words (n=120) and pseudowords (n=120). Similar to the phonological experiments, the pseudowords were preceded by all three types of prime. However, as masked priming effects are generally not observed in pseudoword, only the lexicality effect will be reported here.

6.2.1.1. Methods

6.2.1.1.1. Participants

The same participants who participated in Experiment 1, were included in the current study (Experiment 4), except for one who did not complete this task. Data from 13 congenitally deaf adult participants (5 female) are reported here. The target number to recruit was 30, however, this was interrupted by the COVID-19 pandemic. This study was approved by the University College London Research Ethics Committee (Project ID Number 10991/001). Instructions were given in BSL and in written English. Participants were asked to provide written consent at the beginning of the sessions and were told that they could withdraw at any time.

All participants were profoundly or severely deaf from birth, did not report history of neurological or psychiatric impairments, and had normal or corrected to normal vision. Their ages ranged from 23 to 53 years (M = 37.64, SD = 10.81). Five participants were native BSL signers, 4 participants were early signers (AoA between 3 and 9 years old), and the remaining 4 participants learnt BSL after the age of 9 years and were considered late signers. Twelve participants were fluent signers of BSL (self-ratings 6-7, in a 1-7 Likert scale) and used BSL as their preferred means of communication in their daily lives. One participant rated his BSL proficiency at 4 and reported using English as their preferred form of communication.

6.2.1.1.2. Offline behavioural measures

Participant's performance on the tasks described in Section '6.1.1.1.2 Offline behavioural measures' are reported in Table 19. All participants had non-verbal IQ above 85, their reading comprehension score was above 33.3%.

Table 19. Participant characteristics and test scores of the deaf adult readers of English. For full details of the tests see section 6.1.1.1.2.

	Mean (SD)	**Range**
Age (Yrs, mths.)	37,6 (10.8)	(23,5-53,1)
Reading Comprehension (% correct)	70.2% (16.4)	(33.3%-90.5%)
Vocabulary Test (% correct)	84% (14.7)	(51.2%-98.8%)
Phonological Processing (Rhyme task, % correct)	74% (18)	(51%-98%)
Speechreading Ability Test (% correct)	91.1% (7.8)	(74.2%-100%)
Fingerspelling Test (% correct)	85.8% (19.5)	(30%-100%)
NVIQ (Standardised score)	114 (9.3)	(100-139)

In order to better describe the sample of participants, correlations between the participant characteristic tasks were calculated (see Table 20). Significant correlations were found between reading comprehension and both, vocabulary and NVIQ. The correlation plots can be found in previous section (Phonological priming experiment). Since these participants are the same as previous experiment, see Figures 9 and 10.

Table 20. Correlations between measures of participant characteristics in deaf adult readers of English.

	Vocabulary Test	Phonological Processing	Speechreading Ability Test	Fingerspelling Test	NVIQ
Reading Comprehension	.94***	.41	.51(+)	-.20	.60*
Vocabulary Test		.42	.52(+)	-.07	.56(+)
Phonological Processing (Rhyme task)			.56(+)	-.26	-.30
Speechreading Ability Test				.03	-.16
Fingerspelling Test					-.03

*(+) p < .08, * p < .05, ** p < .01, *** p < .001*

6.2.1.1.3. Materials

A set of 120 English words were selected (See Appendix G for list of words). In order to ensure that the targets were known to the participants, the selected words had an early age-of-acquisition (AoA; Mean = 5.68 years, range: 3.3-7.6 years, SD = 10.97) (Kuperman et al., 2012), and a high lexical frequency taken from N-watch (Mean = 76.03, range: 0.89 – 998.1, SD = 130.31) (Davis, 2005). The mean length was 6.93 (range: 5-10, SD = 1.35) and the mean token bigram frequencies was 813.06 (range: 92.4-4295.23, SD = 645.05). The mean number of orthographic neighbours was 0.70 (range: 0-6, SD = 1.25). Orthographic neighbourhood values were taken from N-watch (Davis, 2005), the mean of frequency per million in the N-watch database was 115.77 (range: 1.79 - 6981.29, SD = 560.33).

For each target word, three pseudoword primes were created, see table 21:

(1) a transposed-letter consonant (TL-C): two non-adjacent consonants were transposed (panert, PARENT). There was always a letter in between the non-adjacent transposed letters,

(2) a replaced-letter consonant (RL-C), replacing the two non-adjacent transposed letters (pamest, PARENT). The replaced letters kept the ascending or descending letter form of the transposed letter pseudowords.

(3) an unrelated condition, same length as the target but, did not have any orthographic or phonological overlap with the target (calscu, PARENT).

An additional set of 120 orthographically legal pseudowords were included for the purposes of the lexical decision task (see Appendix G). The pseudowords were created with Wuggy, a pseudoword generator (Keuleers & Brysbaert, 2010). The mean length was 6.93 (range: 5-10, SD = 1.35), the mean token bigram frequencies was 665.71 (range: 79.1-2975.84, SD = 532.80). The mean number of orthographic neighbours was 0.70 (range: 0-6, SD = 1.25), values taken from N-watch (Davis, 2005). The pseudowords trials were manipulated with the same characteristics as the word trials.

Three lists of materials were created so that each target appeared once in each list, but it was paired with all priming conditions across lists. For example, all participants would see target 'PARENT, but participant one would see it primed by 'panaret" (TL_C condition). participant two primed by 'pamest' (RL-C condition) and participant three primed by 'calscu' (unrelated condition).

Table 21. Example stimuli. See the target word (on the left) followed by its 3 prime conditions.

	PRIME CONDITIONS		
Target word	Transposed-letter Consonant (TL-C)	Replacement-letter Consonant (RL-C)	Unrelated condition
PARENT	panert	pamest	calscu

6.2.1.1.4. Procedure

Participants were tested individually in a quiet room. A MacBook (Retina, 12-inch, Early 2015) was used to display the stimuli using PsychoPy (Peirce, 2007): a software written in Python used to present the stimuli and to save the outputs of the experiment. There were 12 practice trials. The order of the experimental trials was random for each participant. The procedure was the same as in Experiment 1. Figure 42 shows the sequence of events in each trial as well as the Experimental conditions.

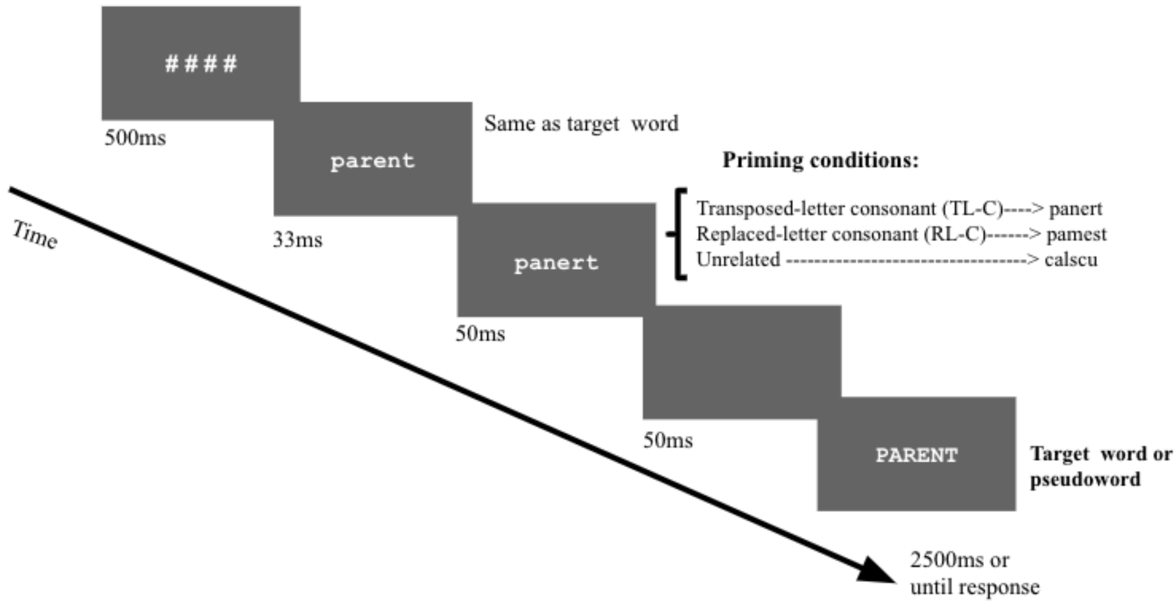


Figure 42. Description of events in a Sandwich Masked Priming paradigm trial and experimental conditions for adult readers of English.

6.2.1.2. Results – deaf adult readers of English

Accuracy for all items (n= 120) was above 78.6% (Mean = 97.9%, SD = 3.75). The list of items included in this Experiment 4, can be found in Appendix G.

First, a *t*-tests contrasting word and pseudoword fingerspelled stimulus was performed. Then, a paired-samples t-test was used to contrast the two conditions of interest (TL_C and RL_C) both for the subjects (t_1) and items (t_2) scores. The RT analysis was performed only on correct trials of word targets.

6.2.1.2.1. *Lexicality effect and Orthographic masked priming effects*

Lexicality effect - Separate paired-samples t-tests for the RTs and the accuracy data showed that responses to words were significantly faster (718.68ms vs 843.17ms); $t_1(24) = -2.08$, $p = .048$; t_2 (238) = -11.47, $p < .001$, and more accurate, only significant in the item analyses, (98% vs 96%); $t_1(24) = -2.08$, $p = .054$; $t_2(238) = 2.56$, $p = .010$.

Orthographical masked priming effects - To test for the effect of masked orthographical priming we performed a paired samples *t*-test contrasting the TL-C vs TL-R prime conditions (see Table 22, Figures 43 and 44). Analysis on the RTs showed that participants were faster to respond to targets preceded by TL-C primes than preceded RL-C primes (705.43ms vs 732.64ms; $t_1(12) = -3.35$, $p = .006$; $t_2(119) = -1.30$, $p = .197$. No difference was found in the accuracy data (98% vs. 97% correct), $t_1(12) = 0.29$, $p = .776$; $t_2(119) = -.29$, $p = .771$.

Table 22. Mean lexical decision times (RTs in ms, upper half), and percentage accuracy (lower half) for Transposed-letter consonant (TL-C) and Replaced-letter consonant (RL-C) prime conditions, in deaf adult readers of English.

	Orthographic Effect
	RT
Type of prime	Mean (SD)
TL-C primes	705.44 (115.53)
RL-C primes	732.64 (118.79)
difference	**-27.20****

	Accuracy
Type of prime	Mean (SD)
TL-C primes	98% (2.3)
RL-C primes	97% (2.5)
difference	**1%**

* $p < .05$, ** $p < .01$, *** $p < .001$

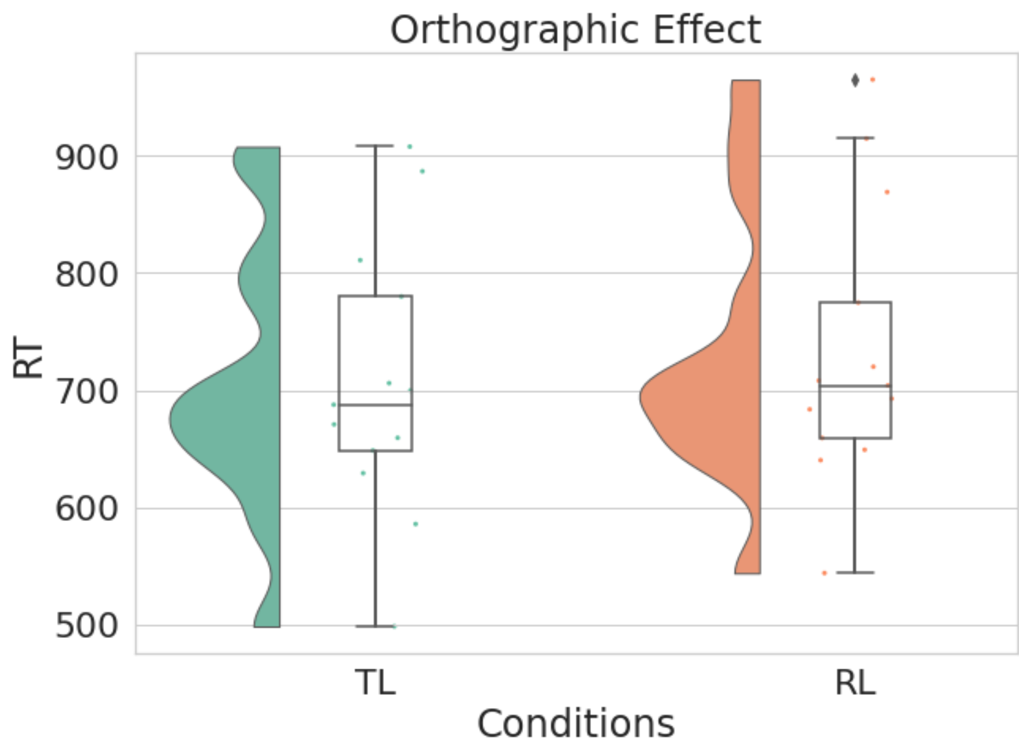


Figure 43. Response times (RT) for Transposed-letter (TL, left) and Replaced-letter (RL, right) during the LDT, in deaf adult readers of English.

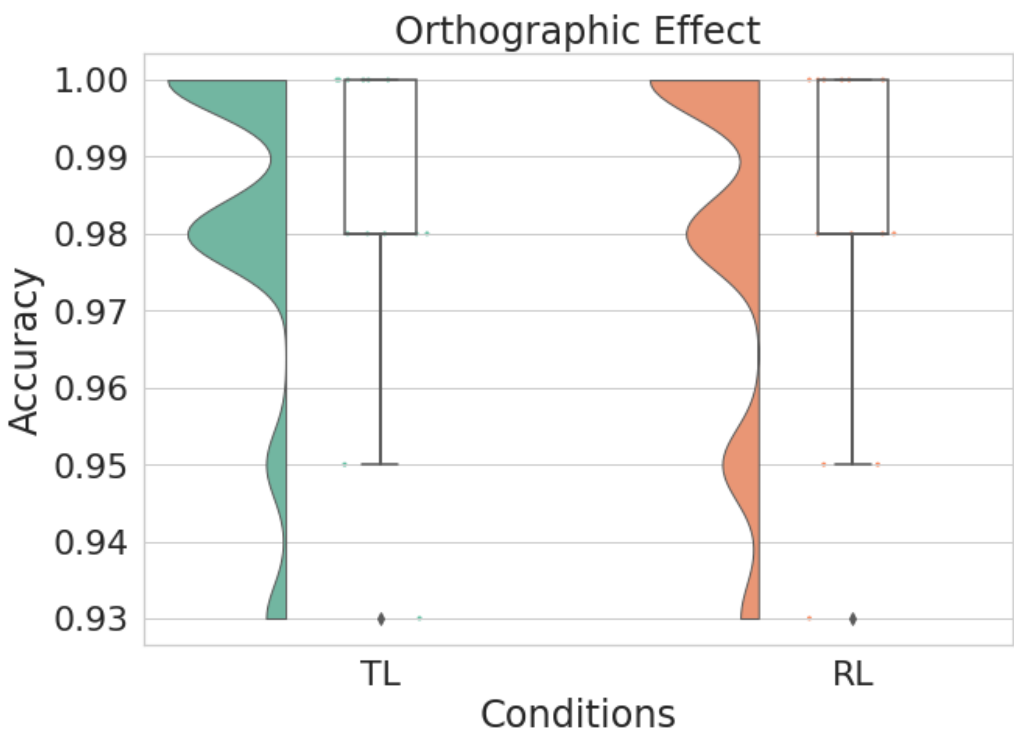


Figure 44. Accuracy of correct responses for Transposed-letter (TL, left) and Replaced-letter (RL, right) during the LDT, in deaf adult readers of English.

Correlations between offline behavioural measures and masked orthographic priming effects

Correlations between the size of the masked orthographical priming effect (i.e., difference in RTs and accuracy, between the TL-C and RL-C conditions) and the performance in offline behavioural measures: a) reading comprehension, b) vocabulary c) phonological processing, d) speechreading ability and e) fingerspelling ability, are shown in Table 23. Significant positive correlations were found between the size of the masked orthographic effect in accuracy and both vocabulary and reading. The larger the vocabulary, and the better the reading skills, the larger orthographic effect, suggesting greater use of orthographic information during SWR. However, it is important to remember that this is a small sample of deaf readers of English, and some of them did not show any difference in their responses between TL and RL prime in accuracy (See Figures 45 and 46).

Table 23. Correlations with offline behavioural measures and the size of the masked orthographic priming effect in RT (left) and accuracy (right), in deaf adult readers of English.

Offline measures		Size of the masked orthographic priming effect in:	
		RT	Accuracy
Reading Comprehension (% correct)	r	.09	.61
	p	.761	.025*
Speechreading Ability Test (% correct)	r	.31	.37
	p	.331	.241
Vocabulary Test (% correct)	r	.22	.63
	p	.498	.029*
Fingerspelling Ability Test (% correct)	r	-.17	-.39
	p	.597	.216
Rhyme judgement task (% correct)	r	.45	.14
	p	.145	.667

*(+) p < .07, * p < .05, ** p < .01, *** p < .001*

Note . Size of the masked orthographic priming effect (in RT and Accuracy) = TL-C - RL-C priming condition. After Bonferroni correction no correlations were significant.

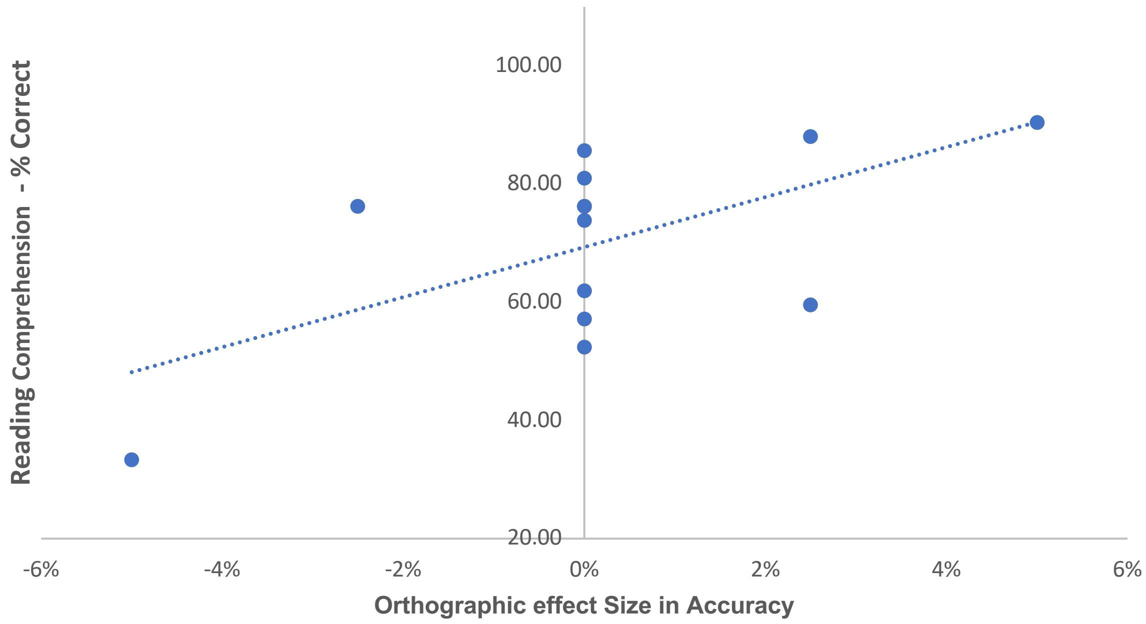


Figure 45. Correlation between the Size of the masked Orthographic Priming Effect in RT (x-axis) and Reading Comprehension (y-axis) in deaf adult readers of English.

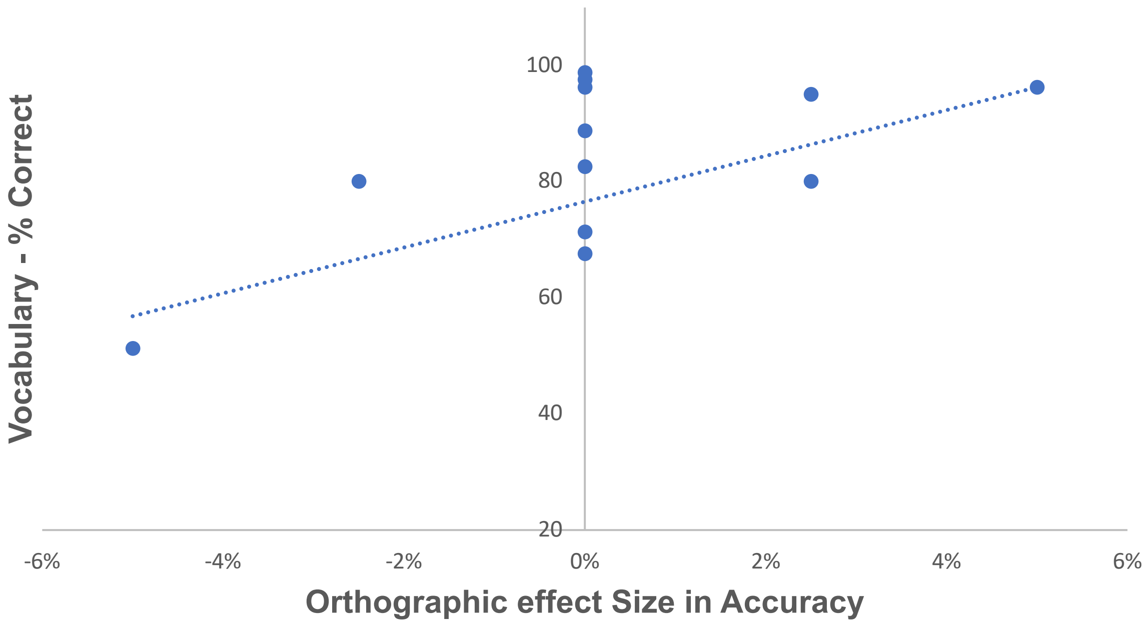


Figure 46. Correlation between the Size of je masked Orthographic Priming Effect in Accuracy (x-axis) and Vocabulary (y-axis) in deaf adult readers of English.

6.2.2. Adult deaf readers of Spanish

The conditions included in this sandwich masked orthographic priming experiment no.5, were those where the target was preceded by a transposed letter consonant (TL-C) and by a replaced letter consonant (RL-C) prime. Additionally, transposed letter vowel and replaced letter vowel conditions were included in this Experiment 5. Given that TL-C effect provides a more precise information of the use or orthographic codes (Comesaña et al., 2016; Perea & Lupker, 2004), the condition of interest here were TL-C and RL-C.
For the participants to be able to perform a lexical decision task, the experiments included equal number of words (n=120) and pseudowords (n=120). The pseudowords were preceded by all four types of prime. Similar to previous experiments, only the targets words were analysed here as masked priming in pseudowords non-words tends to be negligible.

6.2.2.1. Methods

6.2.2.1.1. Participants

The participants were the same than in Experiment 2, except for one that did not complete this experiment and one new participant that had not completed Experiment 3 (n=16, 10 female). This study was approved by the University College

London Research Ethics Committee (Project ID Number 10991/001). Participants were asked to provide written consent at the beginning of the sessions. Instructions were given in LSM and in written and were told that they could withdraw at any time. All participants were profoundly or severely deaf from birth, did not report history of neurological or psychiatric impairments, and had normal or corrected to normal vision. Four participants were native signers of Mexican Sign Language (Lengua de Señas Mexicana: 'LSM'). Three had learned LSM from teachers and friends before the age of 9, and 9 learned LSM between 12 and 15 years old. Participants rated their LSM skills (Likert scale from 1 to 7). Eleven participants considered themselves skilled signers (self-ratings = 6-7), four medium skilled signers (self-ratings = 4-5) and one with poor signing skills (self-ratings < 4). Three participants had completed secondary school (i.e., year 7 to 9, year one starts at 6 years old). Eight participants completed high school (i.e., year 10 to 12). Four participants had a bachelor's degree, and one a master's degree. All participants reported to have always attended mainstream schools and all of them received literacy training using a phonological (i.e., syllabic) method.

6.2.2.1.2. Offline behavioural measures

Table 24 shows the average scores in the offline behavioural tasks (as described in section 6.1.1.1.2) for this group of participants. See table 25 for correlations between these measures, in order to better describe the sample of participants (see figures 47 and 48 and section 6.2.1. for the rest of the plots with significant correlations, as the participants are the same in both experiments). All participants had non-verbal IQ above 85 and their reading comprehension score was above 50%.

Table 24. Participant's characteristics and test scores of the deaf adult readers of Spanish.

	Mean (SD)	**Range**
Age (Yrs, mths.)	30,91 (9.8)	(21,7-61,4)
Reading Comprehension (% correct)	66% (13)	(50%-87.5%)
Sentence Reading (% correct)	88% (11)	(68.8%-100%)
Vocabulary Test (% correct)	69% (17.2)	(45.6%-98.5%)
Phonological Processing (visual bias index)	17 (15.44)	(-5- 44)
Speechreading Ability Test (% correct)	65% (26.8)	(17.5%-98.3%)
Fingerspelling Test (% correct)	86% (21.1)	(30%-100%)
NVIQ (Standardised score)	109.19 (9.74)	(91-125)

Table 25. Correlations between offline behavioural measures in deaf adult readers of Spanish.

	Reading Comprehension	Vocabulary Test	Phonological Processing	Speechreading Ability Test	Fingerspelling Test	NVIQ
Sentence Reading	.66**	.72**	-.54(+)	.62*	.26	.09
Reading Comprehension		.57*	-.55(+)	.79**	.26	-.07
Vocabulary Test			-.71**	.60*	.53*	.02
Phonological Processing				-.54(+)	-.62*	-.23
Speechreading Ability Test					.43	-.19
Fingerspelling Test						.30

*(+) p < .052, *p < .05, **p < .01, *** p < .001*

Note: After Bonferroni correction there were no significant correlations.

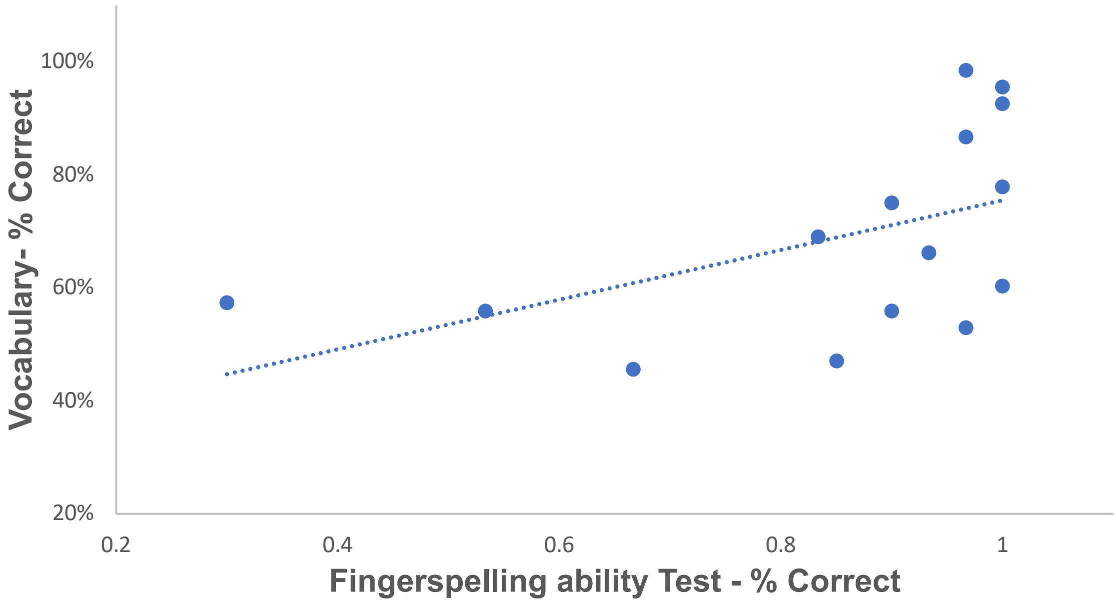


Figure 47. Correlation between Fingerspelling ability Test (x-axis) and Vocabulary (y-axis) in deaf adult readers of Spanish.

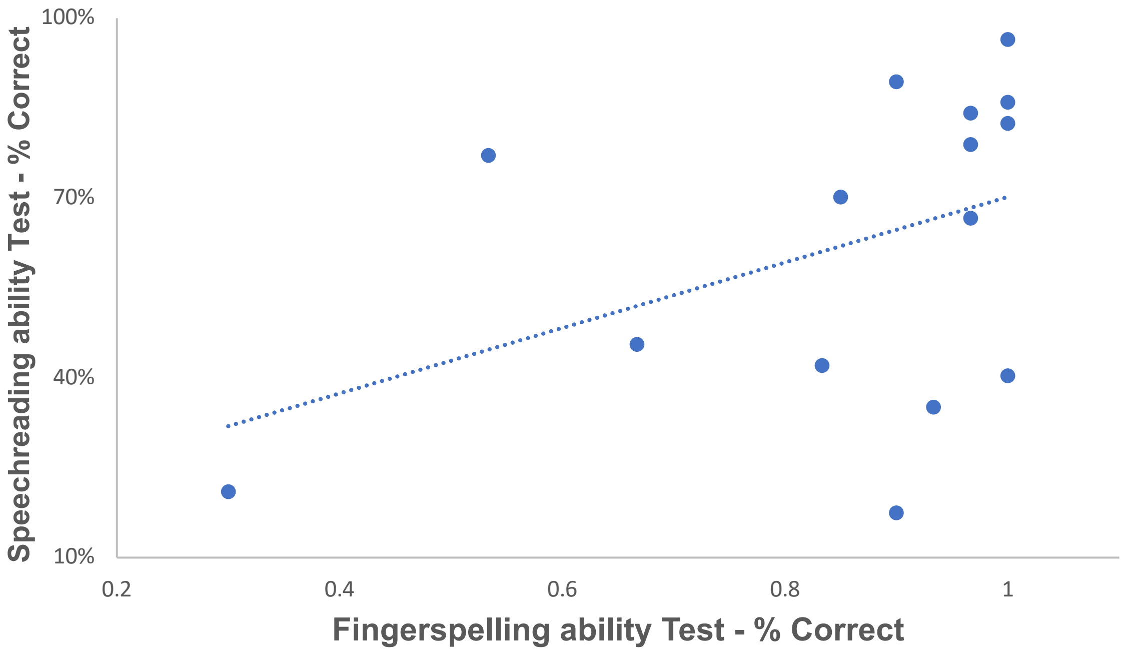


Figure 48. Correlation between Fingerspelling ability Test (x-axis) and Speechreading ability Test (y-axis) in deaf adult readers of Spanish.

6.2.2.1.3. Materials

One hundred and twenty words and 120 matched pseudowords targets were used in this Experiment no.5. Stimuli from a similar study with hearing young and adult readers of Spanish (see Comesaña et al., 2016) were searched in the Mexican lexical database “Lexmex” (Silva-Pereyra et al., 2014). Thirteen words were replaced with the same characteristics (i.e., length, frequency, syllable structure) due to their extremely low frequency in Mexican Spanish (See Appendix no. H). The mean of word frequency per million in the Lexmex database was 52 (range: 0.40–744.51, SD = 101.43). Each word and pseudoword was between 7 and 12 letters long (M = 9.38, SD = 1.28).

The target words were preceded by one of four possible primes (see Table 26): 1) a transposed-letter (TL-C) pseudoword created by transposing two non-adjacent consonants; 2) a replacement-letter (RL-C) pseudoword by replacing the transposed letters consonants; 3) a transposed-letter pseudoword (TL-V) created by transposing two non-adjacent vowels, 4) a replacement-letter pseudoword (RL-V) by replacing the transposed letters vowels. See an example of each prime condition in Table 26. The replaced letters kept the ascending or descending letter shape of the letters transposed condition.

Table 26. Example stimuli. See the target word (on the left) followed by its 4 prime conditions.

	PRIME CONDITIONS			
Target word	Transposed-letter Consonant (TL-C)	Replacement-letter Consonant (RL-C)	Transposed-letter Vowel (TL-V)	Replacement-letter Vowel (RL-V)
ANIMALES	aminales	arivales	anamiles	anemoles

The manipulation of the prime-target relationship was the same for words and pseudowords. The set of the experimental stimuli can be found in Appendix H. Four counterbalanced lists of materials were constructed in a Latin-square type. Therefore, each target appeared once in each list, but its prime was different across the four lists. For example, if a target word was preceded by the TL-C prime condition in “List 1”, then in “List 2” the same target word was preceded by the RL-C prime condition, in “List 3” by the TL-V prime condition, and finally in “List 4” by the RL-V prime condition.

The comparisons were done between TL-C and RL-C prime conditions and between TL-V and RL-V prime conditions. The analysis only considers the target words, this is because pseudowords usually show extremely small or none masked priming effects.

6.2.2.1.4. Procedure

Participants were tested individually in a quiet room. A MacBook (Retina, 12-inch, Early 2015) was used to display the stimuli using PsychoPy (Peirce, 2007), software written in Python which was used to present the stimuli and to save the outputs of the experiment. The procedure followed was the same as in Experiment 4 for the conditions described above. Figure 49 shows the sequence of events in each trial.

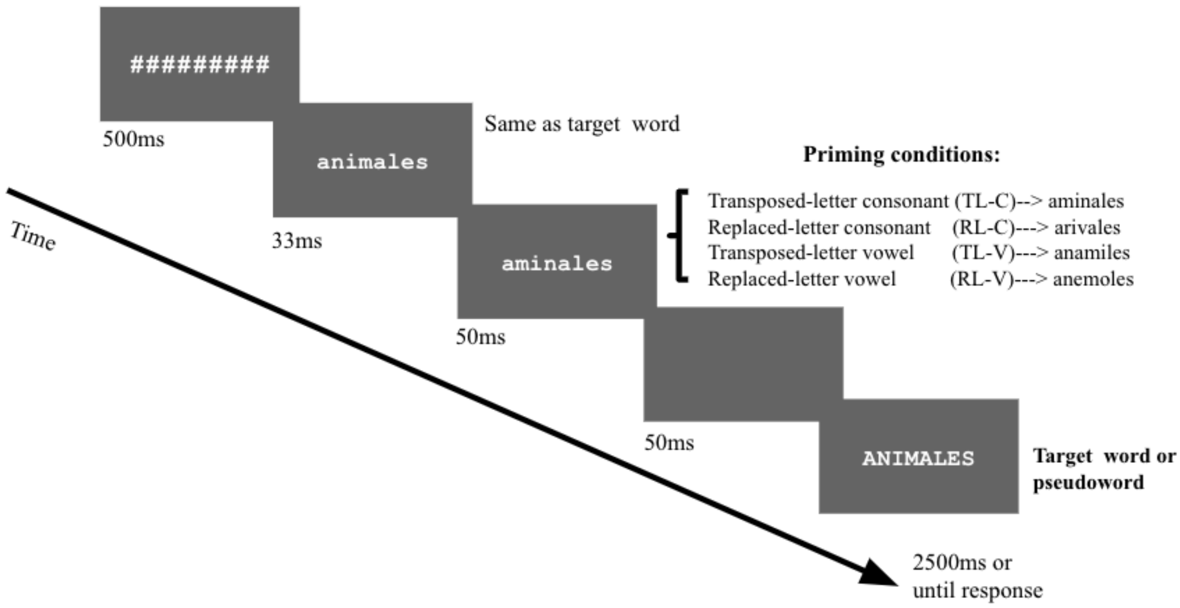


Figure 49. Description of events in an Orthographic Sandwich Masked Priming paradigm trial and experimental conditions for adult and young readers of Spanish.

6.2.2.2. Results – deaf adult readers of Spanish

From the 120-word items used in this experiment, six items with the accuracy below 58% were removed from the analyses (see Appendix H for the list of stimuli included in the analyses). Therefore, one hundred and fourteen items were included in the analyses, (Mean = 88%, SD = 11.19). As before, we first looked into the differences between words and pseudowords. Then, a paired-samples t-test was performed contrasting the two conditions of interest TL-C vs RL-C for the orthographic priming effects both on the subjects (t_1) and items (t_2) scores. Same analysis was used to contrast the other two conditions: TL-V vs RL-V. The RT analysis was performed only on correct trials of word targets.

6.2.2.2.1. Lexicality effect and Orthographic masked priming effects

Lexicality effect - A separate paired-samples t-tests for the RTs and the accuracy data showed a significant lexicality effect in RTs (slower responses to pseudowords than words) by subject and by item analyses; (1174.71ms vs 1362.09ms); $t_1(30) = -2.10$, $p = .044$; $t_2(226) = -5.26$, $p < .001$. There was significant difference in accuracy between words and pseudoword only in the analyses by item, (88% vs 83%); $t_1(30) = .705$, $p = .486$; $t_2(226) = 3.08$, $p = .002$.

Orthographic masked priming effect - Transposed Letter Consonant To test for the effect of masked orthographic priming we performed a separate paired-samples t-tests for the RTs and accuracy contrasting the TL-C vs TL-R prime conditions (see Table 27 and Figures 50 and 51). Analysis of the RTs showed that participants were faster to respond to targets preceded by TL-C primes than preceded RL-C primes (1048.34ms vs. 1095.48ms); $t_1(15) = -2.14$, $p = .041$; $t_2(113) = -1.36$; $t_2(113) = -1.36$, $p = .178$. Accuracy data showed that participants were significantly more accurate in the RL-C than the TL-C condition, (86% vs 89%); $t_1(15) = -2{,}27$, $p = .039$; $t_2(113) = -1.29$, $p = .199$.

Orthographic masked priming effect - Transposed Letter Vowel - Separate paired-samples t-tests showed no difference in the responses between TL-V and RL-V condition neither in the RTs (1150.60ms vs. 1104.31ms); $t_1(15) = -1.83$, $p = .088$; $t_2(113) = -1.61$, $p = .111$, nor in accuracy (89% vs 88%); $t_1(15) = .600$, $p = .558$; $t_2(113) = .549$, $p = .584$, (see table 27).

Table 27. Mean lexical decision times (RTs in ms, upper quadrants), and percentage accuracy (lower quadrants) for each experimental condition: Transposed-letter consonant (TL-C) and Replaced-letter consonant (RL-C) prime conditions (left) and Transposed-letter vowel (TL-V) and Replaced-letter vowel (RL-V) prime conditions (right), in deaf adult readers of Spanish.

Orthographic Effect

Transposed-letter Consonant		**Transposed-letter Vowel**	
	RT	**RT**	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
TL-C primes	1048.43 (295.33)	1050.60 (286.94)	TL-V primes
RL-C primes	1095.48 (331.34)	1104.31 (354.96)	RL-V primes
difference	**-47.06***	**-53.72(+)**	**difference**
	Accuracy	**Accuracy**	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
TL-C primes	86% (16.4)	89% (14.3)	TL-V primes
RL-C primes	89% (13.9)	88% (16.2)	RL-V primes
difference	**-3%***	**-1%**	**difference**

(+) p = .088, * $p < .05$, ** $p < .01$, *** $p < .001$

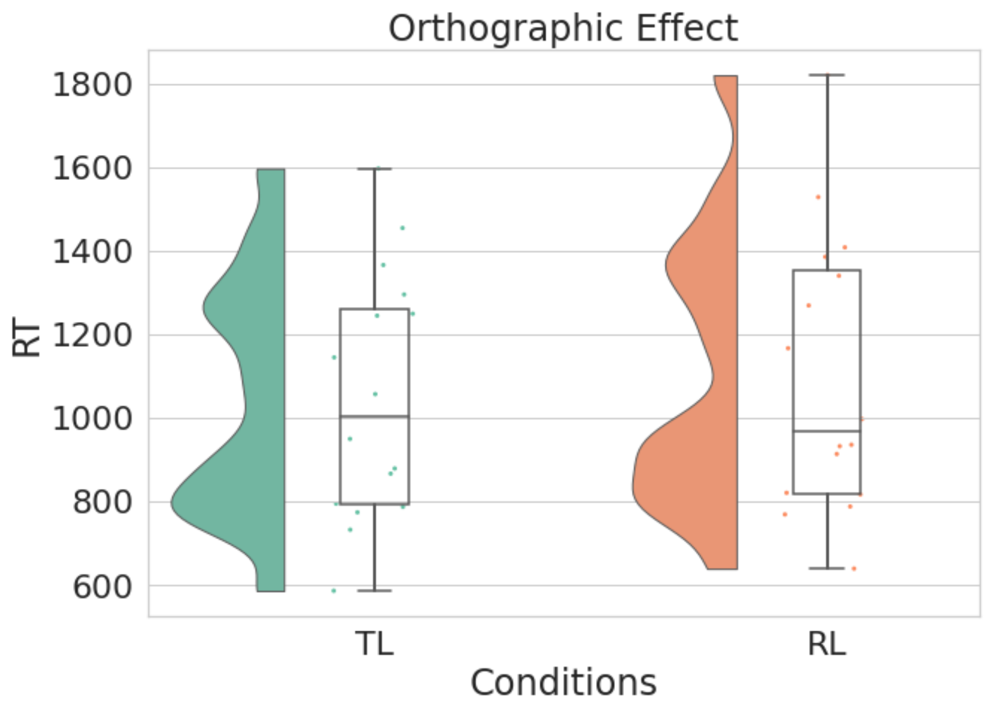


Figure 50. Response times (RT) for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in deaf adult readers of Spanish.

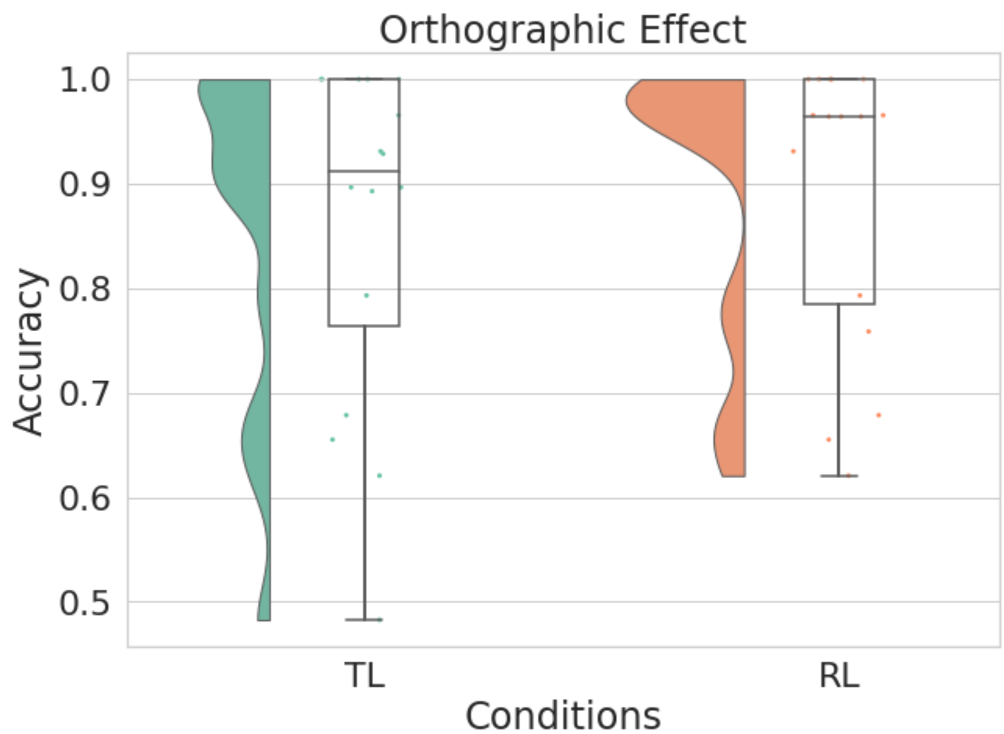


Figure 51. Accuracy of correct responses for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in deaf adult readers of Spanish.

Correlations between offline behavioural measures and masked priming effects

Transposed letter – Consonant -The size of the orthographic masked priming effect in RTs (i.e., difference between the TL-C and RL-C conditions) was significantly positively correlated with vocabulary. However, visual inspection of the scatterplot does not show a clear relationship (See Figure 52). No other correlations were seen with the rest of the offline behavioural measures, (reading tests, phonological processing, speechreading and fingerspelling abilities), all ps > .327. The size of the orthographic masked priming TL-C effects in accuracy was not correlated with any of the offline behavioural measures (all *p*s > .096, see table 28).

Transposed letter – Vowel - The size of the orthographic masked priming (TL-V) effect when tested using a transposed vowel in RTs was significantly correlated to Vocabulary ($r = .54$, $p = .030$) The size of the orthographic masked priming TL-V effect in accuracy was not correlated to any of the other offline behavioural measures (all ps > .085).

Table 28. Correlations with offline behavioural measures and the size of the masked orthographic priming effect (TL-C) in RT (left) and accuracy (right), in deaf adult readers of Spanish.

Offline measures		Size of the masked orthographic priming effect in:	
		RT	Accuracy
Sentence Reading. (% correct)	r	.04	.38
	p	.888	.152
Reading Comprehension (% correct)	r	-.17	.372
	p	.526	.156
Phonological Processing (visual bias index)	r	-.09	-.22
	p	.781	.472
Vocabulary Test (% correct)	r	.50*	.24
	p	.050	.376
Speechreading Ability Test (% correct)	r	-.01	.43
	p	.982	.096
Fingerspelling Ability Test (% correct)	r	-.28	-.10
	p	.327	.734

** $p < .05$, ** $p < .01$, *** $p < .001$*

Note . Size of the masked orthographic priming effect (in RT and Accuracy) = TL-C - RL-C priming condition.

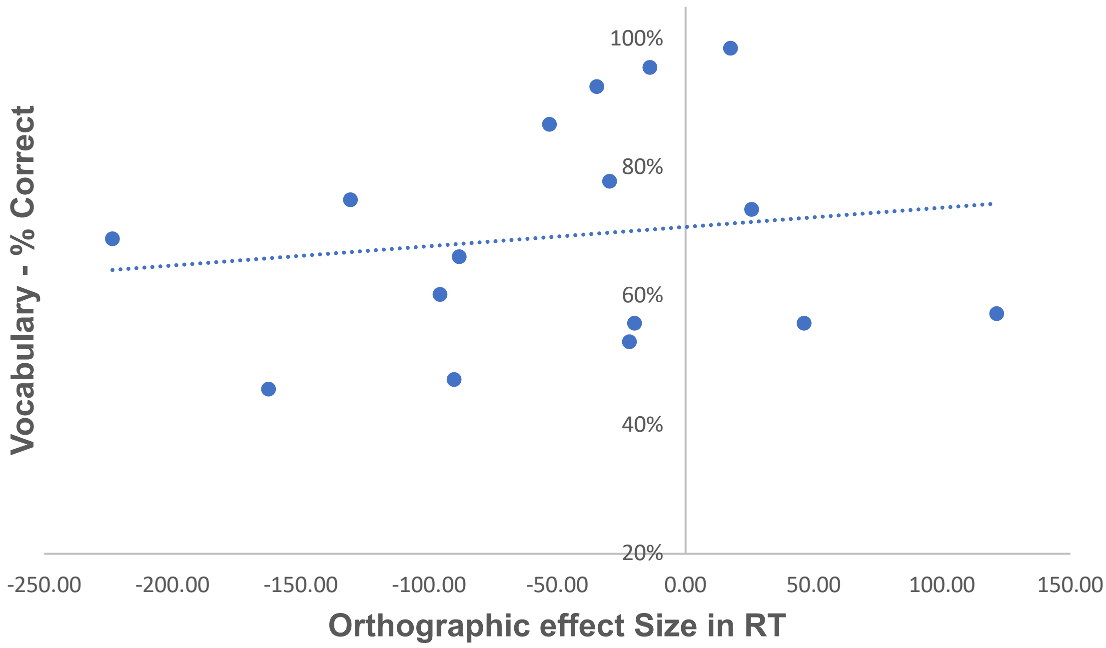


Figure 52. Correlation between the Size of the masked Orthographic Priming Effect in RT (x-axis), and Vocabulary (y-axis) in deaf adult readers of Spanish.

6.2.3. Young deaf readers of Spanish

6.2.3.2. Methods

6.2.3.1.1. Participants

Same participants as in Experiment 3, except for two that did not complete this Experiment 6 and one new participant that did not complete Exp. 3. (n=54, 20 female). Participants were profoundly or severely deaf from birth, did not report history of neurological or psychiatric impairments, and had normal or corrected to normal vision. Nine participants were native signers of Mexican Sign Language (Lengua de Señas Mexicana: 'LSM'). Thirty-six had learned LSM from teachers and friends before the age of 9, and nine learned LSM between 12 and 15 years old. Participants rated their MSL skills (Likert scale from 1 to 7). Twenty-one participants considered themselves skilled signers (self-ratings = 6-7), twenty-eight medium skilled (self-ratings = 4-5) and five with poor sign skills (self-ratings < 4). Thirty-two participants were in secondary school (i.e., year 7 to 9, year one starts at 6 years old) and twenty-two participants were in high school (i.e., year 10 to 12). All participants reported to have always attended mainstream schools and all of them received literacy training on a phonological (i.e., syllabic) method. This study was approved by the University College London Research Ethics Committee (Project ID Number 10991/001). Parental consent was obtained for participants younger than 18 years old. Participants older 18 years old they were asked to provide written consent at the beginning of the sessions. Instructions were given in LSM and in written Spanish.

6.2.3.1.2. Offline behavioural measures

Table 29 shows the average scores in the offline behavioural tasks (as described in section 6.1.1.1.2) for this group of participants. In order to better describe the group of young deaf readers, see table 30 for correlations between these measures (see figure 53 and section 6.2.3. for the rest of the plots with significant correlations, as the majority of the participants took part in both experiments). All participants had non-verbal IQ above 85 and their reading comprehension score was above 50%.

Table 29. Participants' characteristics and test scores of the young deaf readers of Spanish.

	Mean (SD)	Range
Age (Yrs, mths.)	16,4 (2.5)	(11,6-21,7)
Reading Comprehension (% correct)	40% (20)	(10%-82.50%)
Sentence Reading (% correct)	63% (18.9)	(17%-100%)
Vocabulary Test (% correct)	45% (14)	(18%-74%)
Phonological Processing (visual bias index)	21 (19)	(-43 - 50)
Speechreading Ability Test (% correct)	20% (20.8)	(2%-86%)
Fingerspelling Test (% correct)	74% (18.4)	(33%-100%)
NVIQ (Standardised score)	115.85 (13.5)	(88-142)

Table 30. Correlations between offline behavioural measures in young deaf readers of Spanish.

	Reading Comprehension	Vocabulary Test	Phonological Processing	Speechreading Ability Test	Fingerspelling Test	NVIQ
Sentence Reading	.69***	.71***	.14	.59***	.68***	.33*
Reading Comprehension		.61***	.05	.60***	.65***	.43***
Vocabulary Test			.06	.62***	.71***	.43***
Phonological Processing				-.06	.14	.15
Speechreading Ability Test					.45***	.24(+)
Fingerspelling Test						.41**

*(+) p < .08, *p < .05, **p < .01, *** p < .001*

Note. After Bonferroni correction there were no significant correlations.

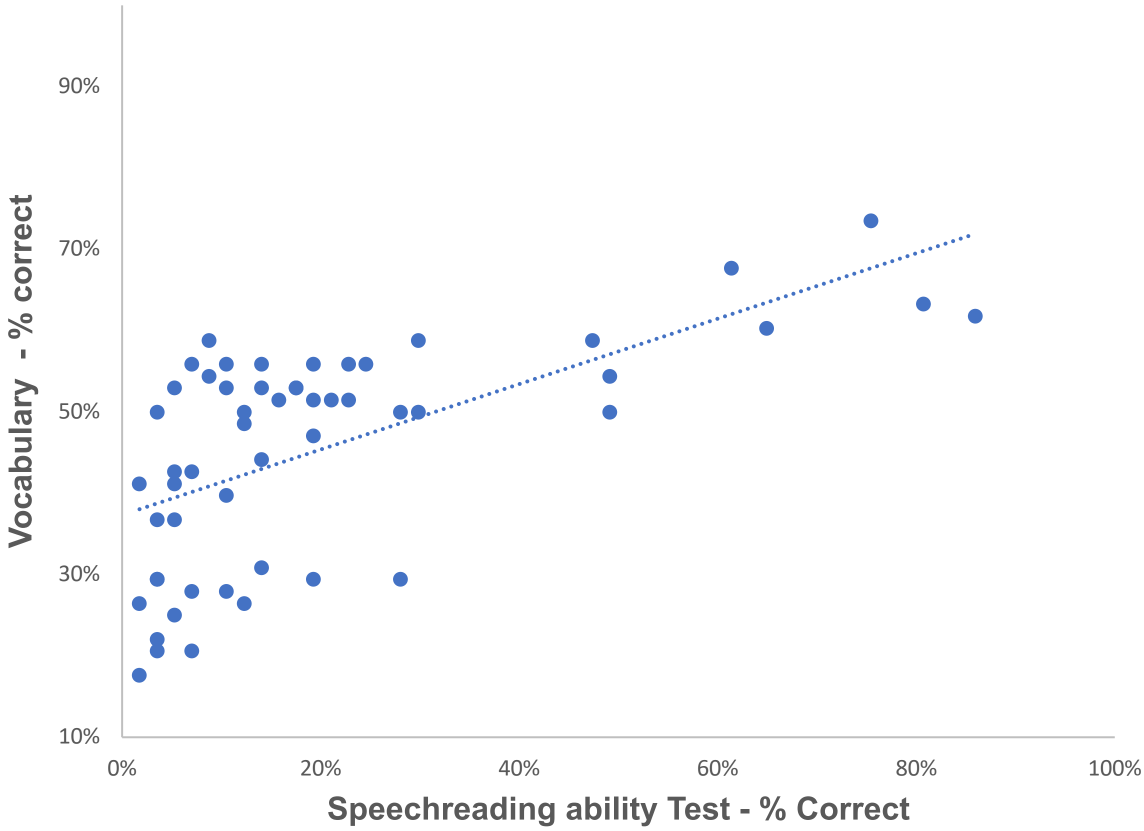


Figure 53. Correlation between Speechreading ability Test (x-axis) and Vocabulary (y-axis) in in young deaf readers of Spanish.

Materials

The materials that were the same as in Experiment 5, (see above, section '6.2.2.1.3. Materials').

6.2.3.1.3. Procedure

The procedure was the same as in Experiment 5 (See section: '6.2.2.1.4. Procedure', Figure 17 shows the sequence of events in each trial).

6.2.3.2. Results – Young deaf readers of Spanish

A total of 87 items were included in this analysis after removing 33 words items that had accuracy below 58% (See appendix H for the items included in the analysis). The same statistical analyses performed with the data from the adult deaf readers studies were performed here (see section '6.1.1.1. Deaf adult readers of Spanish'). The mean lexical decision times and percentage of correct responses per condition are displayed in Table 30.

6.2.3.2.1. Lexicality effect and Orthographic masked priming effects

Lexicality effect - Separate paired-samples t-tests for the RTs and the accuracy data showed that responses to words were faster than to pseudowords targets. This was significant in the analyses by-item; (1175.64ms vs 1248.31ms); $t_1(106) = -1.20$, $p = .237$; $t_2(172) = -5.51$, $p < .001$. Young deaf readers were significantly better at rejecting nonwords than words, this was significant in the analyses by-item, (64% vs 70%); $t_1(106) = -1.42$, $p = .158$; $t_2(172) = -3.47$, $p < .001$.

Orthographic masked priming effect (Transposed Letter Consonant)

Paired-samples t-tests showed no differences between the TL-C and the RL-C condition (see Table 31 and Figures 54 and 55) in RTs (1173.75ms vs. 1202.53ms); $t_1(53) = -1.30$, $p = .199$; $t_2(86) = -1.21$, $p = 231$, nor in accuracy (64% vs 63%); $t_1(53) = .86$, $p = .392$; $t_2(86) = .76$, $p = .452$.

Orthographic masked priming effect (Transposed Letter Vowel) - Separate paired-samples t-tests for the RTs and the accuracy data showed no difference in the responses between TL-V and RL-V condition for RTs (1151.18ms vs. 1172.60ms); $t_1(53) = -.69$, $p = .496$; $t_2(86) = -.773$, $p = .441$, nor in accuracy (65% vs 66%); $t_1(53) = -.74$, $p = .465$; $t_2(86) = -.80$, $p = .425$.

Table 31. Mean lexical decision times (RTs in ms, upper quadrants), and percentage accuracy (lower quadrants) for each experimental condition: TL-C and RL-C primes (left), and TL-V and RL_V primes (right), in young deaf readers of Spanish.

Orthographic Effect

Transposed-letter Consonant		**Transposed-letter Vowel**	
	RT	**RT**	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
TL-C primes	1173.75 (374.40)	1151.18 (337.60)	TL-V primes
RL-C primes	1202.53 (355.50)	1172.60 (345.44)	RL-V primes
difference	**-28.78**	**-21.42**	**difference**
	Accuracy	**Accuracy**	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
TL-C primes	64% (25.4)	65% (25.9)	TL-V primes
RL-C primes	63% (25.9)	66% (24.5)	RL-V primes
difference	**1%**	**-1%**	**difference**

* $p < .05$, ** $p < .01$, *** $p < .001$

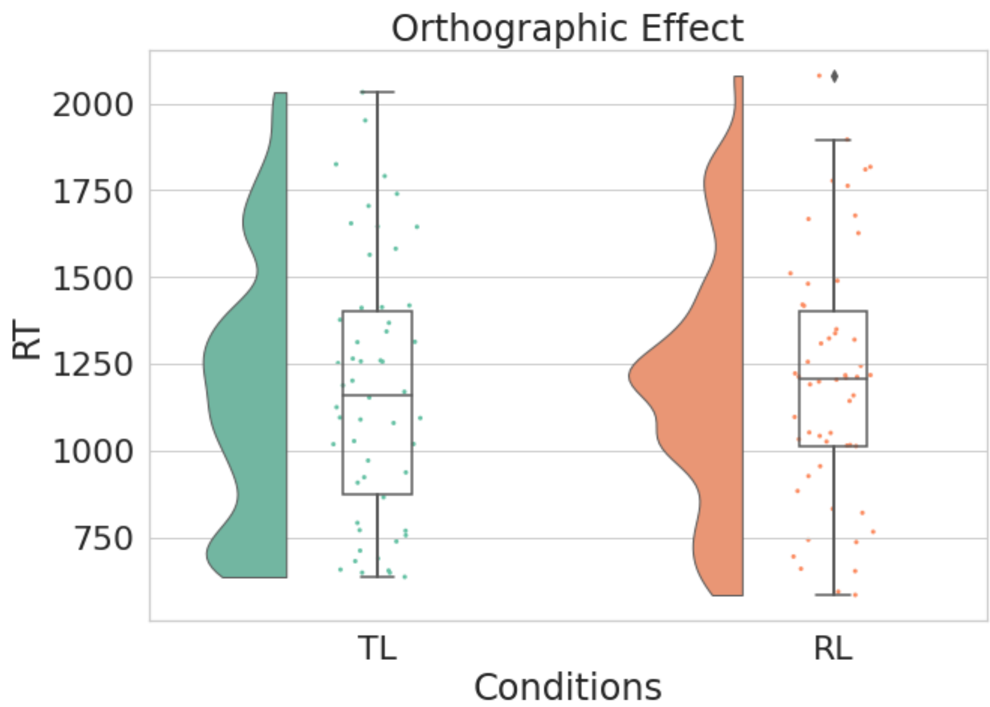


Figure 54. Response times (RT) for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in young deaf readers of Spanish.

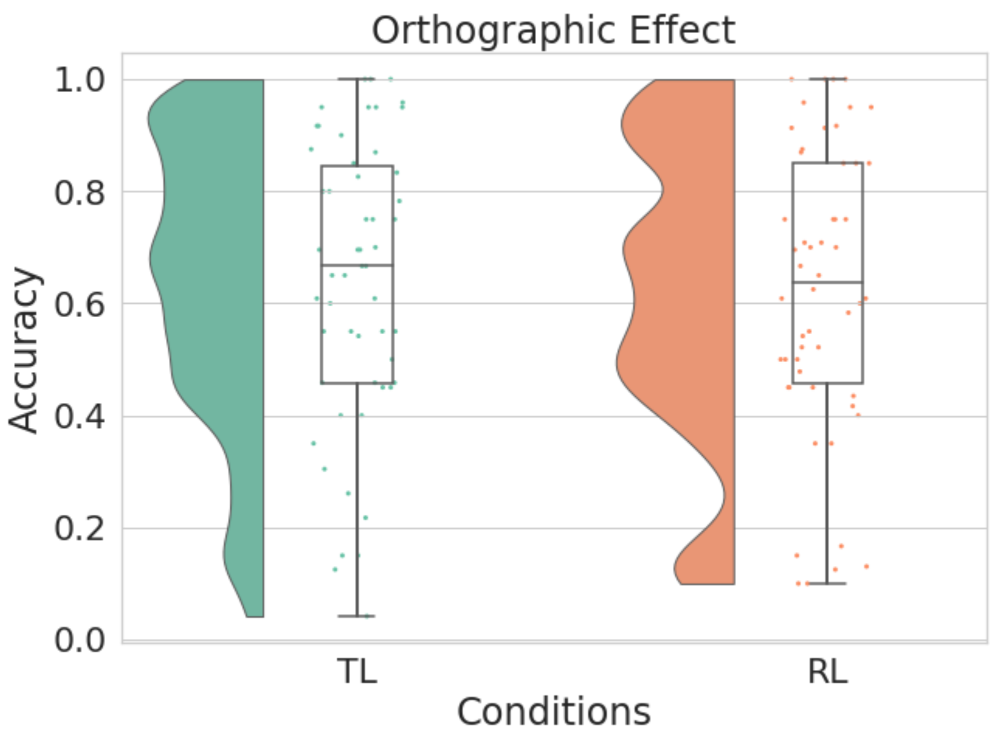


Figure 55. Accuracy of correct responses for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in young deaf readers of Spanish.

In the group of young deaf readers of Spanish there was a significant negative correlation between the size of the orthographic priming effect in RT and vocabulary (see Table 32 and Figure 56). This suggests that the larger the vocabulary, the larger the Transposed Letter effect, which is indicative of use of orthographic information during SWR. The same correlation analyses were performed in the two groups: Small Vocabulary Size (see Table 35), and Large Vocabulary Size (see Table 36).

Table 32. Correlations with offline behavioural measures and the size of the masked orthographic priming effect in RT (left) and accuracy (right), in young deaf readers of Spanish.

Offline measures		Size of the masked orthographic priming effect in:	
		RT	Accuracy
Sentence Reading. (% correct)	r	-.14	-.20
	p	.322	.150
Reading Comprehension (% correct)	r	-.07	-.12
	p	.597	.385
Phonological Processing (visual bias index)	r	-.07	-.04
	p	.641	.767
Vocabulary Test (% correct)	r	-.27*	-.07
	p	.045	.604
Speechreading Ability Test (% correct)	r	-.06	-.19
	p	.659	.178
Fingerspelling Ability Test (% correct)	r	-.27	-.16
	p	.052(+)	.255

*(+) p < .052, * p < .05, ** p < .01, *** p < .001*

Note. Size of the masked orthographic priming effect (in RT and Accuracy) = TL-C - RL-C priming condition.
After Bonferroni correction no correlations were significant.

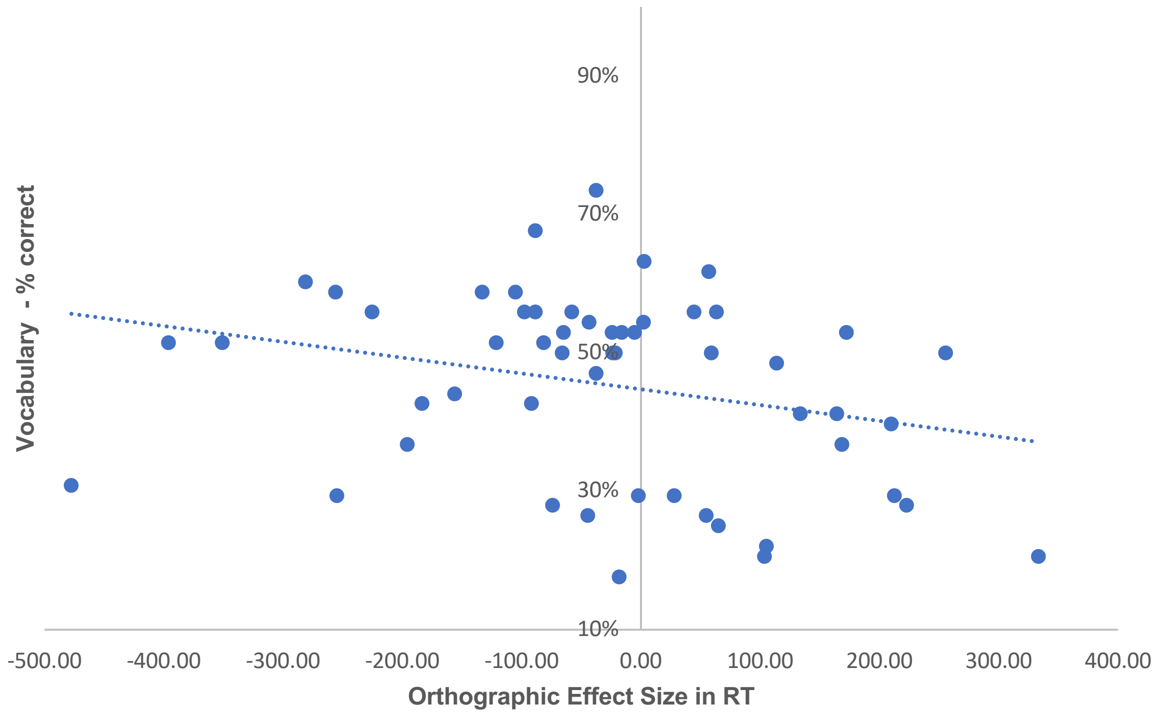


Figure 56. Correlation between the Size of the masked Orthographic Priming Effect in RT (x-axis), and Vocabulary (y-axis) in young deaf readers of Spanish.

The results from the previous sandwich masked experiment with young readers (see Experiment 3, section 6.1.3.), showed that groups with different vocabulary sizes processed words differently. Consistent with our findings, Andrews & Lo, (2012), had previously argued that other factors related to reading skill; such as vocabulary size, seem to affect the use of orthographic codes when recognising a word. Additionally, previous research have showed that experienced readers of Spanish make more use of orthographic than phonological codes to recognise single words (e.g., in hearing; Comesaña et al., 2016, Fariña et al., 2017, in deaf participants). Therefore, a split-half analyses was done to explore whether the orthographic effect was observed in the deaf young readers with small and large vocabulary sizes. The median of the group (50%) in the vocabulary test was used to split the group in two:

Small vocabulary (n= 28, Vocabulary Mean score = 36%, SD = 10.7) and Large vocabulary (n=26, Vocabulary Mean score = 56%, SD = 7.3). The same analyses described above for the whole group of young readers were performed for each group separately (see Table 32 for Small Vocabulary group and Table 33 for Large Vocabulary group).

Small vocabulary group

Lexicality effect – There was no lexicality effect for the small vocabulary group in RTs (1269.10ms vs 1264.29ms); $t_1(54) = .05$, $p = .960$; $t_2(172) = -.04$, $p = .966$. In accuracy data, young deaf readers with small vocabulary responded more accurately for nonwords than for words targets, only the item analyses showed significant difference, (54% vs 63%); $t_1(54) = -1.59$, $p = .119$; $t_2(172) = -4.79$, $p < .001$.

Orthographic masked priming effect (Transposed Letter Consonant) - There was no orthographic (TL-C) priming effect for this group in RTs (1302.47ms vs 1264.72ms); t_1 (27) = 1.36, $p = .184$; $t_2(86) = -.987$, $p = .327$, nor in accuracy (52% vs 51%); $t_1(27) = .43$, $p = .674$; $t_2(86) = 1.25$, $p = .215$ (See Table 32).

Orthographic masked priming effect (Transposed Letter Vowel) - There was no orthographic (TL-V) priming effect for this group in RTs (1215.61ms vs 1270.52ms; t_1 (27) = -1.24, $p = .226$; $t_2(86) = -.35$, $p = .730$, nor in accuracy (55% vs 58%), $t_1(27) = -1.23$, p = .229; $t_2(86) = -1.43$ $p = .156$ (See Table 32).

Table 33. Mean lexical decision times (RTs in ms, upper quadrants), and percentage accuracy (lower quadrants) for each experimental condition: TL-C and RL-C primes (left), and TL-V and RL_V primes (right), in young deaf readers of Spanish with Small Vocabulary Size.

Orthographic Effect

Transposed-letter Consonant		**Transposed-letter Vowel**	
	RT	**RT**	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
TL-C primes	1302.47 (413.86)	1215.61 (366.40)	TL-V primes
RL-C primes	1264.72 (422.00)	1270.52 (394.90)	RL-V primes
difference	**37.75**	**-54.91**	**difference**
	Accuracy	**Accuracy**	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
TL-C primes	52% (21.3)	55% (22.3)	TL-V primes
RL-C primes	51% (22.1)	58% (22.5)	RL-V primes
difference	**1%**	**-3%**	**difference**

* $p < .05$, ** $p < .01$, *** $p < .001$

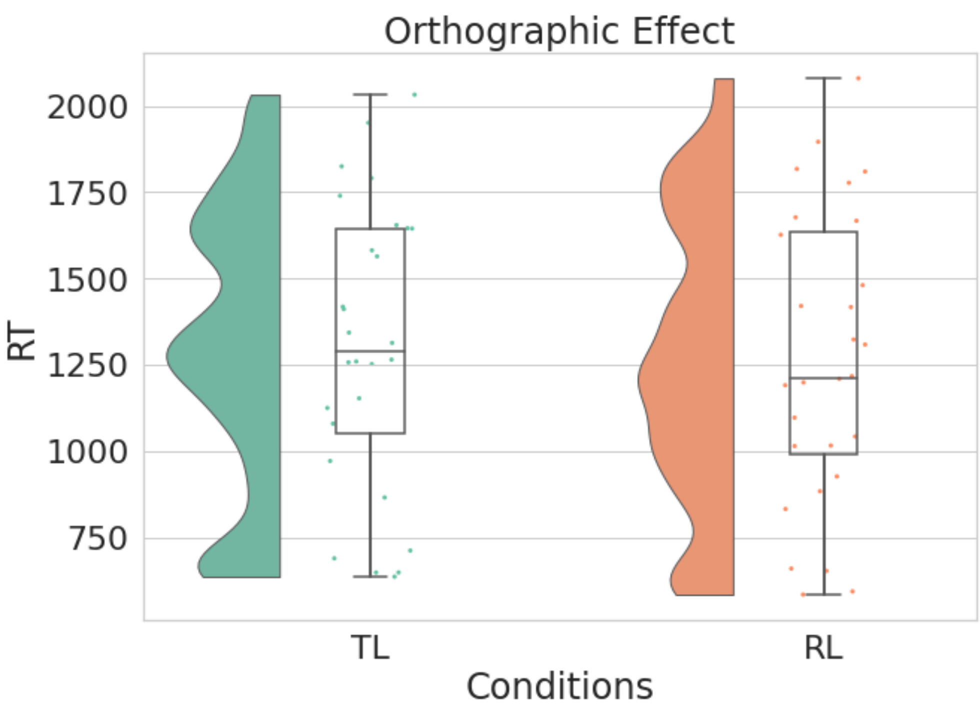


Figure 57. Response times (RT) for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in young deaf readers of Spanish with Small Vocabulary Size.

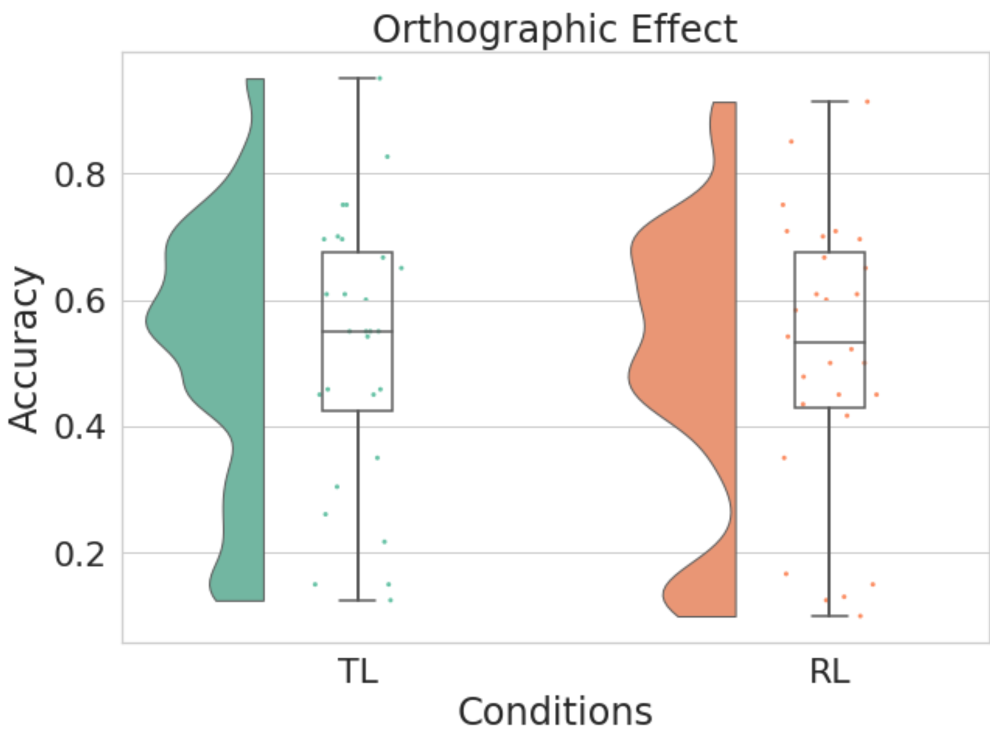


Figure 58. Accuracy of correct responses for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in young deaf readers of Spanish with Small Vocabulary Size.

Large vocabulary group

Lexicality effect – Separate paired-samples t-tests for the RTs and the accuracy data showed significant differences between words and pseudowords in RT; (1074.99ms vs 1231.11ms); $t_1(50) = -.2.16$, $p = .035$; $t_2\ (172) = -9.29$, $p < .001$. No difference in accuracy (75% vs 77%); $t_1(50) = -.465$, $p = .644$; $t_2\ (172) = -.12$, $p = .909$.

Orthographic masked priming effect (Transposed Letter Consonant) - Responses were significantly faster for the TL-C than for the RL-C prime condition only by-subject analyses (1035.13ms vs 1135.56ms); $t_1(25) = -3.34$, $p = .002$; $t_2(86) = -1.29$, $p = .200$.

There were no differences in accuracy (77% vs 75%), $t_1(25) = .84$, $p = .407$; $t_2(86) = -.47$, $p = .637$, (See Table 33).

Orthographic masked priming effect (Transposed Letter Vowel) - There was no difference between the TL-V and the RL-V prime conditions in RTs (1081.80ms vs 1067.15ms), $t_1(25) = .34$, $p = .740$; $t_2(86) = -.27$, $p = .790$, nor in accuracy (75% vs 74%), $t_1(25) = .28$, $p = .782$; $t_2(86) = .54$, $p = .591$, (See Table 34).

Table 34. Mean lexical decision times (RTs in ms, upper quadrants), and percentage accuracy (lower quadrants) for each experimental condition: TL-C and RL-C primes (left), and TL-V and RL_V primes (right), in young deaf readers of Spanish with Large Vocabulary Size.

Orthographic Effect			
Transposed-letter Consonant		**Transposed-letter Vowel**	
	RT	**RT**	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
TL-C primes	1035.13 (271.39)	1081.79 (294.94)	TL-V primes
RL-C primes	1135.56 (258.07)	1067.14 (249.49)	RL-V primes
difference	**-100.43***	**14.65**	**difference**
	Accuracy	**Accuracy**	
Type of prime	Mean (SD)	Mean (SD)	Type of prime
TL-C primes	77% (23.6)	75% (25.9)	TL-V primes
RL-C primes	75% (24.3)	74% (24.2)	RL-V primes
difference	**2%**	**1%**	**difference**

* $p < .05$, ** $p < .01$, *** $p < .001$

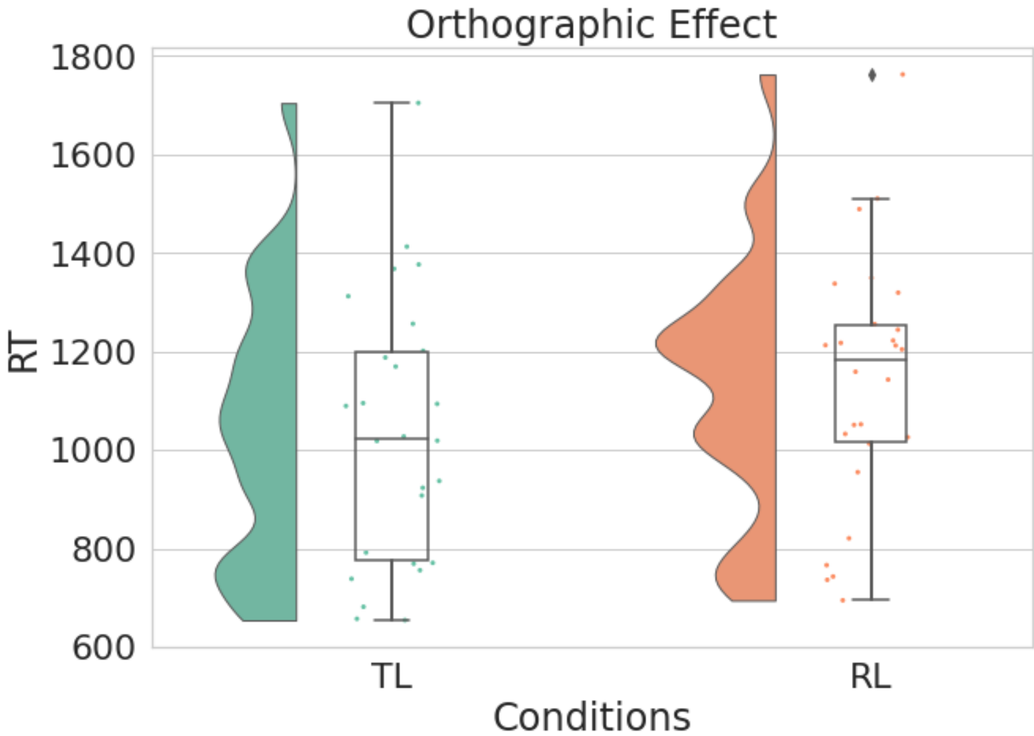


Figure 59. Response times (RT) for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in young deaf readers of Spanish with Large Vocabulary Size.

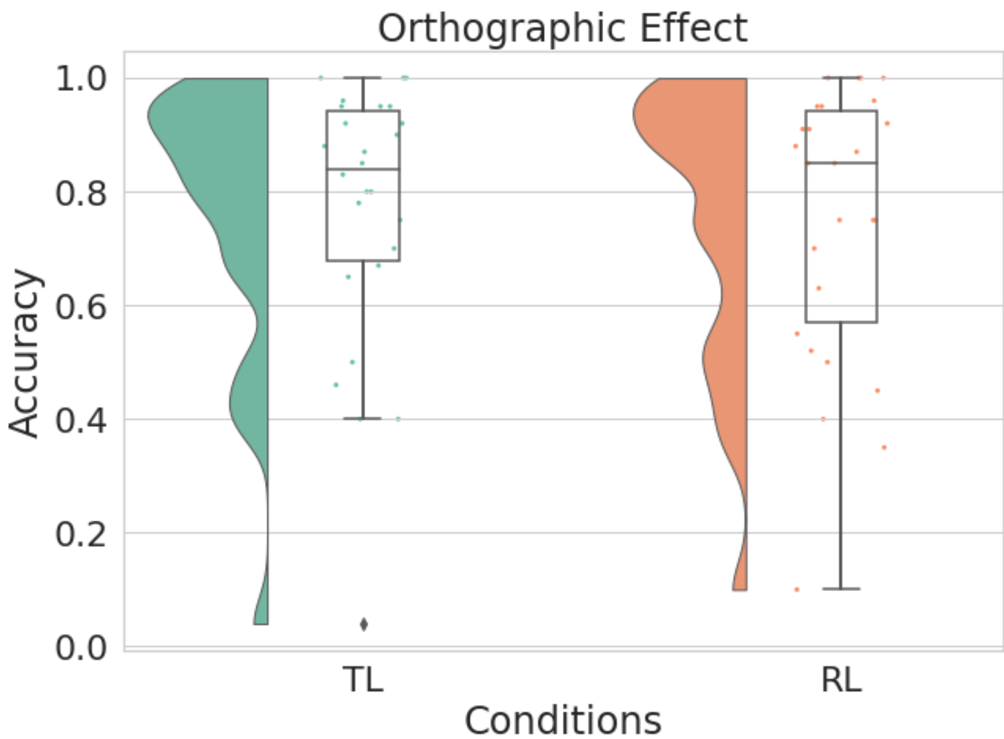


Figure 60. Accuracy of correct responses for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in young deaf readers of Spanish with Large Vocabulary Size.

Correlations between offline behavioural measures to masked priming

In the small vocabulary group, there were not significant correlations between the size of TL-Consonant priming effect (difference between the TL-C and RL-C conditions) with the offline behavioural measures, see table 34.

In the large vocabulary group, the size of TL-Consonant priming effect (difference between the TL-C and RL-C conditions) was positively correlated with vocabulary (see table 36, and Figure 61). This means that the larger the vocabulary the participants have the more affected they are by the TL prime when recognising words. Additionally, a negative correlation was found between Phonological Processing (this is negative because how the index was calculated; see section 6.1.2.1.2) and the size of the TL-C priming effect (See Figure 61). This correlation suggests that the larger the TL effect is, the less phonological codes were used by the participants, during the Phonological task (syllable counting).

The size of TL-Vowel masked priming effect (difference between the TL-V and RL-CV conditions) in RTs was significantly correlated to reading comprehension. In accuracy was also correlated to reading comprehension and to Phonological processing (visual bias index). However, these correlations were not significant after the Bonferroni correction.

Table 35. Correlations with offline behavioural measures and the size of the masked orthographic priming effect in RT (left) and accuracy (right), in young deaf readers of Spanish with Small Vocabulary Size.

Offline measures		Size of the masked orthographic priming effect in:	
		RT	Accuracy
Sentence Reading. (% correct)	r	.12	-.32
	p	.534	.101
Reading Comprehension (% correct)	r	.14	-.03
	p	.503	.882
Phonological Processing (visual bias index)	r	.31	.06
	p	.113	.777
Vocabulary Test (% correct)	r	-.15	-.26
	p	.434	.190
Speechreading Ability Test (% correct)	r	.26	-.14
	p	.183	.475
Fingerspelling Ability Test (% correct)	r	.06	-.32
	p	.776	.099

* $p < .05$, ** $p < .01$, *** $p < .001$

Note. Size of the masked orthographic priming effect (in RT and Accuracy) = TL-C - RL-C priming condition.

Table 36. Correlations with offline behavioural measures and the size of the masked orthographic priming effect in RT (left) and accuracy (right), in young deaf readers of Spanish with Large Vocabulary Size.

Offline measures		Size of the masked orthographic priming effect in:	
		RT	Accuracy
Sentence Reading.	r	.20	-.20
(% correct)	*p*	.332	.318
Reading Comprehension	r	.33	-.33
(% correct)	*p*	.100	.101
Phonological Processing	r	-.47*	-.19
(visual bias index)	*p*	.016	.352
Vocabulary Test	r	.42*	.07
(% correct)	*p*	.031	.743
Speechreading Ability Test	r	.13	-.31
(% correct)	*p*	.533	.118
Fingerspelling Ability Test	r	.17	-.20
(% correct)	*p*	.406	.326

* $p < .05$, ** $p < .01$, *** $p < .001$

Note. Size of the masked orthographic priming effect (in RT and Accuracy) = TL-C - RL-C priming condition.
After Bonferroni correction no correlations were significant.

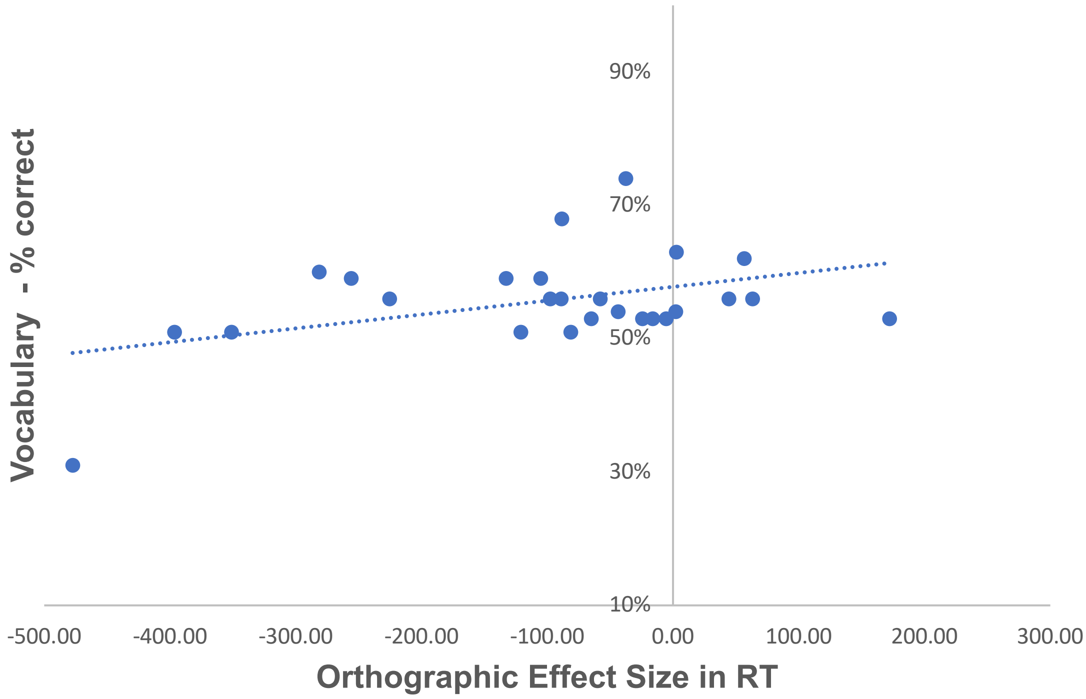


Figure 61. Correlation between the Size of the masked Orthographic Priming Effect in RT (x-axis), and Vocabulary (y-axis) in young deaf readers of Spanish with Large Vocabulary Size.

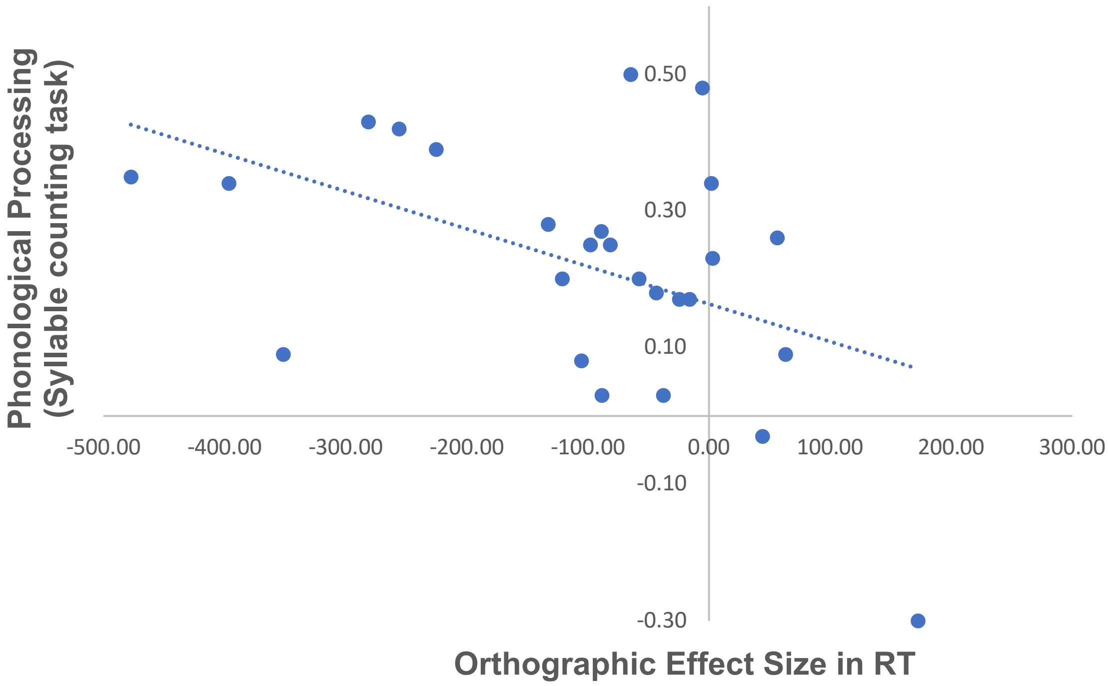


Figure 62. Correlation between the Size of the masked Orthographic Priming Effect in RT (x-axis), and Phonological Processing (Syllable counting task, y-axis) in young deaf readers of Spanish with Large Vocabulary Size.

6.2.4. Discussion

This subsection includes a brief discussion from the results from each experiment in section 6.2. For more detail see the General Discussion in Chapter 8.

Deaf adult readers of English

Significant masked orthographic priming effect in adults reading of English in response times was found, as predicted. This finding is consistent to Perea and Lupker (2004), Lupker et al., (2008), where participants showed some flexibility (i.e., less precise representation) in their orthographic processing, as they were influenced by the TL prime to respond quicker and better than the RL control in the LDT.

The size of the sandwich masked orthographic priming effect (i.e., difference in RTs and accuracy, between the TL-C and RL-C conditions) in accuracy correlates to reading comprehension and vocabulary as expected.

Deaf adult readers of Spanish

Consistent to Meade, et al., (2020) participants showed a sandwich masked priming orthographic effect on RTs. This shows that this paradigm is sensible to detect an automatic use of orthographic information in deaf, as it is in hearing readers (Comesaña et al., 2017). Interestingly, it was also found that deaf skilled readers of

Spanish were better when the target was preceded by the RL-C than by the TL-C (opposite direction to what it was predicted), this is discussed in more detail in the General Discussion (see Chapter 8).

Young deaf readers of Spanish

The groups of young and adult deaf readers of Spanish, showed a positive correlation with the size of sandwich masked orthographic priming (TL-C) and vocabulary. This supports what Meade and colleagues' (2020) mentioned, which TL priming effects are driven by individual differences in reading ability. As our participants with large vocabulary and more experienced readers showed more flexibility (less precise) in the orthographic representations than the group with small vocabulary size (e.g., no orthographic effects).

The young readers with large vocabulary showed an orthographic effect with TL-C in RTs. According to Andrews & Lo, (2012) and Meade et al., (2020) the transposed letter effects refers to a less precise orthographic representation in readers. Andrews & Jo, (2012), found in their study with hearing university students an orthographic effect in participants with low reading skills but no with extremely good reading skills. The authors mentioned that experienced readers had a more precise orthographic representation therefore they do not show an orthographic effect. Reading is developmental process, our group of young readers with large vocabulary were better readers than the young readers with small vocabulary size, however they did show an orthographic effect (less precise orthographic representation). Our findings were similar to Fariña's et al, (2017) where good readers were influenced by the TL prime and showed an orthographic effect.

The groups of young readers with large vocabulary and adult deaf readers, showed a clearly lexical effect ($p > .001$), readers showed an advantage of knowing the words over the pseudowords. Opposite to the young readers with small vocabulary that showed no lexicality effect. This could be explained as this group had small vocabulary; therefore, they knew less words.

Reading is a skill that with experience gets more visual through experience, therefore the access to orthography becomes more important role in skilled readers over the time. According to our results where adult deaf readers and young readers with large vocabulary showed an orthographic effect with TL-C in RTs, shows this process in the development of reading.

7. Fingerspelled word processing in deaf readers

The previous experimental chapter explored the automatic use of phonology (section 6.1) and orthography (section 6.2) using a masked priming sandwich paradigm during an LDT in deaf readers of English (adults) and Spanish (adults and young readers). In the current chapter, a total of six experiments were ran to explore the recognition of fingerspelled words in profoundly or severe deaf readers. Fingerspelled words were presented in isolation and participants were asked to do an LDT, (Experiments 7-9, Phonological processing of fingerspelled stimuli, section 7.1, and Experiments 10–12, Orthographic processing of fingerspelled stimuli, section 7.2).

7.1. Phonological Processing of fingerspelled words

In order to assess whether phonological information is used during fingerspelled word processing by deaf adults and adolescents, videos of words and pseudowords fingerspelled by a native signer were presented in isolation to deaf participants who completed an LDT. The same paradigm was used to test groups of readers in two languages with different orthographic depth (English vs. Spanish). Specifically, data was collected from adult deaf readers of English, adult deaf readers of Spanish and young deaf readers of Spanish. Data collection with deaf readers of English was interrupted by the COVID-19 pandemic.

The research questions addressed here are the following:

1. Do deaf readers use speech phonology during recognition of fingerspelled words? It was predicted that if deaf readers use speech phonology during recognition of fingerspelled words (e.g., clue), they should show slower lexical decision reaction times and more errors to pseudohomophones (e.g., klue) than to the orthographic control (e.g., plue), as participants would be more easily confused with their phonologically related words.

2. Is the size of a speech phonological effect related to reading, speechreading and fingerspelling skills? It was hypothesized that better readers, speechreaders and those with better fingerspelling skills will show a larger the phonological priming effect (defined as the difference between the pseudohomophone and the orthographic control condition in either RTs or accuracy).

Data are reported separately for deaf adult readers of English (7.1.1.), deaf adult readers of Spanish (7.1.2.) and finally by the young deaf readers of Spanish (7.1.3.).

7.1.1. Deaf adult readers of English

The conditions of interest in the present single word recognition phonological experiment with fingerspelled stimuli presented in isolation were the pseudohomophone and the orthographic control. The base word of these pseudowords (e.g., klue, plue, CLUE), was also included for the LDT to be possible. Therefore, half of the items that participants saw were words, the other half were pseudowords.

7.1.1.1. Methods

7.1.1.1.1. Participants

The same participants that took part in the written word masked priming experiments (see section 6.1.1) also took part in the current experiment, except for two; one was not a proficient signer, and the other one did not complete the experimental sessions. Therefore, twelve congenitally deaf adults who were users of BSL (6 female) participated in this experiment 7. All 12 participants were severely or profoundly deaf from birth. Their ages ranged from 23.52 to 53.14 years (M = 37.16, SD = 10.81). Five participants were native BSL signers, 5 participants were early signers (AoA between 3 and 9 years old), and the remaining 2 participants learnt BSL after the age of 9yrs and were considered late signers. Eleven participants were fluent signers of BSL (self-ratings 6-7, in a 1-7 Likert scale) and used BSL as their preferred means of communication in their daily lives. One participant rated their BSL proficiency at 4 and reported using English as their preferred form of communication. This study was approved by the University College London Research Ethics Committee (Project ID Number 10991/001). Instructions were given in BSL and written English. Participants were asked to provide written consent at the beginning of the sessions and were informed that they could withdraw at any time.

7.1.1.1.2. Behavioural measures

The performance of the twelve participants included in this experiment on Non-Verbal IQ, Sentence Reading, Speechreading ability, Fingerspelling ability, and Rhyme Judgement is reported in Table 37. All participants had non-verbal IQ above 85 and their reading comprehension score was above 33.3% correct responses.

Table 37. Participant characteristics and test scores of the adult deaf readers of English. For full details see section 6.1.1.1.2.

	Mean (SD)	**Range**
Age (Yrs, mths.)	37,16 (10.81)	(23,52-53,14)
Reading Comprehension (% correct)	67% (17.52)	(33%-90.5%)
Vocabulary Test (% correct)	80% (15.4)	(51.2%-98.8%)
Phonological Processing (Rhyme task) (% correct)	71% (16.9)	(51%-98%)
Speechreading Ability Test (% correct)	90.9% (7.3)	(74.2%-100%)
Fingerspelling Test (% correct)	88.3% (14.8)	(50%-100%)
NVIQ (Standardised score)	113.58 (9.09)	(100-139)

In order to better describe the sample of participants, correlations between the participant's scores in the above tasks were calculated (see Table 37). Significant correlations were found between vocabulary and reading comprehension; NVIQ and vocabulary; NVIQ and reading comprehension (see table 38, Figure 63)

Table 38. Correlations between measures of participant characteristics in deaf adult readers of English.

	Vocabulary Test	Phonological Processing	Speechreading Ability Test	Fingerspelling Test	NVIQ
Reading Comprehension	.94***	.39	.46	-.24	.63*
Vocabulary Test		.38	.44	-.12	.59*
Phonological Processing (Rhyme task)			.53	-.02	-.07
Speechreading Ability Test				.04	-.17
Fingerspelling Test					-.05

* *p* < .05, ** *p* < .01, *** *p* < .001

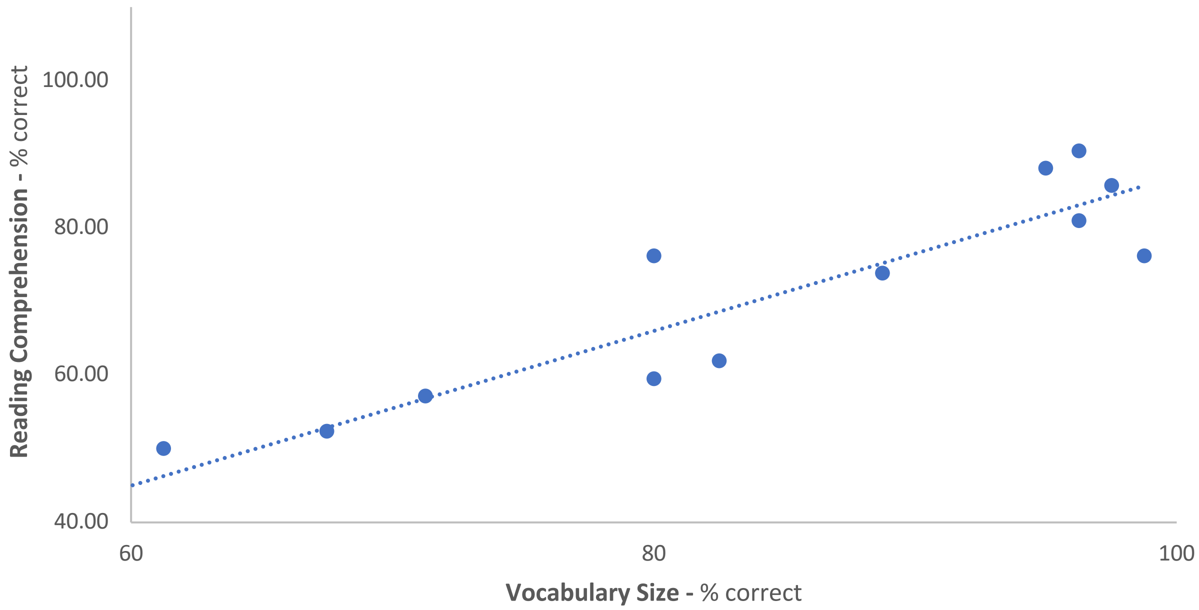


Figure 63. Correlation between Vocabulary Size (x-axis), and Sentence reading (y-axis) in deaf adult readers of English.

7.1.1.1.3. Materials

The current experiment included three stimulus sets: 160 fingerspelled words, 160 fingerspelled pseudohomophones and 160 fingerspelled orthographic controls. The stimuli were the same as used in the written word study (experiment 1). However only the pseudohomophones, orthographic control conditions, and their base word, were included here. See characteristics of the stimuli selection in section 6.1.1.1.3. Materials.

The stimuli were modelled by a native BSL signer. The recordings of the fingerspelled stimuli were then edited to display the hands only. This was to ensure that the only source of information was the hands and not also the mouth.
The stimuli were displayed as videos (.mp4) in the centre of the screen with a dark grey background. Figure 19 shows the sequence of events in each trial. The videos had a high resolution of 1920×1080 pixels, 16:9 aspect ratio. The duration of each stimulus was on average 2000ms. All videos were carefully edited, the hands were cropped from the background, and they were reproduced at a natural pace, as the signer was in a comfortable position and was instructed to fingerspell the words and pseudowords as they would do normally. The video started with a static image of the first letter of the word or pseudoword. This was static for 10 frames then followed by the rest of the word or pseudoword. This signalled the beginning of the word or pseudoword after the fixation cross and allowed the participant to see the first letter of the stimulus and not miss it, which was very important for the task (LDT). After piloting

the videos with deaf signers, it was decided to slow down the speed of the video 20% in order for the participant to be able to see all the handshapes of the fingerspelled stimulus, since some of our pilot participants reported it to be too fast. Moreover, it was decided to keep all the videos in black and white to avoid tired eyes in the participants that could affect their performance, as they had to see 320 videos of fingerspelled words and pseudowords.

The pseudowords conditions were: (1) pseudohomophones; (sounds same as the base word but could differ in one or more graphemes from the base word. E.g., phan – FAN) and (2) orthographic controls: had the same length as their corresponding pseudohomophone (therefore they are on average longer than their base words, e.g., chan – FAN).

Each participant saw 160 words, 80 pseudohomophones and 80 orthographic controls. Therefore, half of the participants saw 80 pseudohomophones and their 80 base words, and 80 orthographic controls and their 80 base words. The other half of participants saw the same 160 words but the other half of the pseudowords (80 pseudohomophones and 80 orthographic controls). A total of 320 fingerspelled items, 160 words and 160 pseudowords were seen by each participant during the LDT. The stimuli can be found in Appendix I.

7.1.1.1.4. Procedure

Participants were tested individually in a quiet room at the University College London, Deafness Cognition and Language Centre (DCAL). A MacBook (Retina, 12-inch, Early 2015) was used to display the stimuli using PsychoPy (Peirce, 2007), a software written in Python which was used to present the stimuli and to save the outputs of the experiment.

First, participants saw a fixation cross for 500ms. Then, the video stimulus was presented. Participants were asked to respond as quickly and as accurately as possible if the stimulus was a word or not. They were asked to press one key for "Yes" and another key for "No". The duration of the video was around 2000ms, followed by a blank screen. The blank screen disappeared after a response was recorded or after 3000ms if no response was recorded before then (see Figure 64). The hand used to respond was counterbalanced across participants. Response times (RTs) were measured from target onset until participant's response, which could be given before the end of the 3 seconds video. Before the experiment began participants completed eight practice trials with stimuli not used in the experimental trials. The experiment was run in two sessions run on two different days: each sessions lasted approximately 20mins, included 160 trials (80 words and 80 pseudowords).

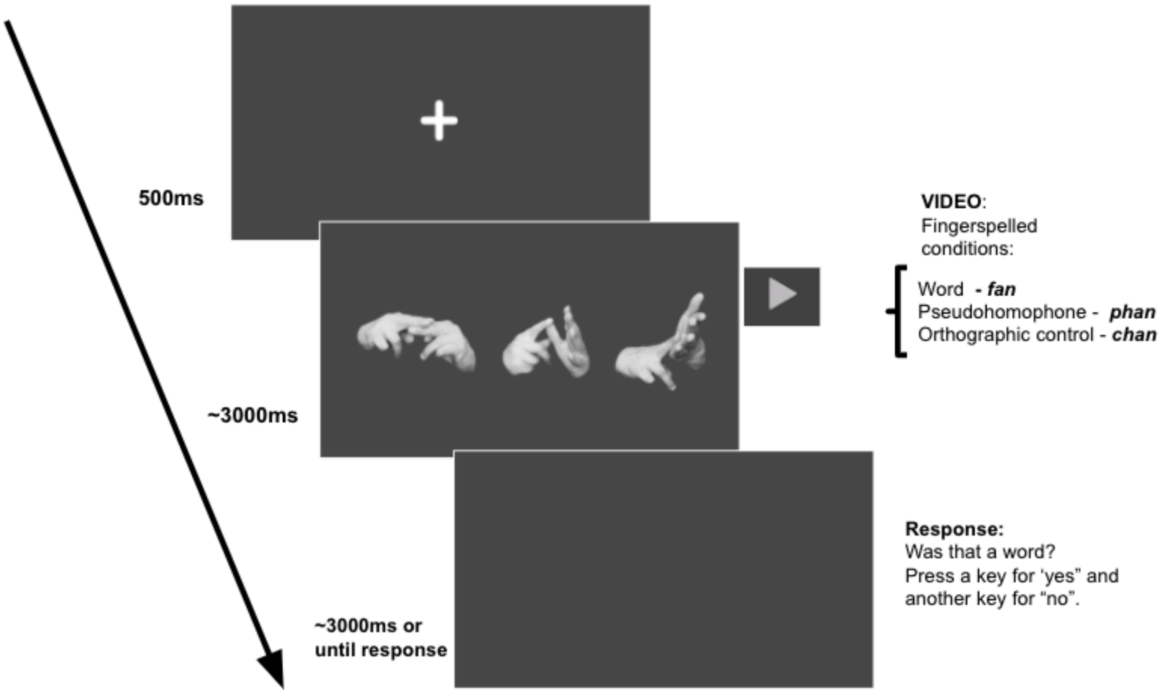


Figure 64. Schematic representation of events in the fingerspelled lexical decision task and description of experimental conditions for deaf adult readers of English.

7.1.1.2. Results – deaf adult readers of English

Nine words were excluded from the analysis because they were identified as words with lower than 58% accuracy by participants (see Appendix I, for the words and pseudowords removed from the list of the stimuli used in this experiment). As previously, first, the differences between words and pseudowords were tested. Then a paired-samples t-test were performed to contrast accuracy and RT of responses in the pseudohomophones and orthographic control conditions, both for the subjects (t_1) and items (t_2) scores. The mean lexical decision times and percentage of correct responses per condition are displayed in Table 38.

.

7.1.1.2.1. *Lexicality effect and Phonological effects*

Lexicality effect - Paired-samples *t*-tests showed that responses to words were significantly faster than responses for pseudowords (2576.13 vs 2983.64ms) for both subject and item analyses; $t_1(22) = -1.96$, $p = .032$; t_2 $(300) = -15.23$, $p < .001$. In terms of accuracy, only the analyses by item showed a significantly greater accuracy for words than pseudowords, (82% vs 74%); $t_1(22) = 1.28$, $p = .217$; t_2 $(300) = 8.41$, $p < .001$.

Phonological effect - To test the phonological effect, paired-samples t-tests including the pseudohomophone and the orthographic control conditions were performed separately for the RTs and the accuracy data (see Table 39 and Figures 65 and 66). Analysis on the RTs showed that participants were faster to respond to the fingerspelled pseudohomophones than to the orthographic control conditions (2936.81ms vs 3030.48ms); $t_1(11) = -31.71$, $p = .007$; $t_2(150) = -1.64$, $p = .104$. Analysis on the accuracy data showed that participants were more accurate for the pseudohomophones than for the orthographic controls; (76% vs. 73% correct); $t_1(11) = 2.28$, $p = .044$; $t_2(150) = .91$, $p = .366$.

Table 39. Mean lexical decision times (RTs in ms, upper half), and percentage accuracy (lower half) for Pseudohomophones and Orthographic control conditions, in deaf adult readers of English.

	Phonological Effect
Type of condition	RT Mean (SD)
Pseudohomophone	2936.81 (566.60)
Orthographic control	3030.48 (611.32)
difference	**-93.68****
Type of condition	Accuracy Mean (SD)
Pseudohomophone	75% (19.1)
Orthographic control	73% (19.7))
difference	**3%***

* $p < .05$, ** $p < .01$, *** $p < .001$

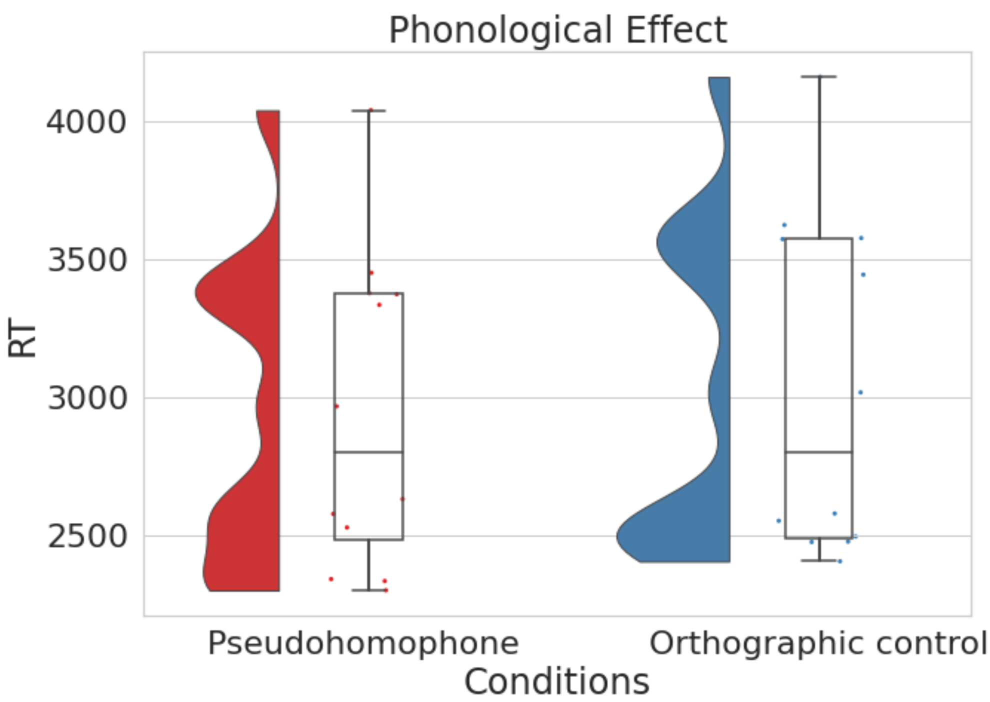


Figure 65. Response times (RT) for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in deaf adult readers of English.

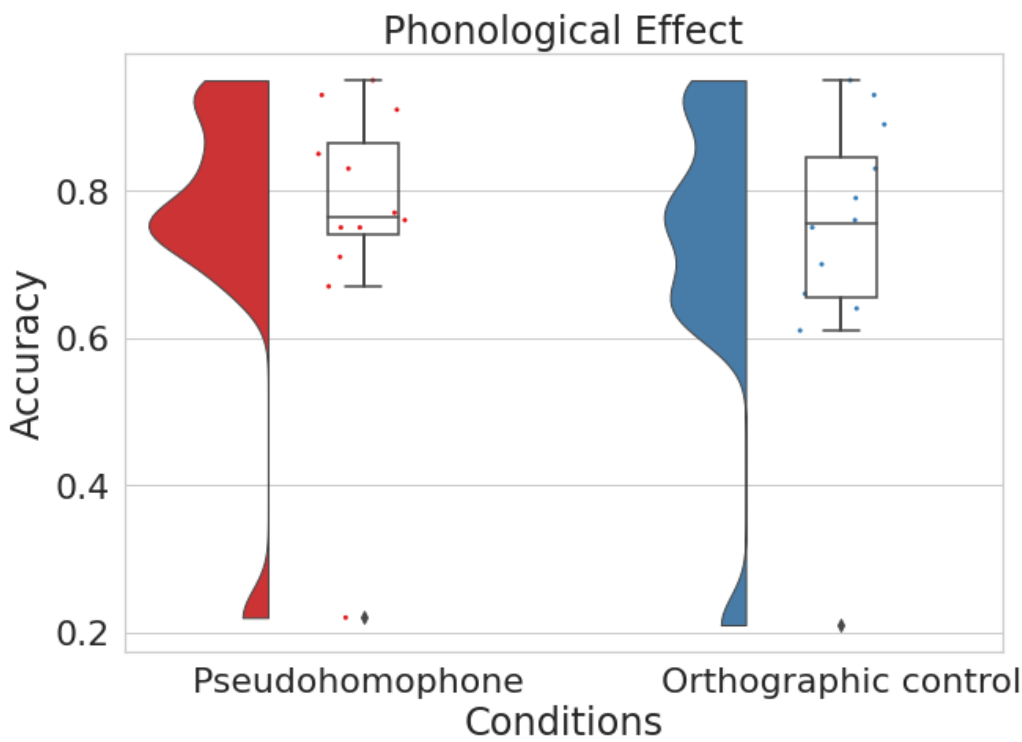


Figure 66. Accuracy of correct responses for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in deaf adult readers of English.

Correlations between offline behavioural measures and size of phonological effects in the fingerspelling lexical decision task

Correlations between the size of the phonological effect (i.e., difference in RTs and accuracy, between the Pseudohomophones and Orthographic control conditions) and the performance in offline behavioural measures: a) reading comprehension, b) vocabulary c) phonological processing, d) speechreading ability and e) fingerspelling ability. There are no significant correlations between the size of phonological effect in either RT or accuracy and any of the behavioural measures (see Table 40).

Table 40. Correlations with offline behavioural measures and the size of the phonological effect in RT (left) and accuracy (right), in deaf adult readers of English.

Offline measures		Size of the phonological effect in:	
		RT	Accuracy
Reading Comprehension	r	-.11	-.19
(% correct)	*p*	.729	.543
Speechreading Ability Test	r	.09	.03
(% correct)	*p*	.765	.916
Vocabulary Test	r	-.32	-.20
(# correct answers; max = 80)	*p*	.314	.525
Fingerspelling Ability Test	r	.09	.01
(% correct)	*p*	.767	.989
Rhyme judgement task	r	-.14	-.09
(% correct)	*p*	.665	.781

*(+) p < .07, * p < .05, ** p < .01, *** p < .001*

Note . Size of the phonological effect (in RT and Accuracy) = Phonological - Orthographic control condition.

7.1.2. Deaf adult readers of Spanish

The majority of the previous research into reading in deaf adults has been conducted in English, an opaque orthography. It has been proposed that orthographic depth plays a role modulating phonological processing during reading. Therefore, some authors have attributed the lack of phonological effects during word recognition in deaf adults to the lack of transparency of the language (e.g., English, French, Hebrew). In the current experiment we used the same experimental design from the previous experiment (See section 7.1.1.), but with deaf adult readers of Spanish a transparent orthography, and with Spanish fingerspelled words.

A previous study conducted by Gutierrez-Sigut et al., (2017) with deaf readers of Spanish showed that deaf readers use phonological information during an LDT The group of readers in Gutierrez-Sigut et al., (2017) study had a wide variability of reading levels and the paradigm used was a masked priming. In another study, Costello et al., (2021) found that deaf skilled readers did not use phonological information during LDT. The paradigm used in Costello and colleagues' study (Experiment 2), similar to the current study (umprimed LDT). However, our stimuli were fingerspelled words presented in isolation where participants had to do an LDT. We also were interested to see whether a language with a transparent orthography, such as Spanish, would modulate the use of phonological coding during word processing in deaf readers in two groups: readers in development (young deaf readers) and skilled readers (deaf adults). In this section the results of the deaf adult group readers of Spanish are presented.

7.1.2.1. Methods

7.1.2.1.1. Participants

Fifteen deaf adults (9 female) participated in this experiment. All participants were profoundly or severely deaf from birth. Their ages ranged from 21.7 to 61.4 years (M = 30.80, SD = 10.08). Four participants were native signers of Mexican Sign Language (Lengua de Señas Mexicana: 'LSM'), one participant was an early signer (AoA between 3 and 9 years old), and ten participants learnt LSM after the age of 9. Ten participants were fluent signers of LSM (self-ratings 6-7, in a 1-7 Likert scale) and used LSM as their preferred means of communication in their daily lives. Five participants rated their LSM proficiency at 4 and reported using LSM with friends and Spanish with their families. This study was approved by the University College London Research Ethics Committee (Project ID Number 10991/001). Instructions were given in LSM and in written Spanish. Participants were asked to provide written consent at the beginning of the sessions, and they were informed that they could withdraw at any time of the session if they would like to.

7.1.2.1.2. Offline behavioural measures

The participants that took part in this experiment were the same from the previous masked priming experiments from this thesis, with the exception of one that was not a proficient signer and could not do the LDT with fingerspelled words. The description of the tasks can be found in section 6.1.1.1.2 'Offline behavioural measures'. The participant's performance on the reading and reading related tasks are reported in Table 41. All participants had non-verbal IQ above 85, their reading comprehension score was above 50% of correct responses.

Table 41. Participant characteristics and test scores of deaf adult readers of Spanish. For full details of the tests see section 6.1.1.1.2.

	Mean (SD)	Range
Age (Yrs, mths.)	30,80 (10.8)	(21,75-61,43)
Reading Comprehension (% correct)	63% (18)	(50%-87.5%)
Sentence Reading (% correct)	88% (10.4)	(68.8%-100%)
Vocabulary Test (% correct)	69% (18.3)	(46%-99%)
Phonological Processing (visual bias index)	19 (14)	(6- 44)
Speechreading Ability Test (% correct)	62% (26.1)	(18%-96%)
Fingerspelling Test (% correct)	85% (20)	(30%-100%)
NVIQ (Standardised score)	108.8 (9.9)	(91-125)

Table 42. Correlations between offline behavioural measures in deaf adult readers of Spanish.

	Reading Comprehension	Vocabulary Test	Phonological Processing (visual bias index)	Speechreading Ability Test	Fingerspelling Test	NVIQ
Sentence Reading	.47(+)	.73*	-.44	.58*	.25	.05
Reading Comprehension		.45(+)	-.24	.73**	.15	-.11
Vocabulary Test			-.63*	.61*	.50(+)	.01
Phonological Processing				-.40	-.61*	-.15
Speechreading Ability Test					.43	-.27
Fingerspelling Test						.27

*(+) p < .09, *p < .05, **p < .01, *** p < .001*

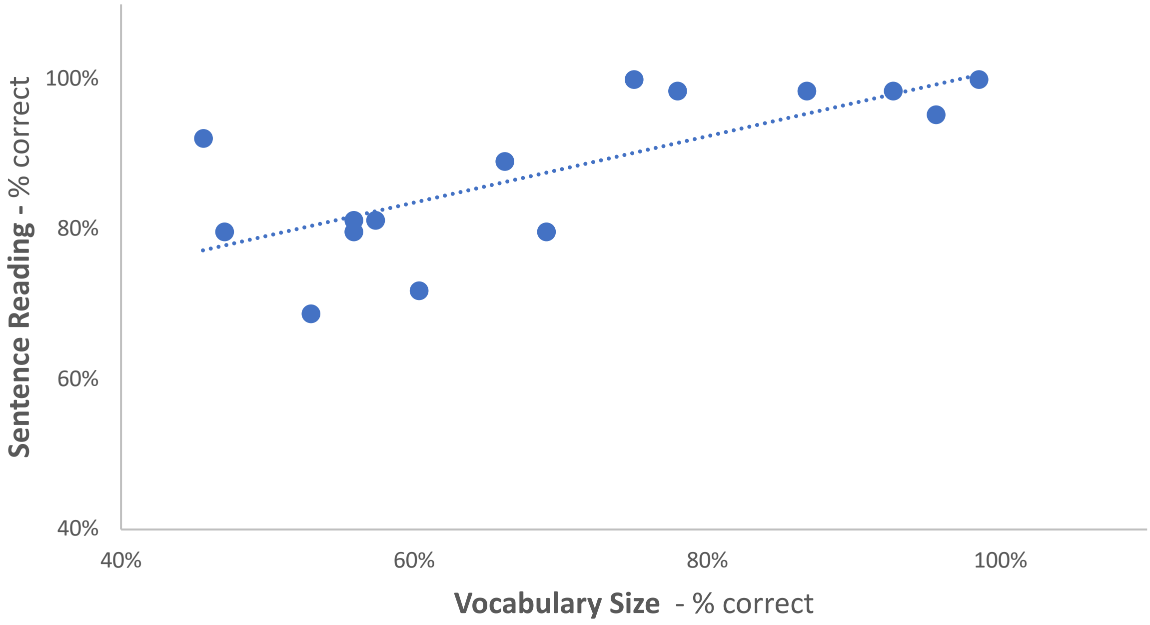


Figure 67. Correlation between Vocabulary Size (x-axis), and Sentence reading (y-axis) in deaf adult readers of Spanish.

7.1.2.1.3. Materials

One hundred and sixty fingerspelled Spanish words, 160 fingerspelled pseudohomophones and 160 fingerspelled orthographic controls were included. The stimuli were the same used in experiments 2 and 3 (see section 6.1.2.1.3.). Similar stimuli were used by Comesaña et al., (2016, with hearing adults and children) and by Gutierrez-Sigut et al., (2017 with deaf and hearing adults). However, only the conditions of interest were included in this experiment: pseudohomophones, orthographic controls and their base word (see characteristics of the stimuli in section 6.1.2.1.3. Materials).

The pseudowords conditions were: (1) pseudohomophones; the first letter was replaced by another letter with the same sound (e.g., kopa-COPA) and (2) orthographic controls: the first letter was replaced by a letter matched in shape to the one used in the pseudohomophone condition (e.g., lopa-COPA).

Each participant saw 320 videos in total: 160 fingerspelled words, 80 fingerspelled pseudohomophones and 80 fingerspelled orthographic controls. Half of the participants saw 80 pseudohomophones and 80 base words (e.g., kopa-COPA), and 80 orthographic controls and 80 base words (e.g., lopa- COPA). The other half of participants saw the same 160 words but the other half of the pseudowords (80 pseudohomophones and 80 orthographic controls). The set of stimuli can be found in Appendix J. All the videos were created and edited with the same criteria as experiment 7 (see section 7.1.1.1.3. Materials).

7.1.2.1.4. Procedure

Participants were tested individually in a quiet room. A MacBook (Retina, 12-inch, Early 2015) was used to display the stimuli using PsychoPy (Peirce, 2007), software written in Python which was used to present the stimuli and to save the outputs of the experiment. The procedure followed was the same as in Experiment 7 (see section 7.1.1.1.4). The stimuli were displayed in videos of fingerspelled words and pseudowords. They were presented in the centre of the screen with a dark grey background. Figure 68 shows the sequence of events in each trial.

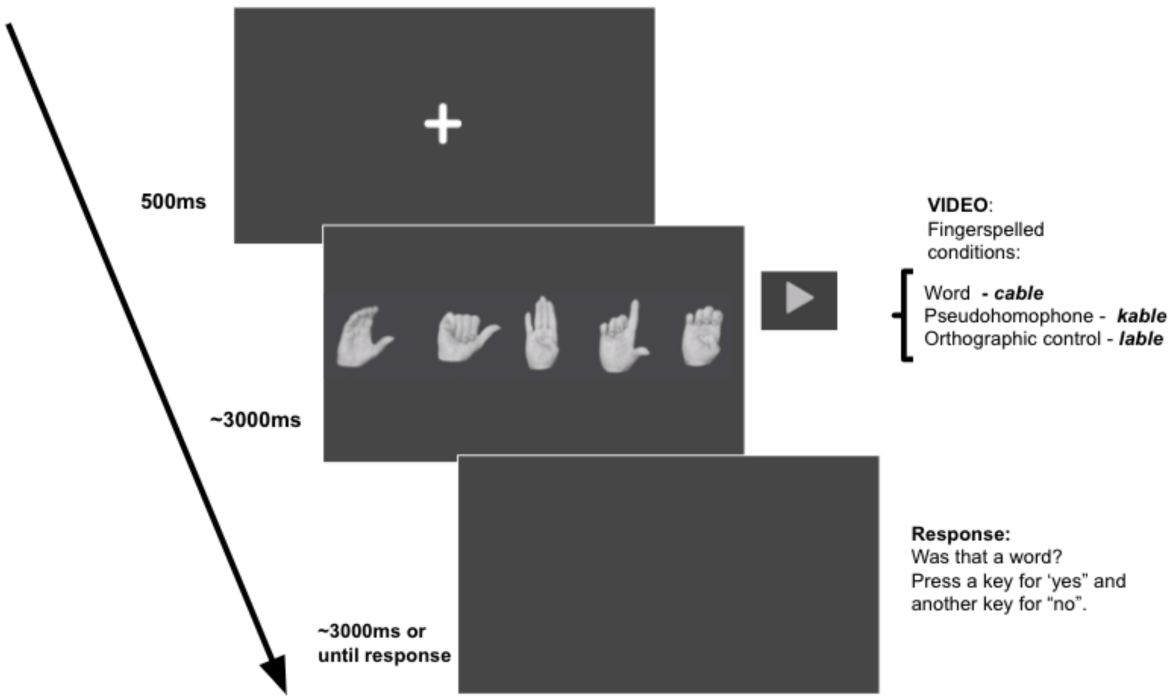


Figure 68. Description of events in a Lexical Decision trial and experimental conditions for deaf adult readers of Spanish.

7.1.2.2. Results – deaf adult readers of Spanish

A total of six words and their pseudoword conditions were excluded from the analysis (bollo, cuchara, cazo, bolso, viña and vagón), as they had less than 58% accuracy overall. The included words and pseudowords in the set of stimuli can be found in appendix J. In order to explore the phonological effects in both subjects (t_1) and items (t_2), a paired-samples t-test was performed to contrast the conditions of interest (pseudohomophones and orthographic control conditions). The mean lexical decision times and percentage of correct responses per condition are displayed in Table 43.

7.1.2.2.1. Lexicality effect, and Phonological priming effects

Lexicality effect- Separate paired-samples t-tests for the RTs and the accuracy data showed lexicality effects only in the analyses by item. In RTs, (3327.06ms vs 3504.90ms); $t_1(28) = -1.28$, $p = .211$; t_2 $(306) = -5.05$, $p < .001$, and in accuracy; (82% vs 79%); $t_1(28) = .40$, $p = .695$; t_2 $(306) = 11.49$, $p < .001$.

Phonological effect - To test the phonological effect, paired-samples t-tests including the pseudohomophone and the orthographic control conditions were performed separately for the RTs and the accuracy data (see Table 43 and Figures 69 and 70).

Analysis on the RTs did not show significant differences between both conditions, (3513.36ms vs 3496.43ms); $t_1(14) = .28$, $p = .784$; $t_2(153) = -.33$, $p = .745$. Analysis on the accuracy did not show any significant difference between pseudohomophones and orthographic control conditions either (80% vs. 77%); $t_1(14) = 1.10$, $p = .289$, neither in the analyses by-item (76% vs 73%); $t_2(153) = 1.88$, $p = .062$.

Table 43. Mean lexical decision times (RTs in ms, upper half), and percentage accuracy (lower half) for Pseudohomophones and Orthographic control conditions, in deaf adult readers of Spanish.

	Phonological Effect
Type of condition	RT Mean (SD)
Pseudohomophone	3513.36 (406.04)
Orthographic control	3496.43 (404.77)
difference	**16.93**
Type of condition	Accuracy Mean (SD)
Pseudohomophone	80% (2.9)
Orthographic control	77% (3.2)
difference	**3%**

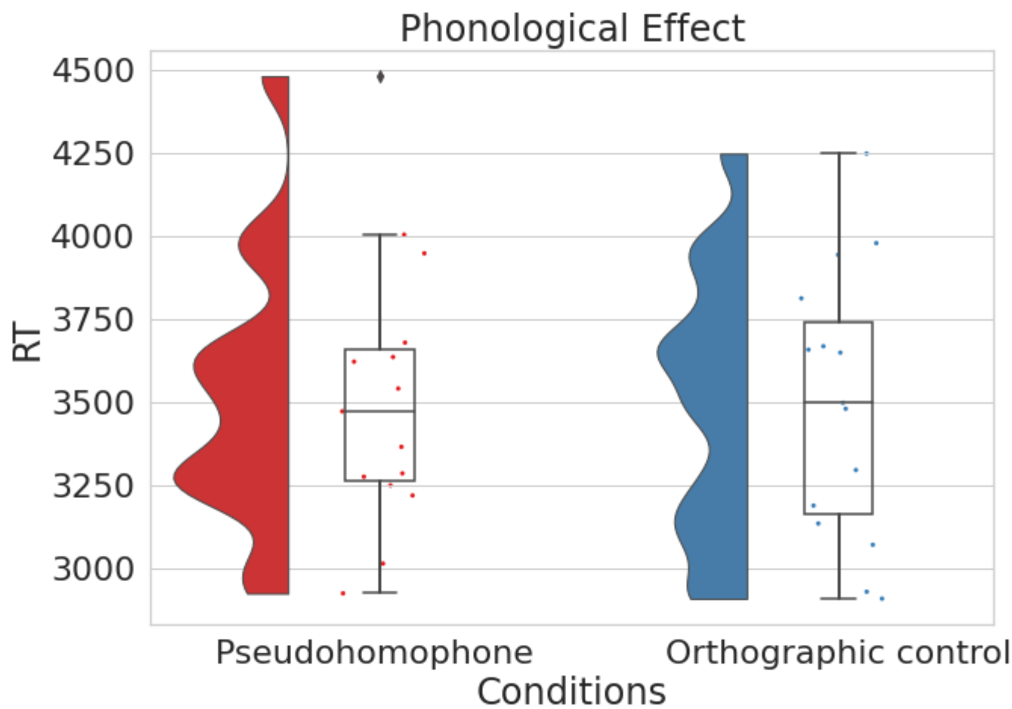


Figure 69. Response times (RT) for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in deaf adult readers of Spanish.

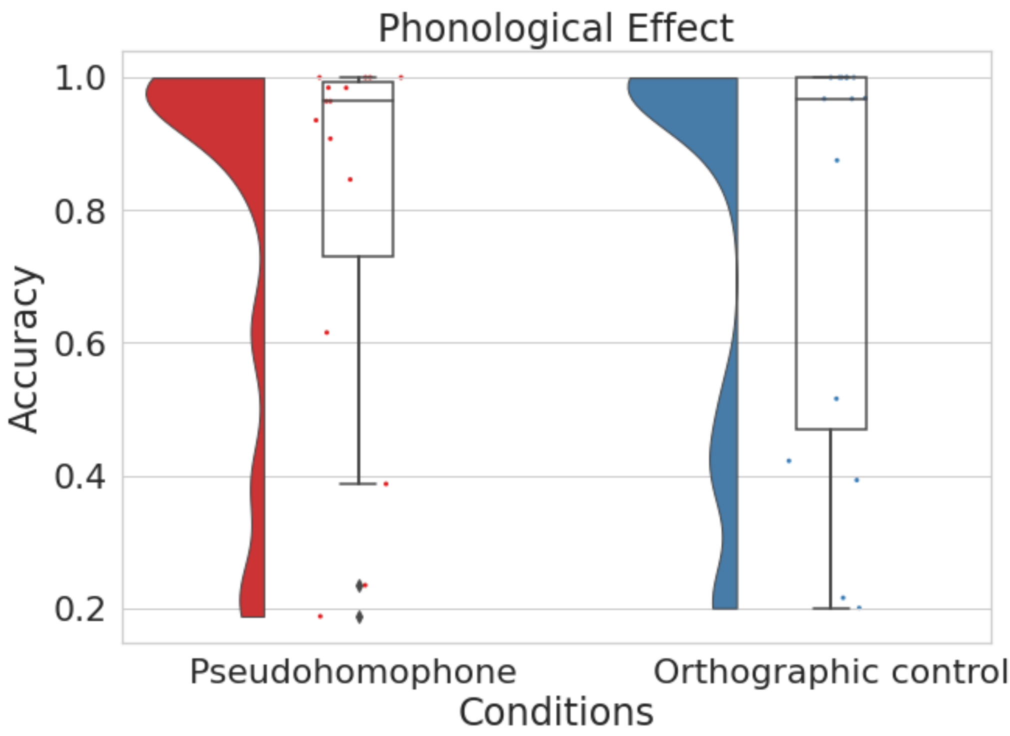


Figure 70. Accuracy of correct responses for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in deaf adult readers of Spanish.

Correlations between offline behavioural measures and phonological effects

Correlations between the size of the phonological effect (i.e., difference in RTs and accuracy, between the Pseudohomophones and Orthographic control conditions) and the performance in offline behavioural measures: a) reading comprehension, b) vocabulary c) phonological processing, d) speechreading ability and e) fingerspelling ability, are shown in Table 44. No correlations were found between the size of the phonological effect and any of the behavioural measures.

Table 44.Correlations with offline behavioural measures and the size of the phonological effect in RT (left) and accuracy (right), in adult deaf readers of Spanish.

Offline measures		Size of the phonological effect in:	
		RT	Accuracy
Sentence Reading. (% correct)	r	.03	-.22
	p	.824	.427
Reading Comprehension (% correct)	r	.17	.14
	p	.227	.621
Speechreading Ability Test (% correct)	r	.14	-.28
	p	.319	.315
Vocabulary Test (# correct answers; max = 68)	r	.02	-.04
	p	.879	.901
Fingerspelling Ability Test (% correct)	r	.09	-.06
	p	.537	.826
Phonological Processing (visual bias index)	r	-.03	-.18
	p	.831	.517

7.1.3. Young deaf readers of Spanish

Developing readers have shown to be more sensitive to phonology compared to skilled readers (Castles et al., 2018). Therefore, in this Experiment 9 it was investigated whether young deaf readers of Spanish were influenced by the phonological information of the fingerspelled pseudohomophone condition compared to the orthographic control. The research questions and experimental design were the same as the ones used for adult deaf readers of English and Spanish, (see above sections: 7.1.1. and 7.1.2).

7.1.3.1. Methods

7.1.3.1.1. Participants

Fifty-four congenitally deaf participants were recruited. All participants were profoundly or severely deaf from birth, did not report history of neurological or psychiatric impairments, and had normal or corrected to normal vision. The data from 6 participants were discarded, because they did not meet the inclusion criteria (non-verbal IQ below 85 and score categorized as deficient reading at the reading comprehension test). Of the remaining 48 participants (19 female, Age mean = 16.5, SD = 2.5), eight were native signers of Mexican Sign Language (Lengua de Señas Mexicana: 'LSM'). Thirty-four had learned LSM from teachers and friends before the age of 9, and six learned LSM between 12 and 15 years old. Participants rated their MSL skills (Likert scale from 1 to 7). Nineteen participants considered themselves skilled signers (self-ratings = 6-7), twenty-four medium skilled (self-ratings = 4-5) and five with poor sign skills (self-ratings < 4). Twenty-seven participants were in secondary school (i.e. year 7 to 9, year one starts at 6 years old) and twenty-one participants were in high school (i.e. year 10 to 12). All participants reported to have always attended mainstream schools and all of them received literacy training using a phonological (i.e., syllabic) method. This study was approved by the University

College London Research Ethics Committee (Project ID Number 10991/001). Parental consent was obtained for participants younger than 18 years old. Participants older 18 years old they were asked to provide written consent at the beginning of the sessions. Instructions were given in LSM and in written Spanish.

7.1.3.1.2. Offline behavioural measures

The young deaf readers were tested on: Reading comprehension, Sentence reading, Vocabulary, Speechreading, Fingerspelling and Phonological processing. These offline behavioural measures were the same as the ones used with the adult deaf readers of Spanish. The description of the tests can be found in section: 6.1.2.1.2 'Offline behavioural measures'. See participant's performance in Table 45. In order to describe better this group of young deaf readers correlation analyses were performed between the offline behavioural measures (see Table 46). A significant correlation was found between Vocabulary Size and Sentence Reading (See Figure 71). Table 46 shows all the significant correlations found between the behavioural measures. Since the participants that took part in this experiment also took part in the Phonological priming experiment, the scatter plots are showed in section 6.1.3.

Table 45. Participants' characteristics and test scores of the young deaf readers of Spanish.

	Mean (SD)	**Range**
Age (Yrs, mths.)	16,5 (2.5)	(11,6-21,7)
Reading Comprehension (% correct)	44% (18.7)	(10%-83%)
Sentence Reading (% correct)	63% (19)	(17%-100%)
Vocabulary Test (% correct)	46% (14)	(21%-74%)
Phonological Processing (visual bias index)	20 (19)	(-43 - 50)
Speechreading Ability Test (% correct)	21% (21.6)	(2%-86%)
Fingerspelling Test (% correct)	75% (18.8)	(33%-100%)
NVIQ (Standardised score)	117 (13)	(88-142)

Table 46. Correlations between offline behavioural measures in young deaf readers of Spanish.

	Reading Comprehension	Vocabulary Test	Phonological Processing (visual bias index)	Speechreading Ability Test	Fingerspelling Test	NVIQ
Sentence Reading	.72***	.73***	-.26(+)	.59***	.73***	.35*
Reading Comprehension		.76***	.12	.65***	.40**	.40**
Vocabulary Test			.06	.66***	.51***	.72***
Phonological Processing				-.04	.14	.16
Speechreading Ability Test					.46***	.27(+)
Fingerspelling Test						.44**

*(+) p < .07, *p < .05, **p < .01, *** p < .001*

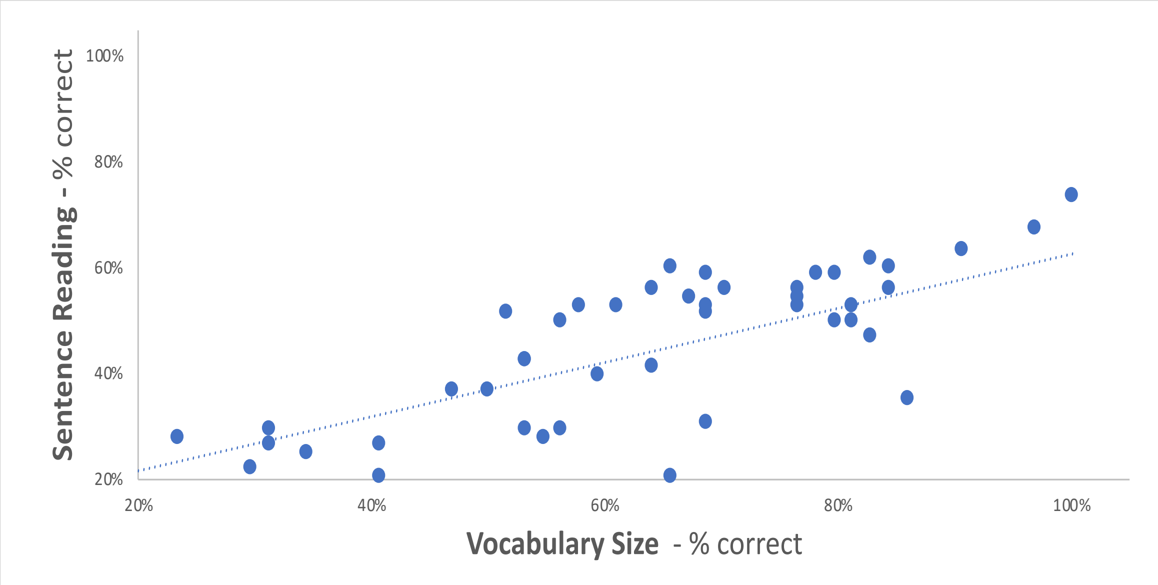


Figure 71. Correlation between Vocabulary Size (x-axis), and Sentence Reading (y-axis) in young deaf readers of Spanish.

7.1.3.1.3. Materials

The same materials were used with deaf adult readers of Spanish. See section '7.1.2.1.3. Materials'.

7.1.3.1.4. Procedure

Same procedure followed as with deaf adult readers of English and Spanish. See section: '7.1.2.1.4. Procedure'.

7.1.3.2. Results - Young deaf readers of Spanish

One hundred and thirty-four words were included in the analyses after removing the words (n=26) that had less than 58% accuracy and their respective conditions (See Appendix J) for the list of words and pseudowords removed and the list of the stimuli used in this experiment). The same statistical analysis performed with the deaf adult data was performed here (see section 7.1.2). Therefore, phonological effects were explored in both subjects (t_1) and items (t_2) scores, a paired-samples t-test was performed to contrast the conditions of interest (pseudohomophones and orthographic control conditions). The mean lexical decision times and percentage of correct responses per condition are displayed in Table 46.

7.1.3.2.1. Lexicality effect, and Phonological effects

<u>Lexicality effect -</u> Responses to words were faster than to pseudowords (3080.89ms vs 3291.85ms); $t_1(94) = -2.44$, $p = .017$; $t_2(266) = -3.27$, $p = .001$. In the accuracy analyses, there was only a significant difference in the analyses by-item; (65% vs 64%) $t_1(94) = .12$, $p = .905$; $t_2(266) = 2.16$, $p = .032$.

<u>Phonological effects -</u> To test the phonological effect, paired-samples *t*-tests including the pseudohomophone and the orthographic control conditions were performed separately for the RT and the accuracy data (see Table 47 and Figures 72 and 73).

Analysis on the RTs showed that responses to pseudohomophones were slower than to orthographic controls; 3342.76ms vs 3240.96ms; $t_1(47) = 2.83$, $p = .007$; $t_2(133) = 2.09$, $p = .039$. Analysis on the accuracy did not show any significant difference between pseudohomophones and orthographic control conditions (66% vs. 63%; $t_1(47) = 1.19$, $p = .242$; $t_2(133) = 1.88$, $p = .139$.

Table 47. Mean lexical decision times (RTs in ms, upper half), and percentage accuracy (lower half) for Pseudohomophones and Orthographic control conditions, in young deaf readers of Spanish.

	Phonological Effect
Type of condition	RT Mean (SD)
Pseudohomophone	3342.76 (504.09)
Orthographic control	3240.96 (479.04)
difference	**101.8****
Type of condition	Accuracy Mean (SD)
Pseudohomophone	66% (17.14)
Orthographic control	63% (18.19)
difference	**3%**

* $p < .05$, ** $p < .01$, *** $p < .001$

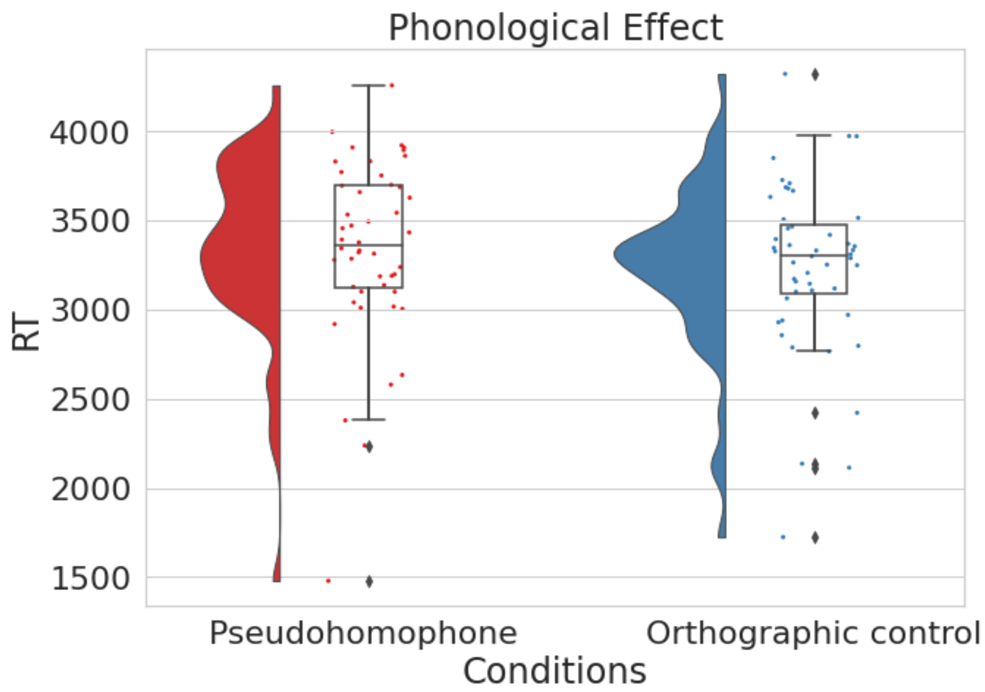


Figure 72. Response times (RT) for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in young deaf readers of Spanish.

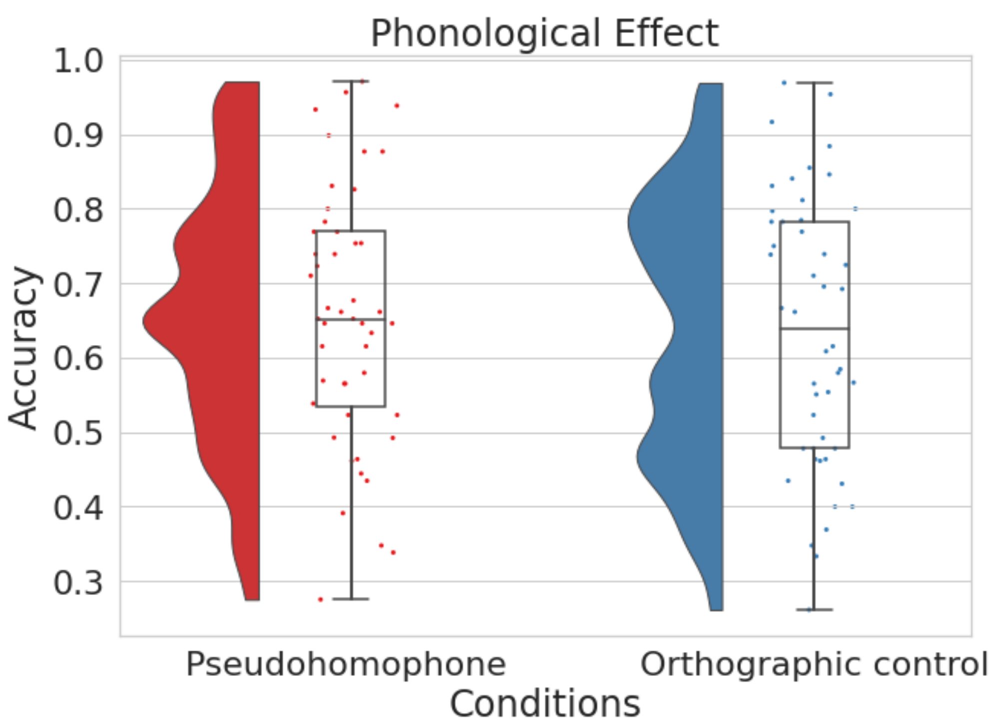


Figure 73. Accuracy of correct responses for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in young deaf readers of Spanish.

Correlations between offline behavioural measures and phonological effects

There were significant negative correlations between the size of the phonological effect in RTs for the group of young readers and the offline behavioural measures: sentence reading, speechreading ability and vocabulary (all *p*s $< .05$, see table 48). These correlations suggest that better readers, with larger vocabulary size and better speechreading skills, seem to use phonology less during single word recognition. Moreover, there was a negative correlation between the size of the phonological effect in accuracy and the phonological processing (visual bias index) when analysed as a whole group. This correlation was negative because of how the index of the phonological processing was calculated (see section 6.1.2.1.2.). This correlation suggests that the larger the phonological effect size in accuracy, the more use of phonological codes by the participants during the syllable judgement tasks (phonological processing).

Table 48. Correlations with offline behavioural measures and the size of the phonological effect in RT (left) and accuracy (right), in young deaf readers of Spanish.

Offline measures		Size of the phonological effect in:	
		RT	Accuracy
Sentence Reading	r	-.47***	-.08
(% correct)	*p*	<.001	.603
Reading Comprehension	r	-.263(+)	.02
(% correct)	*p*	.081	.924
Speechreading Ability Test	r	-.411**	.24
(% correct)	*p*	.004	.100
Vocabulary Test	r	-.29*	.19
(# correct answers; max = 68)	*p*	.050	.219
Fingerspelling Ability Test	r	.09	-.001
(% correct)	*p*	.537	.996
Phonological Processing	r	-.03	-.31*
(visual bias index)	*p*	.831	.034

*(+) p < .09, * p < .05, ** p < .01, *** p < .001*

Note. Size of the phonological effect (in RT and Accuracy) = Phonological - Orthographic control condition.
After Bonferroni correction no correlations were significant.

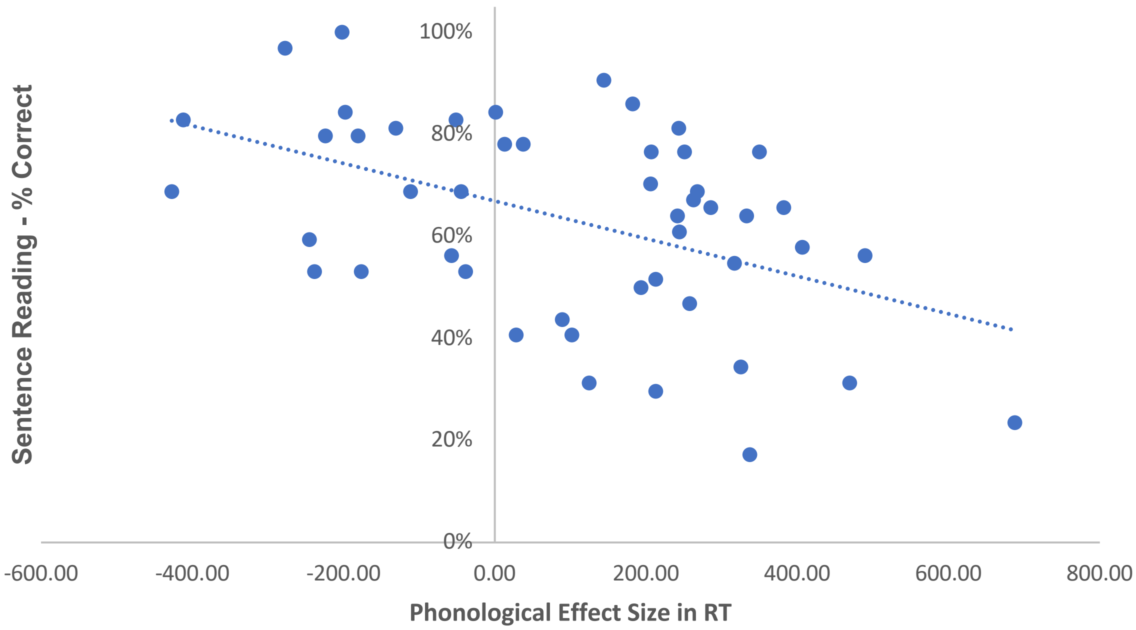


Figure 74. Correlation between the Size of the Phonological Effect in RT (x-axis), and Sentence Reading (y-axis) in young deaf readers of Spanish.

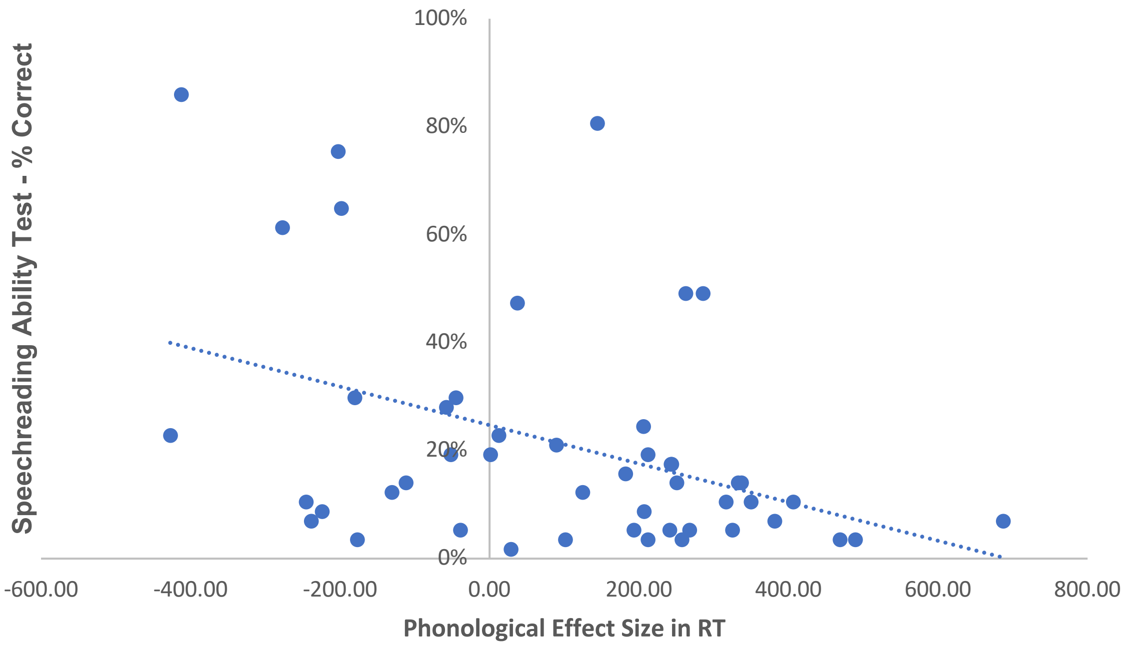


Figure 75. Correlation between the Size of the Phonological Effect in RT (x-axis), and Speechreading Ability Test (y-axis) in young deaf readers of Spanish.

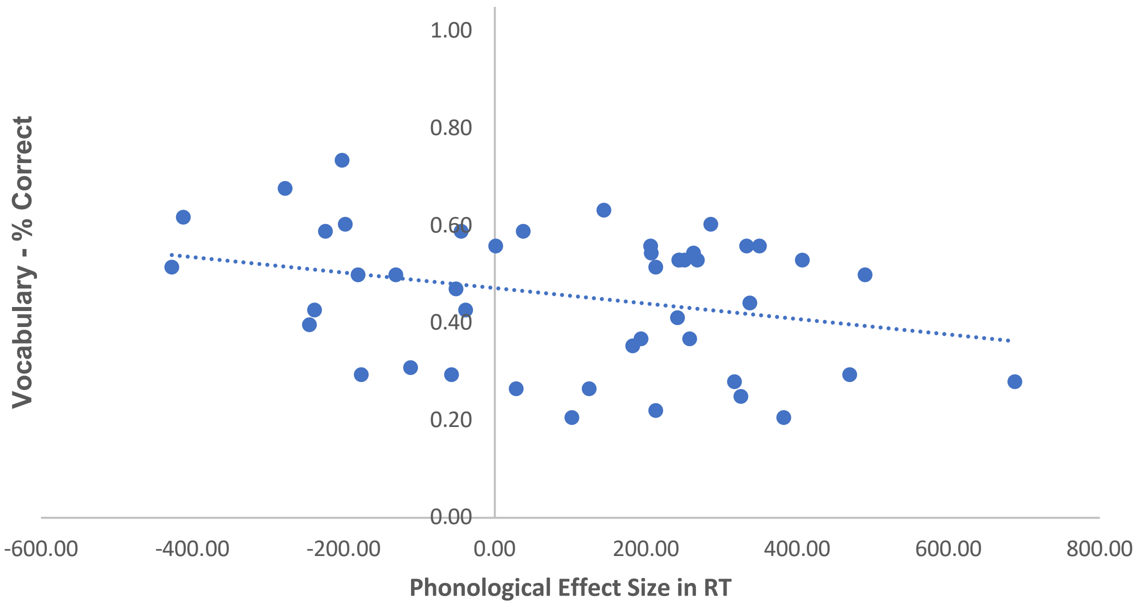


Figure 76. Correlation between the Size of the Phonological Effect in RT (x-axis), and Vocabulary (y-axis) in young deaf readers of Spanish.

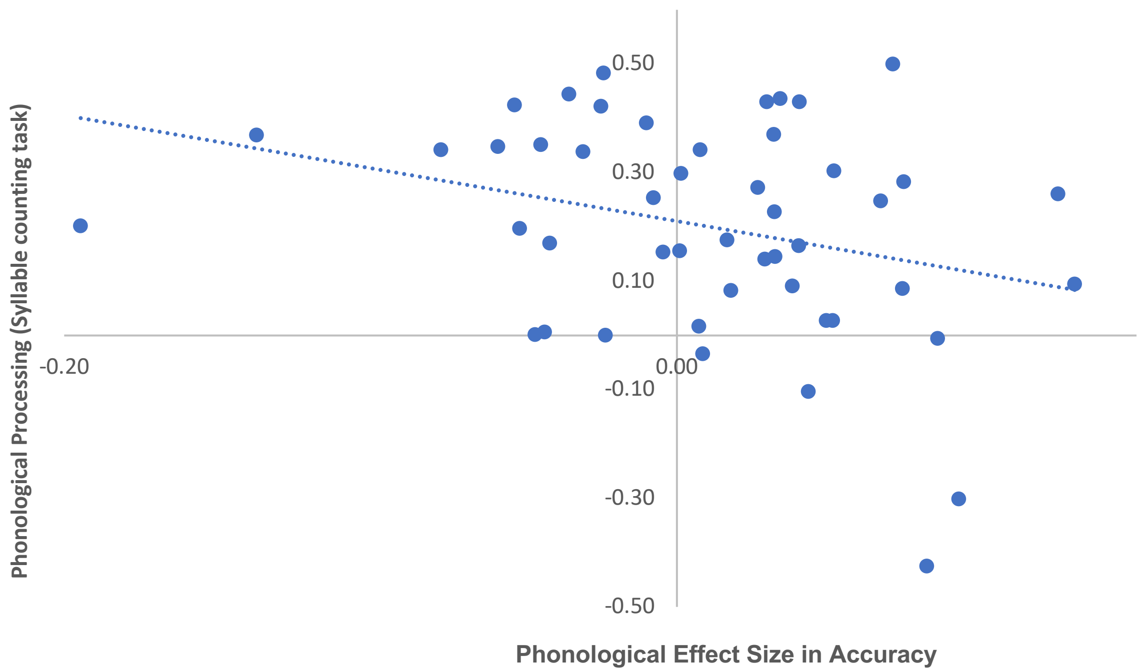


Figure 77. Correlation between the Size of the Phonological Effect in Accuracy (x-axis), and Phonological Processing (y-axis) in young deaf readers of Spanish.

There is robust evidence that vocabulary is the main predictor of reading ability in deaf readers (Kyle & Harris, 2010; Harris, Terlektsi, & Kyle, 2017; Cates, Taxler & Corina, 2021; Wauters, van Gelder, & Tijsseling, 2021). Furthermore, the masked priming experiment (Exp., 3, section 6.1) showed that only young deaf readers of Spanish with small vocabulary size showed strong phonological priming effect, while the effect was not significant in the group of young deaf readers with larger vocabulary, nor in the deaf adult skilled readers. Therefore, in this Experiment 9 we performed the same split-half analysis as for the masked priming, in order to explore whether the phonological effects exist in young readers with small and large vocabulary when perceiving fingerspelled words. The median of the group in the vocabulary test was used to split the group in two: small vocabulary (n= 24, Vocabulary Mean score = 35%, SD = 10) and large vocabulary (n=24, Vocabulary Mean score = 57%, SD = 5). The same analyses described above for the whole group were performed for each group separately (see Table 48 for Small Vocabulary group and Table 49 for Large Vocabulary group).

Small vocabulary group

Lexicality effect – There were no significant difference in reaction times to words and pseudowords targets (3092.66ms vs 3246.97ms); $t_1(46) = -1.20$, $p = .236$; $t_2(266) = -1,05$, $p = .296$. There was a significant difference in accuracy between responses to words and pseudowords in the analyses by item but not by subjects (55% vs 59%); $t_1(46) = -.84$, $p = .404$; $t_2(266) = -3.51$, $p < .001$.

Phonological effects - Responses were significantly slower for the pseudohomophone than the orthographic control condition in the by-subject analyses, (3311.93ms vs 3182.02ms); $t_1(23) = 2.51$, $p = .020$; $t_2(133) = 1.61$, $p = .110$ (See Table 49 and Figures 78 and 79). There were no significant differences in accuracy:(60% vs 59%), $t_1(23) = .195$, $p = .847$; $t_2(133) = .53$, $p = .595$.

Large vocabulary group

Lexicality effect - Responses to target words were faster than for pseudowords targets, (3069.12ms vs 3336.74ms); $t_1(46) = -2.27$, $p = .028$; $t_2(266) = -5.61$, $p < .001$. There was only a significant difference in accuracy between words and pseudowords in the analyses by-item, (75% vs 69%), $t_1(46) = 1.25$, $p = .219$; $t_2(266) = 5.50$, $p < .001$.

Phonological effects - There were no differences between the pseudohomophone and the orthographic control condition in RTs (3373.58ms vs 3299.9ms), $t_1(23) = 1.47$, $p = .156$; $t_2(133) = 1.18$, $p = .241$, nor in accuracy (72% vs 68%), $t_1(23) = 1.38$, $p = .182$; $t_2(133) = 1.88$, $p = .062$ (See Table 50 and Figures 80 and 81).

Table 49. Mean lexical decision times (RTs in ms, upper half), and percentage accuracy (lower half) for Pseudohomophones and Orthographic control conditions, in young deaf readers of Spanish with Small Vocabulary Size.

	Phonological Effect
Type of condition	RT Mean (SD)
Pseudohomophone	3311.92 (557.56)
Orthographic control	3182.02 (480.42)
difference	**129.90****

Type of condition	Accuracy Mean (SD)
Pseudohomophone	60% (18.3)
Orthographic control	59% (20.6)
difference	**1%**

* $p < .05$, ** $p < .01$, *** $p < .001$

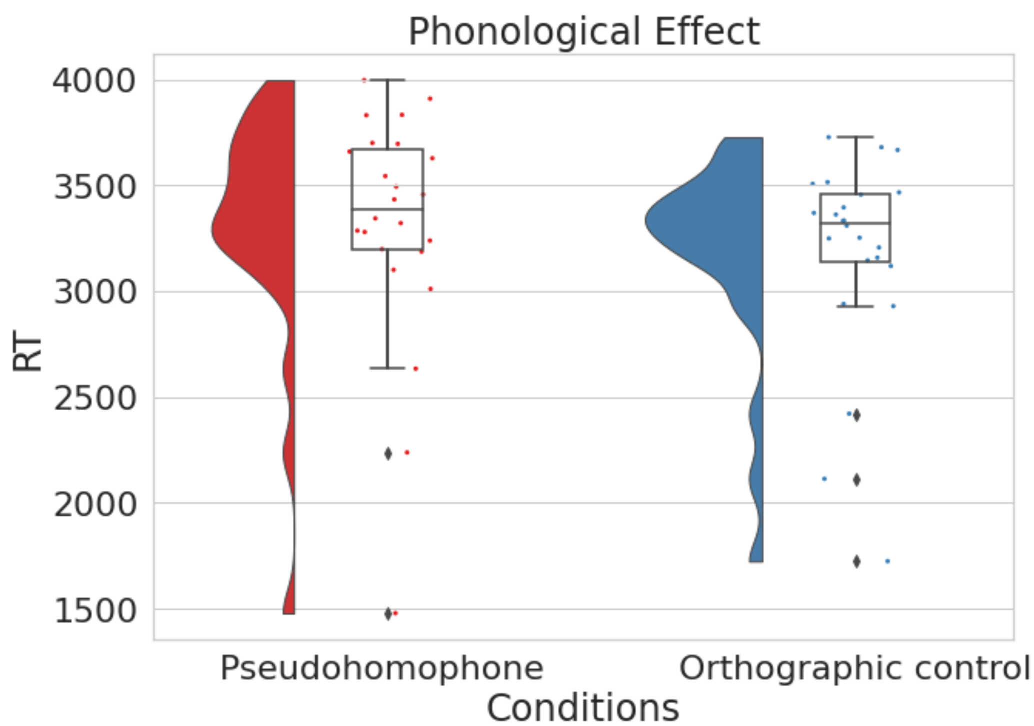


Figure 78. Response times (RT) for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in young deaf readers of Spanish with Small Vocabulary Size.

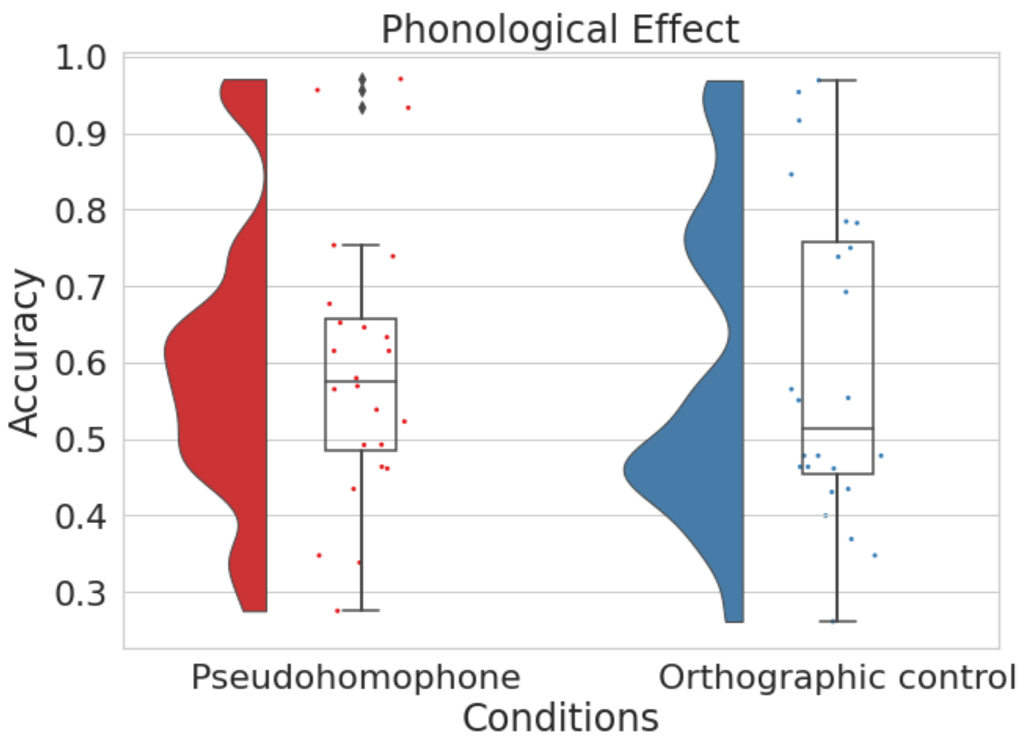


Figure 79. Accuracy of correct responses for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in young deaf readers of Spanish with Small Vocabulary Size.

Table 50. Mean lexical decision times (RTs in ms, upper half), and percentage accuracy (lower half) for Pseudohomophones and Orthographic control conditions, in young deaf readers of Spanish with Large Vocabulary Size.

	Phonological Effect
	RT
Type of condition	Mean (SD)
Pseudohomophone	3373.58 (454.32)
Orthographic control	3299.9 (480.51)
difference	**73.68**
	Accuracy
Type of condition	Mean (SD)
Pseudohomophone	72% (13.84)
Orthographic control	68% (14.62)
difference	**4%**

* $p < .05$, ** $p < .01$, *** $p < .001$

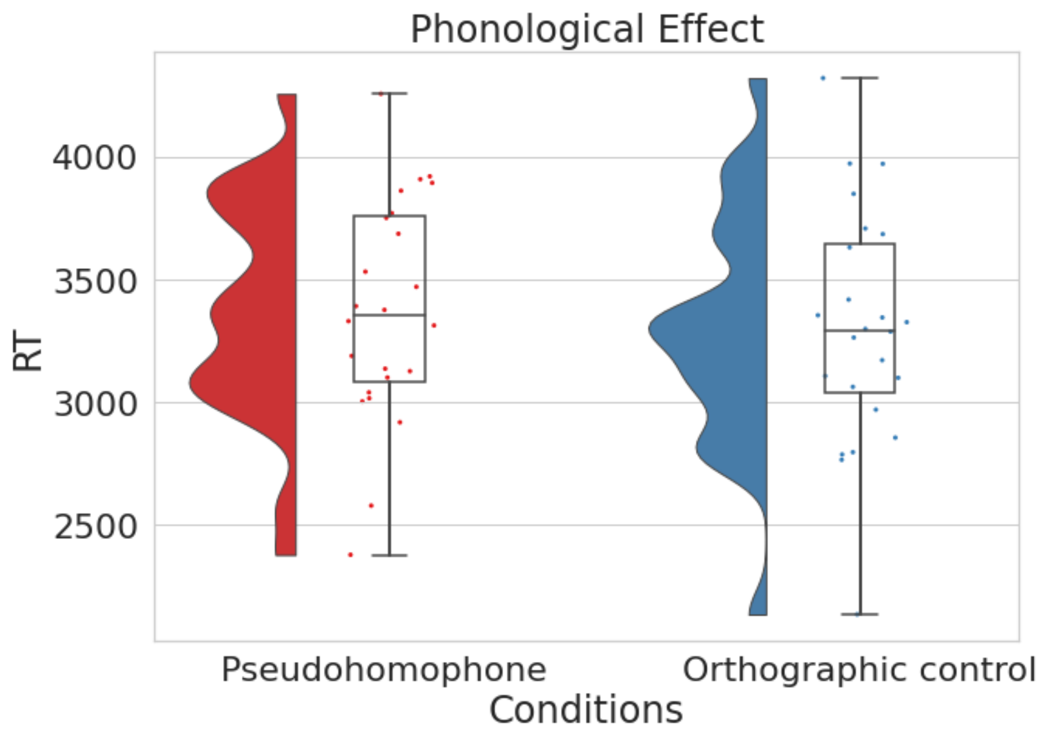


Figure 80. Response times (RT) for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in young deaf readers of Spanish with Large Vocabulary Size.

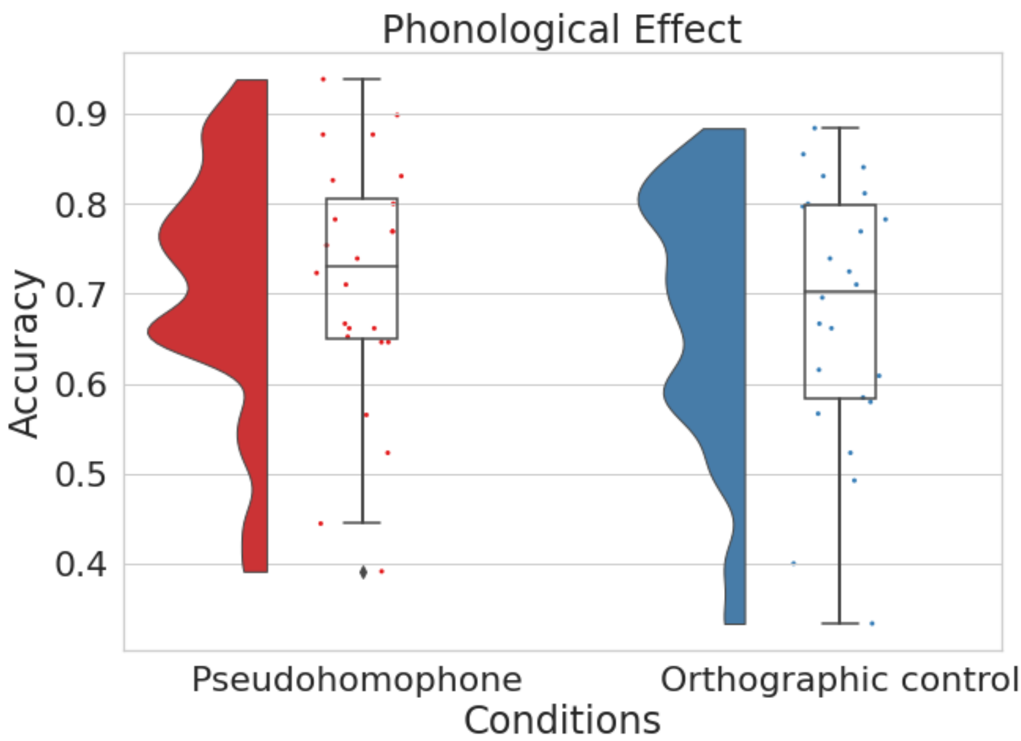


Figure 81. Accuracy of correct responses for Pseudohomophone (left) and Orthographic (right) control primes during the LDT, in young deaf readers of Spanish with Large Vocabulary Size.

The correlation analyses between the size of the phonological effect and the measures of the behavioural tests were performed in the two groups: Small Vocabulary Size (see Table 51 and Figure 82), and Large Vocabulary Size (see Table 52 and Figures 83-85). These correlations replicate the findings in the whole group. The better readers, with larger vocabulary size and better speechreading skills, seem to use less phonological information when recognising single words (See Figures 83-85). However, when we look at young deaf readers with small vocabulary, our data show that they use phonological information during SWR (See Figure 82).

Table 51. Correlations with offline behavioural measures and the size of the phonological effect in RT (left) and accuracy (right), in young deaf readers of Spanish with Small Vocabulary Size.

Offline measures		Size of the phonological effect in:	
		RT	Accuracy
Sentence Reading	r	-.51*	-.37
(% correct)	*p*	.012	.076
Reading Comprehension	r	-.28	-.21
(% correct)	*p*	.206	.352
Speechreading Ability Test	r	-.38(+)	-.27
(% correct)	*p*	.064	.202
Vocabulary Test	r	-.30	.07
(# correct answers; max = 68)	*p*	.148	.755
Fingerspelling Ability Test	r	-.13	-.27
(% correct)	*p*	.549	0.21
Phonological Processing	r	-.26	-.38
(visual bias index)	*p*	.225	.071(+)

*(+) p < .076, * p < .05, ** p < .01, *** p < .001*

Note. Size of the phonological effect (in RT and Accuracy) = Phonological - Orthographic control condition.
After Bonferroni correction no correlations were significant.

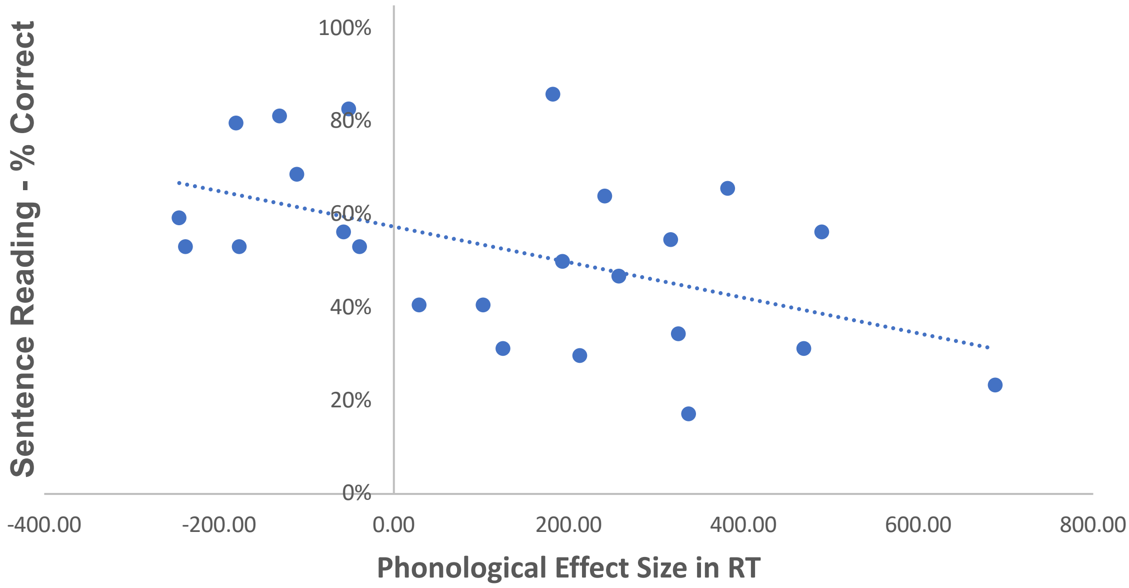


Figure 82. Correlation between the Size of the Phonological Effect in RT (x-axis), and Sentence Reading (y-axis) in young deaf readers of Spanish with Small Vocabulary Size.

Table 52. Correlations with offline behavioural measures and the size of the phonological effect in RT (left) and accuracy (right), in young deaf readers of Spanish with Large Vocabulary Size.

Offline measures		Size of the phonological effect in:	
		RT	Accuracy
Sentence Reading (% correct)	r	-.48*	.02
	p	.017	.916
Reading Comprehension (% correct)	r	-.36	-.15
	p	.096	.503
Speechreading Ability Test (% correct)	r	-.50*	.34
	p	.012	.104
Vocabulary Test (# correct answers; max = 68)	r	-.50*	.16
	p	.018	.485
Fingerspelling Ability Test (% correct)	r	-.29	.04
	p	.172	.839
Phonological Processing (visual bias index)	r	.007	-.27
	p	.073	.206

*(+) p < .061, * p < .05, ** p < .01, *** p < .001*

Note. Size of the phonological effect (in RT and Accuracy) = Phonological - Orthographic control condition.
After Bonferroni correction no correlations were significant.

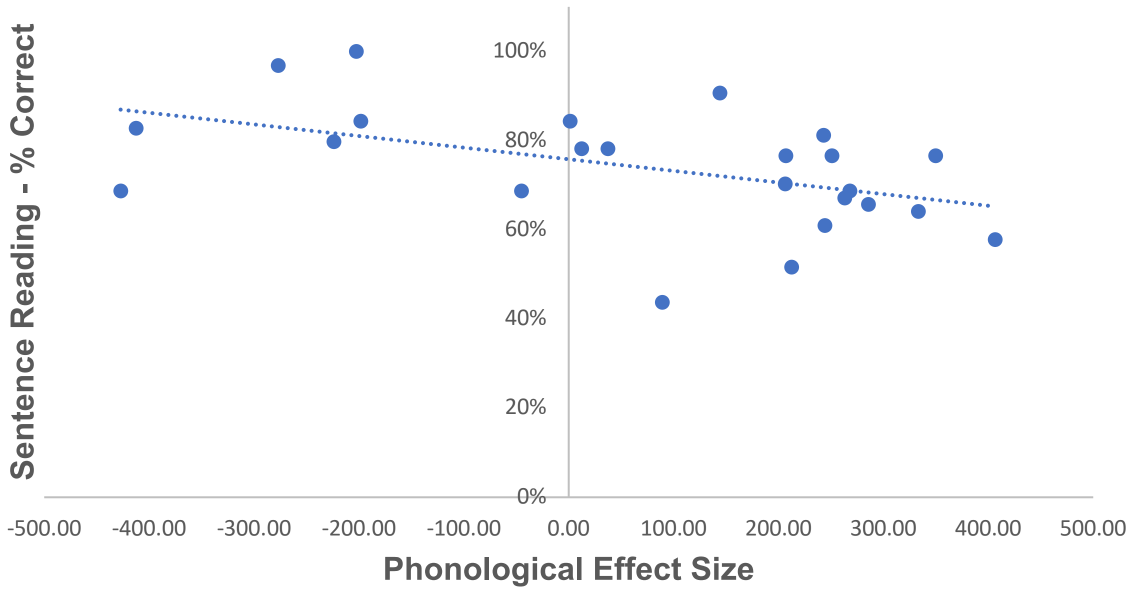


Figure 83. Correlation between the Size of the Phonological Effect in RT (x-axis), and Sentence Reading (y-axis) in young deaf readers of Spanish with Large Vocabulary Size.

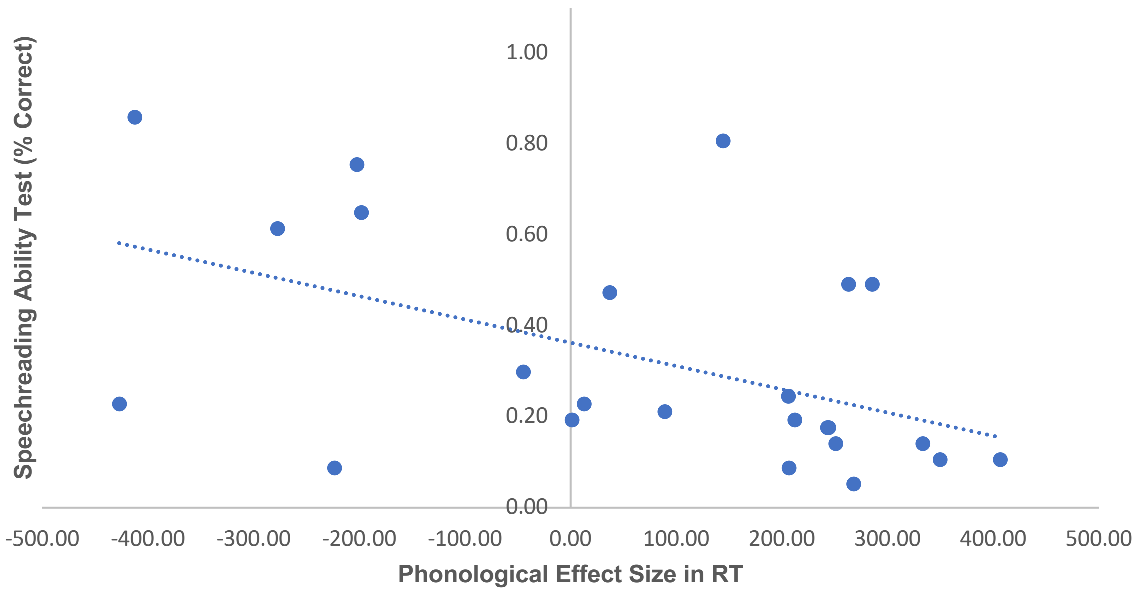


Figure 84. Correlation between the Size of the Phonological Effect in RT (x-axis), and Speechreading Ability Test (y-axis) in young deaf readers of Spanish with Large Vocabulary Size.

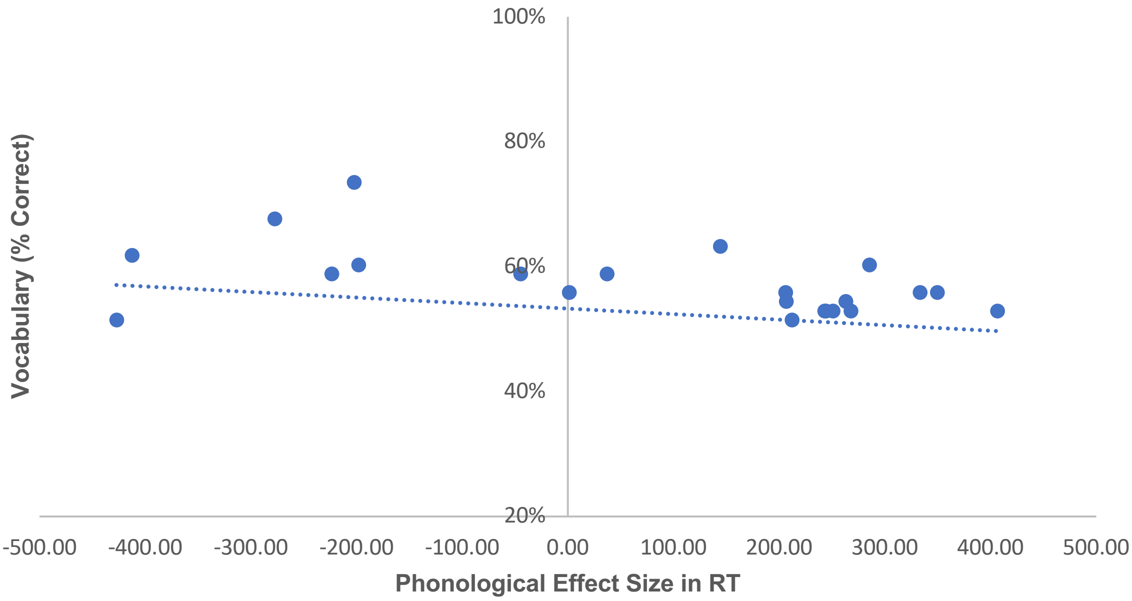


Figure 85. Correlation between the Size of the Phonological Effect in RT (x-axis), and Vocabulary (y-axis) in young deaf readers of Spanish with Large Vocabulary Size.

7.1.4. Discussion

This subsection includes a brief discussion from the results from each experiment in section 7.1. For more detail see the General Discussion in Chapter 8.

Deaf adult readers of English

Deaf adult readers of English showed significant effects of phonology in their response times and accuracy. However, in terms of RT this was in the opposite direction to that predicted. Participants were faster in their responses and showed less errors to pseudohomophones (e.g., kable) than to orthographic controls (e.g, lable) condition. In line with previous studies with deaf and hearing adults we predicted that participants would show slower response times and more errors for the pseudohomophone condition than for the orthographic control. However, despite the shared phonology of the pseudohomophones with their base word, deaf readers in the current study rejected the pseudohomophones faster than the orthographic controls. Possible interpretations of these findings are discussed in detail in the general discussion (Chapter 8).

Participants had a high variability in their reading levels, in comparison with previous studies that only included skilled deaf readers (Costello et la.,2021 & Fariña et al., 2017). Perhaps poorer readers may be more likely to use phonology during the task. As a recent study done by Gutierrez-Sigut et al., (2017), using masked priming paradigm found that adult deaf readers were using phonology to recognise words. Even though their paradigm (masked priming) was different to ours (LDT), we could suggest that both groups use phonological information to do the LDT. In the masked priming experiments presented in this thesis (see section 6.1.1.) the group of deaf readers of English showed phonological masked priming effects. Overall our results from both experiments (masked priming with printed words and SWR with fingerspelled words), show that our participants were using phonology to do the LDT.

No correlations between the size of the phonological effect and the reading ability (and reading related measures) were found. This is consistent with previous research that did not find correlations between phonological processing and reading ability in deaf readers (e.g., Hanson & Fowler; 1987, Kyle & Harris 2006; Mayberry et al., 2011; Meade et al., 2020; Miller, 2011; Miller & Clark; 2011.). However, there is the possibility that a correlation was not found due to the small N.

Importantly, English vocabulary and reading skill were positively correlated in deaf adult readers of English. This was as predicted and replicates findings from previous research (e.g., Wauters, van Gelder, & Tijsseling, 2021). Numerous previous studies have shown that vocabulary is a primary predictor of reading ability (Dickinson et al., 2003; Muter et al., 2004; Protopapas et al., 2013). Moreover, according to the simple view of reading (Gough & Tunmer, 1986), vocabulary is essential for reading comprehension. Therefore, finding a correlation between vocabulary and reading skill in our study further confirms the important role that vocabulary plays in reading ability.

Deaf adult readers of Spanish

In this Experiment 8 there were no significant differences between responses to the fingerspelled pseudohomophones and orthographic control nonwords in deaf adult readers of Spanish during a lexical decision task. These results replicated the findings by Costello et al., (2021) and Fariña et al., (2017), in which deaf readers of Spanish were not influenced by the phonological information of the pseudohomophones, rather they appeared to be treated as pseudowords.
The participants of the current experiment were skilled readers and might not need phonology to recognise words and prefer to use the orthographic route.

Reading skill was correlated with vocabulary and with speechreading ability. These findings add evidence to the body of studies that support vocabulary as the main predictor of reading in deaf readers (Kyle & Harris, 2010; Harris, Terlektsi, & Kyle, 2017; Cates, Taxler & Corina, 2021; Moreno-Perez et al., 2015; Dominguez et al; 2014; Wauters, van Gelder, & Tijsseling, 2021). Moreover, we can see that speechreading ability affects positively to improve their reading skills, this replicated previous findings (Arnold & Kopsel, 1996; Kyle, Campbell, & MacSweeney, 2016; Kyle & Harris, 2006, 2010),

We predicted to find a correlation between the phonological effect size and the offline behavioural measures (vocabulary, reading skill and speechreading and fingerspelling abilities). However, no correlation was found. This is not surprising given that there was no significant effect of phonology. However, it could also be the case that this group of skilled readers did not currently use phonology during lexical decision but that they did use it during their reading development.

Young deaf readers of Spanish

The group of the young deaf readers as a whole showed a significant phonological effect in their process of word recognition with fingerspelling stimuli. The young deaf readers seem to be affected by the phonological information of the pseudohomophones. This is, the sound of the pseudowords being exactly the same as real words influenced their responses. Thus, when participants saw them, they took more time in rejecting them. With these results we can show that not only experiments with printed stimuli can find phonological effects in developing readers, also experiments with fingerspelled stimuli can explore phonological effects. In this experiment, the stimuli were produced in fingerspelling. Therefore, the young deaf readers were able to extract this sub lexical phonological information of the pseudohomophones when they were doing the LDT. Hence, more research with deaf readers is needed to explore the role of fingerspelling ability in reading development, which could potentially facilitate their access to single word recognition and reading comprehension. In that manner, it was found in a 2-year longitudinal study (Ormel, Giezen and Gutierrez-Sigut, 2022) with deaf Dutch children (8-10 years old), fingerspelling ability predicted word and text reading fluency. The authors concluded that for deaf children, fingerspelling ability might facilitate the construction of phonological representations of printed words and could reinforce their decoding and recognition skills.

Considering that vocabulary has been found to be the main predictor of reading skill, and differential effects were found in young readers for the same stimuli in printed word recognition, the group of young deaf readers was split according to their vocabulary size. Our results suggest that the whole group phonological effect can be primarily driven by the young readers with small vocabularies, which are the ones that still show a significant phonological effect when the groups are split. This suggest that deaf readers with smaller vocabularies rely more on the phonological information to recognise a word as real or not. Their responses to the pseudohomophones were slower compared to the orthographic controls. Even though the Large Vocabulary group showed responses on the same direction, they did not have a significant effect, as was also the case for the adult skilled readers. This suggests a developmental pattern in which phonological information might carry more weight during word recognition in deaf readers when they have not yet developed a large vocabulary. Once readers start developing a vocabulary and improve their reading skills, their visual knowledge of the words allows them to access to the meaning without necessarily decoding them. In line with this, vocabulary was found to be correlated to reading skill showing that readers with larger vocabulary were better readers than those with smaller vocabulary.

The use of phonological information in the visual process of fingerspelled word recognition in young readers could also been explained by the individual differences found in the group of young deaf readers (e.g., size of vocabulary, reading skill). Davis et al., (1998) suggested that hearing children that benefited from the phonological information were slower readers, which that could be also the case of our group of deaf young readers with small vocabulary.

The lexicality effect: faster and more accurate responses to words than pseudowords was found in the complete group of young deaf readers. However, when the group was split based on their vocabulary size, only the group with large vocabulary showed the lexicality effect. These young readers used the knowledge that they already had of the words and recognised the target words quicker than the pseudowords. In the case of the small vocabulary group, they did not show a lexicality effect. This is consistent with previous studies that have found the same results due to the participant's poor knowledge of the words. Therefore, they might have processed some of the words as pseudowords, and for that reason there were no differences found in their response times nor accuracy between them (words vs pseudowords).

7.2. Orthographic Processing of fingerspelled words

The findings of the previous subsection (7.1) showed that deaf adult readers of English were influenced by the phonological information of the fingerspelled words during a lexical decision task with fingerspelled stimuli. Participants were slower to identify pseudohomophones as nonwords than the orthographic controls. This effect was not seen in the deaf adult readers of Spanish (section 7.1.2.2.1.). However, the young readers of Spanish did show a phonological effect.

In the following experiment the use of orthographic processing by deaf readers during a LDT with fingerspelled stimuli is explored (Meade et al., 2020). Identifying letters and their position are the main subcomponents of orthographic processing. These features can activate the lexical representation of the words, even if the letter positions are transposed, or if there is a similar spelling (Andrews & Lo, 2012).

In this section the precision of orthographic information encoding during fingerspelled word recognition was assessed by Experiment 10 that used the same LDT paradigm used in the previous experiments 7,8 and 9, (section 7.1). Videos of words and pseudowords fingerspelled by a native signer were presented to deaf participants who had to decide if they were words or nonwords. The stimuli were manipulated using transposed letters. The participants were deaf adult readers of English and, both adult and young deaf readers of Spanish. The data collection with deaf readers of English was interrupted by the COVID-19 pandemic.

The research questions addressed in this experiment are the following:

1. How precisely do deaf readers use orthographic codes during visual recognition of fingerspelled words? It was predicted that if deaf readers use orthographic codes during recognition of fingerspelled words (e.g., chocolate), they should show slower lexical decision times and more errors to nonnwords with transposed letters (e.g., cholocate) than to nonwords with a replaced letter (e.g., chofonate). As the lexical representation of the real word would be more likely to be activated by the nonword with transposed letters than nonwords with replaced letters.
2. Is the size of an orthographic effect related to reading, speechreading, and fingerspelling skills? It was hypothesized that better readers, speechreaders and those with better fingerspelling skills will show a larger the orthographic effect (defined as the difference between the TL and the RL control condition in either RTs or accuracy).

Data are reported separately for deaf adult readers of English (7.2.1.), deaf adult readers of Spanish (7.2.2.) and the young deaf readers of Spanish (7.2.3.).

7.2.1. Deaf adult readers of English

The conditions of interest in the study with readers of English were the transposed letter condition (TL, e.g., panert, base word PARENT) and the replaced letter (RL, e.g., pamest, base word PARENT) control condition. The base word of these pseudowords (e.g., PARENT), was also included only to facilitate the LDT. Half of the items that participants saw were fingerspelled words (N=120), the other half were pseudowords (Sixty TL pseudowords, and 60 RL pseudowords).

7.2.1.1. Methods

7.2.1.1.1. Participants

Thirteen deaf adults (6 females) participated in this experiment. All participants were profoundly or severely deaf from birth. Their ages ranged from 23.52 to 53.14 years (M = 37.82, SD = 10.62). Five participants were native signers of BSL, five participants were early signers (AoA between 3 and 9 years old), and three participants learnt BSL after the age of 9. Eleven participants were fluent signers of BSL (self-ratings 6-7, in a 1-7 Likert scale) and used BSL as their preferred means of communication in their daily lives. Two participants rated their BSL proficiency between 4-5 and reported using BSL with friends and English with their families. This study was approved by the University College London Research Ethics Committee (Project ID Number 10991/001). Instructions were given in BSL and written English.

Participants were asked to provide written consent at the beginning of the sessions, and they were informed that they could withdraw at any time of the session if they would like to.

7.2.1.1.2. Behavioural measures

Performance on Non-Verbal IQ, Sentence Reading, Speechreading ability, Fingerspelling ability, and Rhyme Judgement task is reported in Table 53. All participants had non-verbal IQ above 85 and their reading comprehension score was above 33% correct responses.

Table 53. Participant characteristics and test scores of the deaf adult readers of English. For full details see section 7.1.1.1.2.

	Mean (SD)	Range
Age (Yrs, mths.)	37,8 (10.67)	(23,52-53,14)
Reading Comprehension (% correct)	67.8% (16.97)	(33%-90.5%)
Vocabulary Test (% correct)	80.8% (15.4)	(51.3%-98.8%)
Phonological Processing (Rhyme task, % correct)	71% (16.9)	(51%-98%)
Speechreading Ability Test (% correct)	90.9% (7.3)	(74.2%-100%)
Fingerspelling Test (% correct)	88.2% (14.2)	(50%-100%)
NVIQ (Standardised score)	113.46 (9.5)	(100-139)

Note: Vocabulary Test was designed to measure English vocabulary (WASI, Wechsler, 2011), but participants gave their responses in their preferred language (BSL, English or SSE). Reading comprehension was measured with Vernon-Warden reading test (Hedderly, 1996). Speechreading, TOCS Kyle et al., 2013, https://dcalportal.org/). NVIQ was measured using the TONI- 2; (Brown et al., 1990). Fingerspelling was a reception ability test of words. For full description of the behavioural test, see section 6.1.1.1.2.

In order to better describe the sample of participants, correlations between the participant's scores on the above tasks were calculated (see Table 54).

Table 54. Correlations between measures of participant characteristics in deaf adult readers of English.

	Vocabulary Test	Phonological Processing	Speechreading Ability Test	Fingerspelling Test	NVIQ
Reading Comprehension	.98***	.40	.45	-.16	.62*
Vocabulary Test		.39	.44	-.04	.59*
Phonological Processing (Rhyme task)			.54(+)	-.19	-.29
Speechreading Ability Test				.17	-.17
Fingerspelling Test					-.05

*(+) p < .059, * p < .05, ** p < .01, *** p < .001*

7.2.1.1.3. Materials

The current experiment included 3 stimulus sets: 120 fingerspelled words, 120 fingerspelled transposed letter (TL) pseudowords and 120 matched fingerspelled replaced letters (RL) pseudowords were included (e.g., panert, pamest, PARENT). The stimuli were similar to those used in the written word experiment (experiment 4; see 6.2.1.1.3). However, in the current , experiment only the TL consonant and their TL control were used (Unrelated condition was not included). For the TL items two non-adjacent consonants were transposed (panert, PARENT). There was always a letter between the non-adjacent transposed letters, the same two non-adjacent letters were replaced in the RL control condition (pamest, PARENT). The replaced letters kept the ascending or descending letter form of the transposed letter pseudowords.

The videos (3 seconds) featured the same model and were edited in the same way as experiment 7.1, (see 7.1.1.1.3, see also Figure 19).

A total of 240 fingerspelled items were included; 120 words and 120 pseudowords.

The set of stimuli can be found in Appendix K.

7.2.1.1.4. Procedure

Participants were tested individually in a quiet room at the University College London, Deafness Cognition and Language Centre (DCAL). A MacBook (Retina, 12-inch, Early 2015) was used to display the stimuli using PsychoPy (Peirce, 2007), software written in Python which was used to present the stimuli and to save the outputs of the experiment.

The experimental procedure was the same as in Experiment 7.1. (see the description of events in a SWR paradigm trial in section: 7.1.1.1.4. and Figure 19). However here the conditions of interest were TL consonant and RL control.

The experiment was split in two sessions: first participants saw 120 videos (e.g., 60 videos of fingerspelled words and 60 fingerspelled pseudowords), this lasted approximately 20 minutes. The second session had the same duration, and they were presented with the reminder 120 videos. Therefore, the experiment lasted 40 minutes in total. The whole session was run across two meetings in two different days. The order of the videos was randomised within each session and the order of the sessions was counterbalanced so half of the participants saw either set of videos first.

Participants were instructed to respond as quickly and as accurately as possible if the stimulus was a word or not. They were asked to press one key for “Yes” and another key for “No”. The hand used to respond was counterbalanced across participants. Response times (RTs) were measured from video (target) onset until participant’s response. Before the experiment began participants completed eight practice trials with stimuli not used in the experimental trials.

7.2.1.2. Results – deaf adult readers of English

Twenty words were excluded from the analysis because they were identified as words with lower than 58% accuracy by participants. The set of the words and pseudowords included in the analyses and the stimuli removed can be found in appendix no. K. As in Experiment 6 (section 7.1.1), *t*-tests contrasting word and pseudoword fingerspelled stimulus was performed first. Then, paired-samples t-tests were performed to contrast the conditions of interest (TL vs RL conditions), for orthographic effects both for the subjects (t_1) and items (t_2) scores. The mean lexical decision times and percentage of correct responses per condition are displayed in Table 55 and Figures 87 and 88.

7.2.1.2.1. Lexicality effect, and Orthographic effects

Lexicality effect - Separate paired-samples t-tests for the RTs and the accuracy data showed a lexicality effect when analysed by item, but not by subject. Analyses by subject showed, as predicted faster responses for words than pseudowords (3223.37 vs 3577.59ms); $t_1(24) = -1.58$, $p = .127$; $t_2\,(198) = -4.89$, $p < .001$ and higher accuracy (79% vs 63%); $t_1(24) = 3.09$, $p = .005$; ; $t_2\,(198) = 2.86$, $p = .005$

Orthographic effect - To test the orthographic effect, paired-samples t-tests including the TL and the RL control conditions were performed separately for the RTs and the accuracy data (see Table 55 and Figures 86 and 87).

Analysis on the RTs showed that responses were slower for the TL items than for the RL items, (3626.68ms vs 3528.50ms); this just failed to reach significance in the subject's analyses but was significant in the item analyses; $t_1(12) = 2.15$, $p = .052$; $t_2(99) = 2.61$, $p = .011$.

Analysis of the accuracy data showed that participants made significantly more errors in the TL than the RL conditions for both subject and item analyses (46% vs. 79% correct); $t_1(12) = -7.93$, $p < .001$; $t_2(99) = -6.41$, $p < .001$.

Table 55. Mean lexical decision times (RTs in ms, upper half), and percentage accuracy (lower half) for Transposed letter (TL) and Replaced letter (RL) control conditions, in deaf adult readers of English.

	Orthographic Effect
Type of condition	RT Mean (SD)
Transposed letter (TL)	3626.68 (563.28)
Replaced letter (RL)	3528.50 (657.83)
difference	**98.18(+)**
Type of condition	Accuracy Mean (SD)
Transposed letter (TL)	46.% (15.42)
Replaced letter (RL)	79% (16.80)
difference	**-33%*** **

(+) p = .052, * p < .05, ** p < .01, *** p < .001

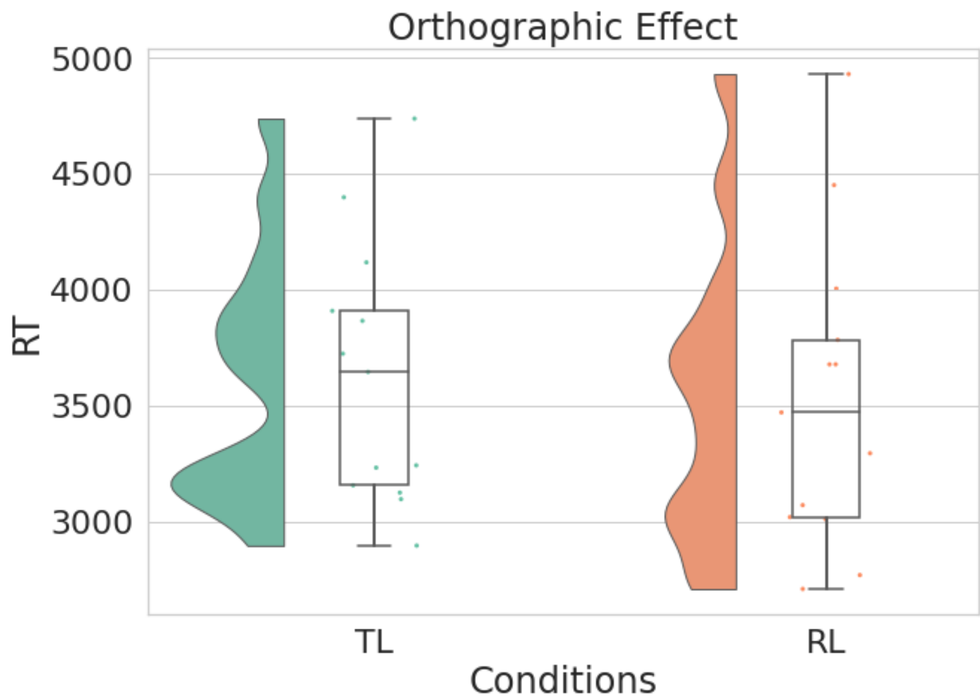


Figure 86. Response times (RT) for Transposed-letter (TL, left) and Replaced-letter (RL, right) during the LDT, in deaf adult readers of English.

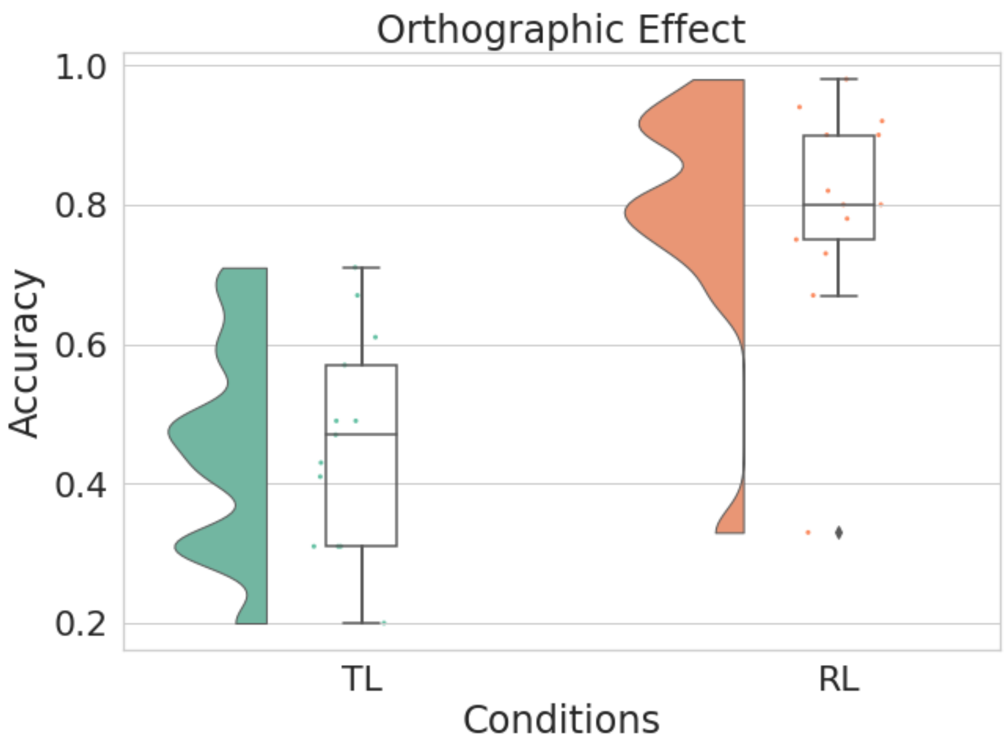


Figure 87. Accuracy of correct responses for Transposed-letter (TL, left) and Replaced-letter (RL, right) during the LDT, in deaf adult readers of English.

Correlations between offline behavioural measures and orthographic effects

Correlations between the size of the orthographic effect (i.e., difference in RTs and accuracy, between the TL and RL control conditions) and the performance in offline behavioural measures: a) reading comprehension, b) vocabulary c) phonological processing, d) speechreading ability and e) fingerspelling ability, are shown in Table 56. There was a significant negative correlation between the size of the orthographic effect in accuracy and the fingerspelling ability (See Figure 88). This correlation was negative because the larger influence of the TL condition in the responses was expressed in negative numbers (TL accuracy minus RL accuracy). Meaning that the better the fingerspelling skills in the participants, the larger the size of the effect of orthography on accuracy.

Table 56. Correlations with offline behavioural measures and the size of the orthographic effect in RT (left) and accuracy (right), in deaf adult readers of English.

Offline measures		Size of the orthographic effect in:	
		RT	Accuracy
Reading Comprehension (% correct)	r	.32	.46
	p	.292	.115
Speechreading Ability Test (% correct)	r	-.09	-.02
	p	.790	.952
Vocabulary Test (# correct answers; max = 80)	r	-.32	-.20
	p	.314	.525
Fingerspelling Ability Test (% correct)	r	.43	-.68*
	p	.147	.010
Rhyme judgement task (% correct)	r	-.31	.47
	p	.334	.122

** p < .05, ** p < .01, *** p < .001*

Note. Size of the orthographic effect (in RT and Accuracy) = Transposed letter - Replaced letter control condition, (TL-RL).

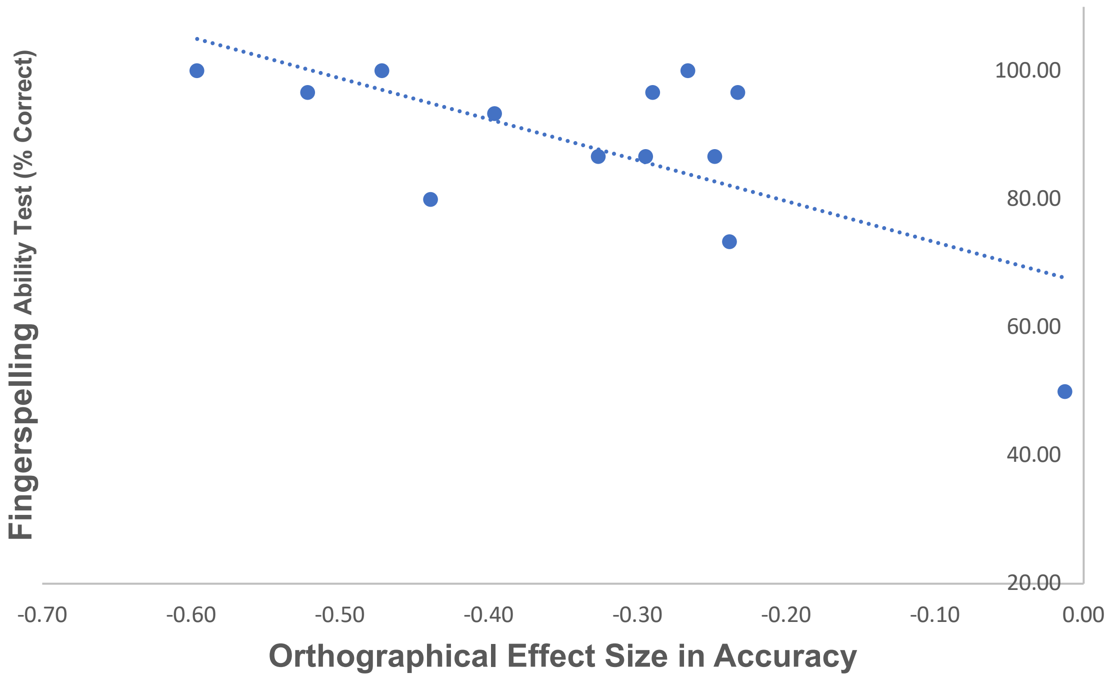


Figure 88. Correlation between the Size of the Orthographic Effect in Accuracy (x-axis), and Fingerspelling Ability Test (y-axis), in deaf adult readers of English.

7.2.2. Deaf adult readers of Spanish

In the current experiment we used the same experimental design from the previous experiment (See section 7.1.1.1), but with deaf adult readers of Spanish, and with Spanish fingerspelled words (a transparent orthography).

The research questions addressed were: How precisely deaf readers of Spanish use orthographic codes during visual recognition of fingerspelled words? Is the size of the orthographic effect related to reading, speechreading, and fingerspelling skills? The hypothesis of these research questions can be found at the beginning of this section (7.2). The conditions of interest in the present SWR orthographic experiment with fingerspelled stimuli presented in isolation were the TL and the RL control condition. As before, the base word of these pseudowords was also included for the LDT to be possible (e.g., TL: aminales, RL: arivales, base word: ANIMALES).

7.2.2.1. Methods

7.2.2.1.1. Participants

Twelve deaf adults (5 female) participated. All participants were profoundly or severely deaf from birth. Their ages ranged from 21.7 to 61.4 years (M = 31.64, SD = 11.08). Five participants were native signers of Mexican Sign Language (Lengua de Señas Mexicana: 'LSM'), one participant was an early signer (AoA between 3 and 9 years old), and six participants learnt LSM after the age of 9. Eight participants were fluent signers of LSM (self-ratings 6-7, in a 1-7 Likert scale) and used LSM as their preferred means of communication in their daily lives. Four participants rated their LSM proficiency between 4 - 5 and reported using LSM with friends and Spanish with their families. This study was approved by the University College London Research Ethics Committee (Project ID Number 10991/001). Instructions were given in LSM and in written Spanish. Participants were asked to provide written consent at the beginning of the sessions, and they were informed that they could withdraw at any time of the session if they would like to.

7.2.2.1.2. Offline behavioural measures

Most of the participants that took part in this experiment were the same from the previous masked priming experiments from this thesis, with the exception of one that was not a proficient signer and could not do the SWR experiment with fingerspelled words. The description of the tasks can be found in section 6.1.1.1.2 'Offline behavioural measures'. The participant's performance on the reading and reading related tasks are reported in Table 57. All participants had non-verbal IQ above 85, their reading comprehension score was above 33.3% of correct responses.

Table 57. Participant characteristics and test scores of the deaf adult readers of Spanish. For full details of the tests see section: 6.1.1.1.2. Offline behavioural measures.

	Mean (SD)	**Range**
Age (Yrs, mths.)	31,64 (11.1)	(21,75-61,43)
Reading Comprehension (% correct)	65% (17)	(50%-88%)
Sentence Reading (% correct)	91% (10)	(69%-100%)
Vocabulary Test (% correct)	74% (18)	(46%-99%)
Phonological Processing (visual bias index)	16 (15)	(3- 44)
Speechreading Ability Test (% correct)	64% (27.6)	(18%-96%)
Fingerspelling Test (% correct)	88% (20.4)	(30%-100%)
NVIQ (Standardised score)	93 (8.9)	(93-125)

Note: Reading comprehension was measured with PLLE; (Hammill et al., 1982 and Sentence Reading, with TECLE (Carrillo and Marin, 1997). Vocabulary Test measured English vocabulary (WASI, Wechsler, 2011), but participants gave their responses in their preferred language (BSL, English or SSE). Phonological Processing (syllable count task); a visual bias index was calculated: the percentage of accurate responses for visually consistent words minus percentage of inconsistent words. Speechreading, was measured with TOCS (Kyle et al., 2013, https://dcalportal.org/). The NVIQ shows IQ score (TONI- 2; Brown et al., 1990). Fingerspelling was a reception ability test of words. For full description of the behavioural test, see section 6.1.2.1.2.

In order to better describe the sample of participants, correlations between the participant's scores in the above tasks were calculated (see Table 58). The variables showing significant correlations remained very similar to the ones found in the written word experiment (section 6.1.2. Table 8), except for a significant correlation found between speechreading and fingerspelling ability, with a slightly smaller number of participants in this study. Lastly, no correlations were found between phonological processing, speechreading and sentence reading.

Table 58. Correlations between measures of participant characteristics in deaf adult readers of Spanish.

	Reading Comprehension	Vocabulary Test	Phonological Processing (visual bias index)	Speechreading Ability Test	Fingerspelling Test	NVIQ
Sentence Reading	.65*	.73**	-.38	.61*	.31	-.10
Reading Comprehension		.61*	-.37	.80**	.40	.02
Vocabulary Test			-.64*	.75**	.53(+)	-.30
Phonological Processing				-.51	-.71**	-.13
Speechreading Ability Test					.64*	-.20
Fingerspelling Test						.14

*(+) p < .07, *p < .05, **p < .01, *** p < .001*

7.2.2.1.3. Materials

In the current experiment we included 120 fingerspelled words, 120 fingerspelled TL and 120 matched RL pseudowords. The stimuli were the same used in experiments 5 and 6 of this thesis. Similar stimuli were used by Comesaña et al., (2016, with hearing adults and children). However, only the conditions of interest (TL and RL pseudowords; see characteristics of the stimuli in section 6.2.2.1.3. Materials) and their base words were included in this experiment. The pseudowords conditions were: (1) TL: two non-adjacent consonants were transposed (aminales, ANIMALES) and (2) RL: replacing the two non-adjacent transposed letters, (arivales, ANIMALES).

The videos, which featured the same model than the other Spanish fingerspelling experiment (Exps., 8-9), were edited in the same way (see. 7.1.1.1.3, see also Figure 21). A total of 240 fingerspelled items were included in the Experiment; 120 words and 120 pseudowords were seen by each participant during the LDT. The set of stimuli can be found in Appendix L.

7.2.2.1.4. Procedure

The procedure followed was the same as in Experiment 8 (see section 7.1.2.1.4). Figure 21 shows the sequence of events in each trial. However, given that the stimuli used in this experiment were based in previous studies in Spanish, the items contained longer words and pseudowords; the average mean duration of each stimulus was on (3000ms), slightly longer than the previous experiment in English (each video average mean duration 2000ms).

7.2.2.2. Results – deaf adult readers of Spanish

A total of fifteen words and their pseudoword conditions were excluded from the analysis as they were accurately identified with less than 58% accuracy. The set of the included words and pseudoword and the stimuli removed can be found in Appendix L. As before, we first looked into the differences between words and pseuodowords. In order to explore the orthographic effects in both subjects (t_1) and items (t_2) scores, a paired-samples t-test was performed to contrast the TL and RL conditions. The mean lexical decision times and percentage of correct responses per condition are displayed in Table 58.

7.2.2.2.1. Lexicality effect, and Orthographic effects

Lexicality effect -Paired-samples *t*-tests for the RTs data showed the expected lexicality effects in for both subject and item analyses, (3995.71ms vs 4280.88 ms); $t_1(22) = -2.33$, $p = .030$; $t_2\,(208) = -3.19$, $p = .002$. In the analysis of accuracy, participants were significantly more accurate for words than for pseudowords, for both subject and item analyses, (88% vs 64%); $t_1(22) = 3.52$, $p = .001$; $t_2\,(208) = 15.87$, $p < .001$.

Orthographic effect - To test the orthographic effect, paired-samples *t*-tests including the TL and the RL control conditions were performed separately for the RTs and the accuracy data (Table 59 and Figures 89 and 90).

Analysis on the RT by subject showed borderline significant difference between conditions, and significant differences in the analyses by item. Responses were slower for the TL than the RL condition, (4420.13 vs 4141.64); $t_1(11)$ =1.95 p = .077; $t_2(104)$ = 2.24, p = .027. In the accuracy analysis response were significantly less accurate for the TL than the RL condition for both subject and item analyses: (58% vs. 70%); $t_1(11)$ = -2.41, p = .035, $t_2(104)$ = -4.34, p = < .001.

Table 59. Mean lexical decision times (RTs in ms, upper half), and percentage accuracy (lower half) for Transposed letter (TL) and Replaced letter (RL) control conditions, in deaf adult readers of Spanish.

	Orthographic Effect
Type of condition	RT Mean (SD)
Transposed letter (TL)	4420.13 (518.78)
Replaced letter (RL)	4141.64 (261.19)
difference	**16.93(+)**
Type of condition	Accuracy Mean (SD)
Transposed letter (TL)	58% (2.1)
Replaced letter (RL)	70% (2.4)
difference	**-.12***

(+) p = .07, * p < .05, ** p < .01, *** p < .001

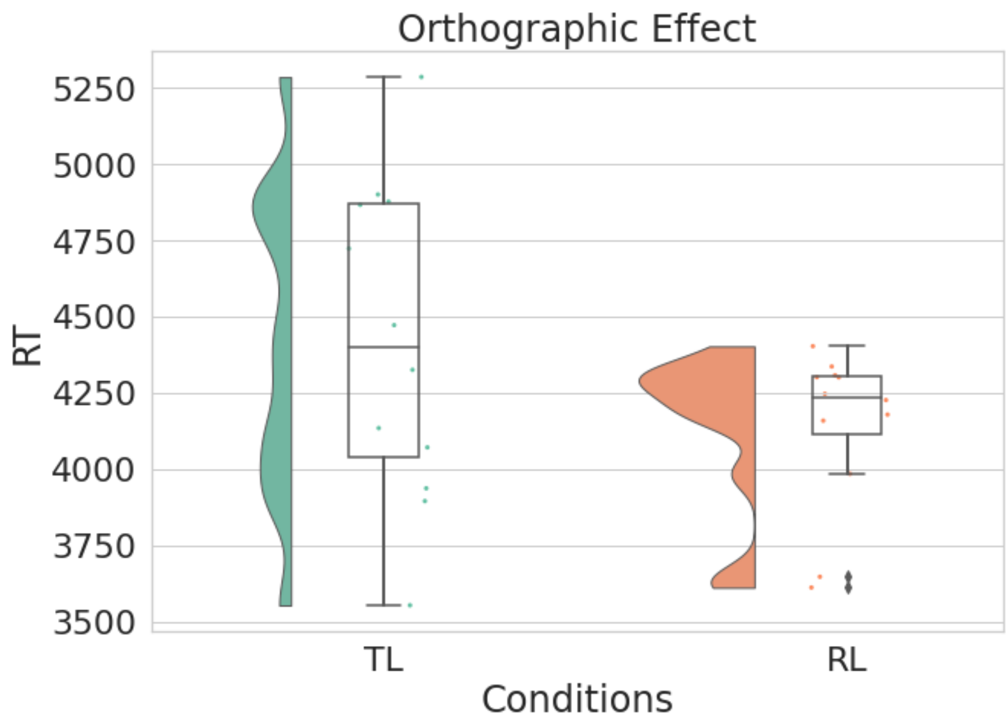


Figure 89. Response times (RT) for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in deaf adult readers of Spanish.

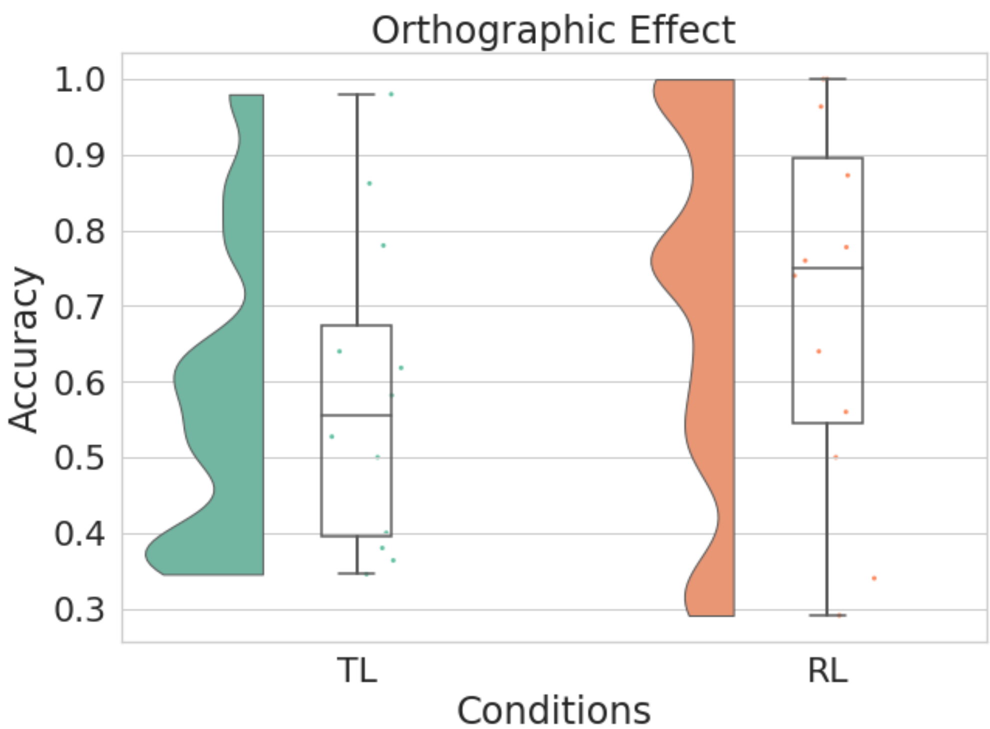


Figure 90. Accuracy of correct responses for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in deaf adult readers of Spanish.

Correlations between offline behavioural measures and orthographic effects.

Correlations between the size of the orthographic effect (i.e., difference in RTs and accuracy, between the TL and RL control conditions) and the performance in offline behavioural measures: a) reading comprehension, b) vocabulary c) phonological processing, d) speechreading ability and e) fingerspelling ability, are shown in Table 60. No significant correlations were found between the size of the orthographic effect and the offline behavioural measures.

Table 60. Correlations with offline behavioural measures and the size of the orthographic effect in RT (left) and accuracy (right), in deaf adult readers of Spanish.

Offline measures		Size of the orthographic effect in:	
		RT	Accuracy
Sentence Reading.	r	.13	.08
(% correct)	*p*	.690	.799
Reading Comprehension	r	-.12	-.28
(% correct)	*p*	.717	.386
Speechreading Ability Test	r	-.17	-.41
(% correct)	*p*	.604	.187
Vocabulary Test	r	.05	-.18
(# correct answers; max = 68)	*p*	.879	.586
Fingerspelling Ability Test	r	-.12	-.22
(% correct)	*p*	.705	.493
Phonological Processing	r	.02	.23
(visual bias index)	*p*	.963	.523

*(+) p < .07, * p < .05, ** p < .01, *** p < .001*

Note. Size of the orthographic effect (in RT and Accuracy) = Transposed letter - Replaced letter control condition, (TL-RL).

7.2.3. Young deaf readers of Spanish

This study investigated whether young deaf readers of Spanish show an orthographic effect during the process of SWR, with TL and RL fingerspelled pseudowords. It was also explored whether the size of the orthographic effect was related to reading, speechreading, and fingerspelling abilities.

7.2.3.1. Methods

7.2.3.1.1. Participants

Fifty-four congenitally deaf participants (aged: 12,7 – 21,7 years) were recruited. All participants were profoundly or severely deaf from birth, did not report history of neurological or psychiatric impairments, and had normal or corrected to normal vision. The data from 6 participants were discarded, because they did not meet the inclusion criteria (non-verbal IQ below 85 and score categorized as 'deficient reading' at the reading comprehension test). Eleven participants could not do the experiment as they were just starting to develop their fingerspelling abilities and they were found to be suboptimal for this study. Of the remaining 37 participants included in the data analysis (12 female, Age mean = 16.7, SD = 2.9), seven were native signers of Mexican Sign Language (Lengua de Señas Mexicana: 'LSM'). Twenty-three had learned LSM from teachers and friends before the age of 9, and seven learned LSM between 12 and 15 years old. Participants rated their MSL skills (Likert scale from 1 to 7). Sixteen participants considered themselves skilled signers (self-ratings = 6-7), eighteen medium skilled (self-ratings = 4-5) and three with poor sign skills (self-ratings < 4). Twenty-one participants were in secondary school (i.e., year 7 to 9, year one starts at 6 years old) and six-teen participants were in high school (i.e., year 10 to 12). All participants reported to have always attended mainstream schools and all of them received literacy training on a phonological (i.e., syllabic) method. This study was approved by the University College London Research Ethics Committee (Project ID Number 10991/001). Parental consent was obtained for participants younger than 18 years old. Participants older 18 years old they were asked to provide written consent at the beginning of the sessions. Instructions were given in LSM and in written Spanish.

7.2.3.1.2. Offline behavioural measures

The young deaf readers were tested on: Reading comprehension, Sentence reading, Vocabulary, Speechreading, Fingerspelling and Phonological processing. These offline behavioural measures were the same as the ones used with the adult deaf readers of Spanish. The description of the tests can be found in section 6.1.2.1.2 'Offline behavioural measures'. See participant's performance Table 60 and the correlations between the behavioural measures in Table 61.

Table 61. Participants' characteristics and test scores of the young deaf readers of Spanish.

	Mean (SD)	Range
Age (Yrs, mths.)	16,7 (2.9)	(12,7-21,7)
Reading Comprehension (% correct)	42% (21.3)	(10%-83%)
Sentence Reading (% correct)	63% (21.7))	(17%-100%)
Vocabulary Test (% correct)	46% (14)	(18%-74%)
Phonological Processing (visual bias index)	18 (21)	(-44 - 50)
Speechreading Ability Test (% correct)	23% (24.2)	(2%-86%)
Fingerspelling Test (% correct)	73% (19.9)	(33%-100%)
NVIQ (Standardised score)	117 (13)	(88-144)

In order to better describe the sample of participants, correlations between the participant's scores in the above tasks were calculated (see Table 62). The variables showing significant correlations remained the same as the ones performed in first experiment (section 6.1.3. Table 12).

Table 62. Correlations between offline behavioural measures in young deaf readers of Spanish.

	Reading Comprehension	Vocabulary Test	Phonological Processing (visual bias index)	Speechreading Ability Test	Fingerspelling Test	NVIQ
Sentence Reading	.68***	.75***	.13	.63***	.71***	.26
Reading Comprehension		.70***	.05	.65***	.71***	.49**
Vocabulary Test			.13	.71***	.71***	.57***
Phonological Processing				-.02	.17	.23
Speechreading Ability Test					.54**	.31(+)
Fingerspelling Test						.49**

*(+) p < .059, *p < .05, **p < .01, *** p < .001*

7.2.3.1.3. Materials

The same materials were used as were used with deaf adult readers of Spanish. See section ‘7.1.2.1.3. Materials’.

7.2.3.1.4. Procedure

Same procedure followed as with deaf adult readers of English and Spanish. See section: ‘7.1.2.1.4. Procedure’.

7.2.3.2. Results - Young deaf readers of Spanish

Eighty-four words were included in the analyses after removing the words (n=36) that had less than 58% accuracy and their respective conditions (See in Appendix L) the list of words and pseudowords removed and the list of the stimuli used in this experiment). The same statistical analyses performed in the deaf adult readers studies were performed here (see section 7.2.1.1.). First, we looked into the differences between words and pseudowords. Then, orthographic effects were explored in both subjects (t_1) and items (t_2) scores. Paired-samples t-tests were performed separately for the RTs and the accuracy data to contrast the conditions of interest (TL vs RL control conditions). The mean lexical decision times and percentage of correct responses per condition are displayed in Table 62.

7.2.3.2.1. Lexicality effect, and Orthographic effects

Lexicality effect – No difference was found in RTs between responses to fingerspelled words vs pseudowords (3807.68ms vs 3967.06ms); $t_1(72) = -1.51$, p = .136; $t_2(166) = -1.76$, $p = .081$. In the accuracy analyses, participants had better accuracy for words than for pseudowords, for both subject and item analyses; (62% vs 50%) $t_1(72) = 4.05$, $p = .001$; $t_2(166) = 8.19$, $p < .001$).

Orthographic effects - Analysis on the RTs showed no differences between TL and RL conditions (4030.15ms vs 3903.98ms); $t_1(36) = 1.62$, $p = .114$; $t_2(183) = .99$, $p = .326$. Analysis on the accuracy showed that participants had more errors for the TL than for the RL pseudowords, for both subject and item analyses (48% vs. 53%); $t_1(36) = -2.28$ $p = .029$; $t_2(83) = -2.01$, $p = .048$ (See Table 63 and Figures 91 and 92).

Table 63. Mean lexical decision times (RTs in ms, upper half), and percentage accuracy (lower half) for Transposed letter (TL) and Replaced letter (RL) control conditions, in young deaf readers of Spanish.

	Orthographic Effect
Type of condition	RT Mean (SD)
Transposed letter (TL)	4030.15 (463.05)
Replaced letter (RL)	3903.98 (490.41)
difference	**126.17**
Type of condition	Accuracy Mean (SD)
Transposed letter (TL)	48% (11.6)
Replaced letter (RL)	53% (14.1)
difference	**-5***

* $p < .05$, ** $p < .01$, *** $p < .001$

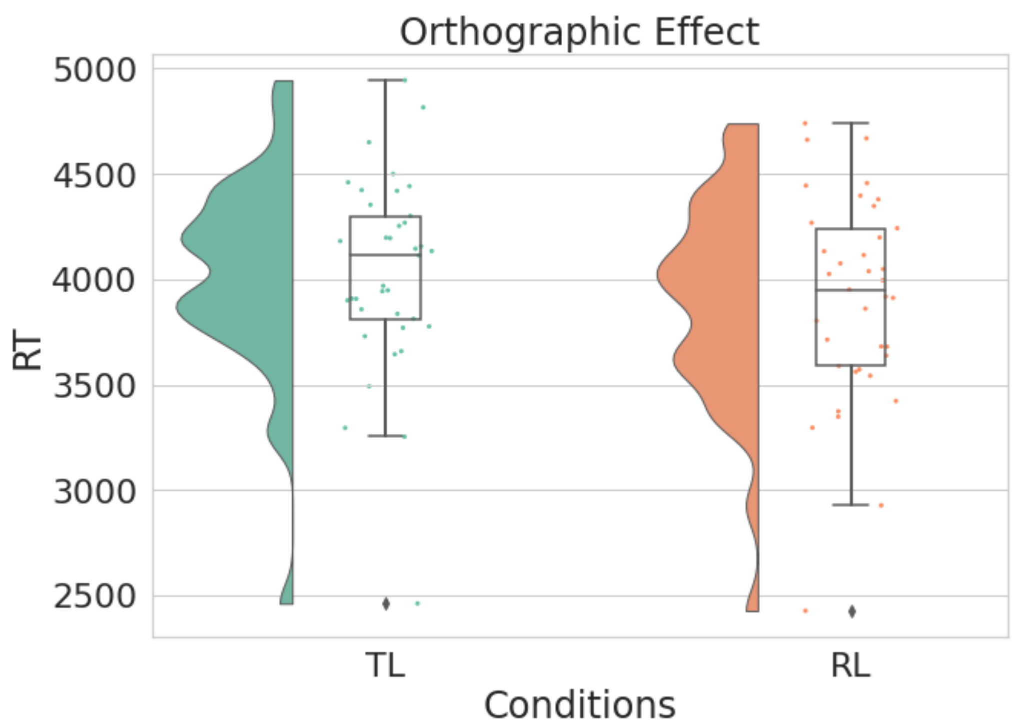


Figure 91. Response times (RT) for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in young deaf readers of Spanish.

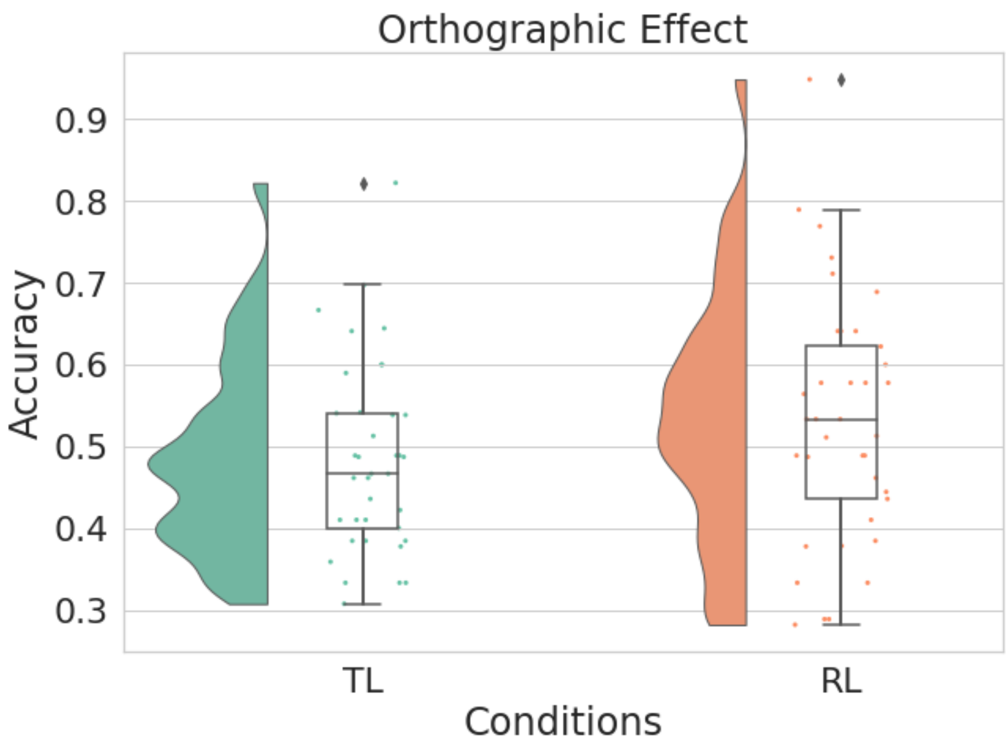


Figure 92. Accuracy of correct responses for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in young deaf readers of Spanish.

Correlations between offline behavioural measures and orthographic effects

Correlations between the size of the orthographic effect (i.e., difference in RTs and accuracy, between the TL and RL control conditions) and the performance in offline behavioural measures: a) reading comprehension, b) vocabulary c) phonological processing, d) speechreading ability and e) fingerspelling ability, are shown in Table 64 and Figures 94 and 95. A significant positive correlation was found between the Size of the Orthographic Effect in RT (TL minus RL therefore a negative figure means facilitation or faster RTs for TL than RL) and Sentence Reading. This means that the larger the orthographic effect size is, the better the young deaf readers read sentences (See Figure 93). Additionally, a significant negative correlation was found between the Orthographic Effect in accuracy and vocabulary. This correlation was negative because the larger influence of the TL-C in the responses was expressed in negative numbers (TL-C accuracy minus RL-C control accuracy therefore negative figure indicates worse accuracy in TL than RL). Meaning that the larger the vocabulary size in the participants, the larger the size of the effect of orthography on accuracy (See Figure 94).

Table 64. Correlations with offline behavioural measures and the size of the orthographic effect in RT (left) and accuracy (right), in young deaf readers of Spanish.

Offline measures		Size of the orthographic effect in: RT	Size of the orthographic effect in: Accuracy
Sentence Reading (% correct)	r	.33*	-.23
	p	.048	.164
Reading Comprehension (% correct)	r	.09	-.31
	p	.605	.064(+)
Speechreading Ability Test (% correct)	r	.21	-.24
	p	.217	.157
Vocabulary Test (# correct answers; max = 68)	r	.31	-.36*
	p	.064(+)	.030
Fingerspelling Ability Test (% correct)	r	.20	-.28
	p	.226	.095
Phonological Processing (visual bias index)	r	.26	.13
	p	.126	.460

*(+) $p < .064$, * $p < .05$, ** $p < .01$, *** $p < .001$*

Note. Size of the orthographic effect (in RT and Accuracy) = Transposed letter - Replaced letter control condition, (TL-RL). After Bonferroni correction no correlations were significant.

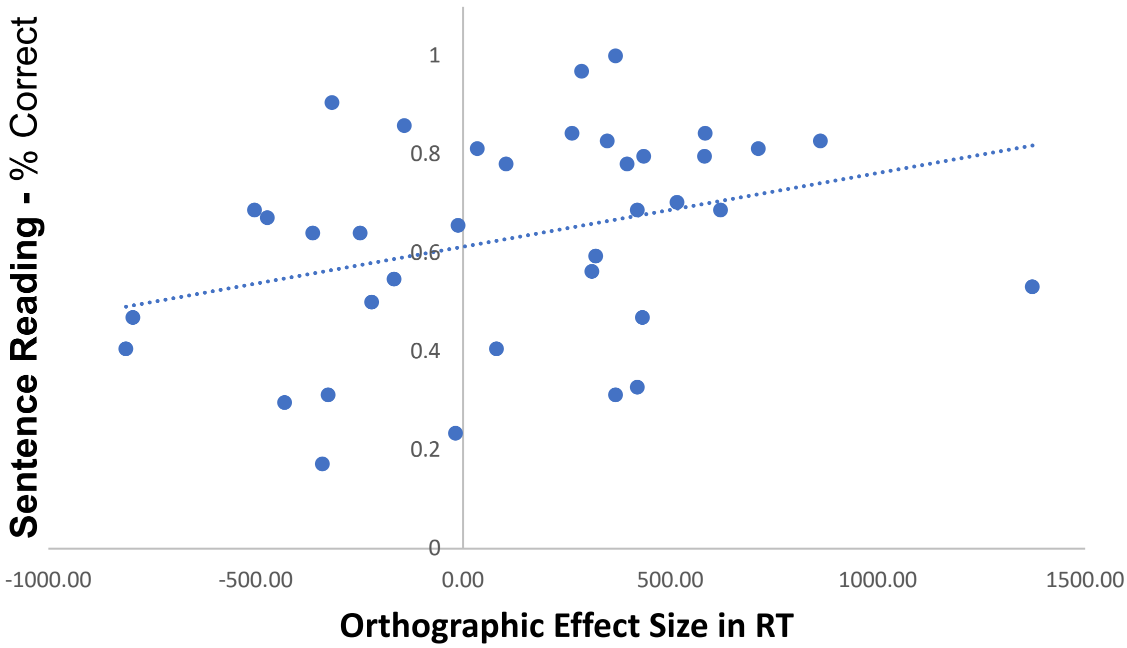


Figure 93. Correlation between the Size of the Orthographic Effect in RT (x-axis), and Sentence Reading (y-axis), in young deaf readers of Spanish.

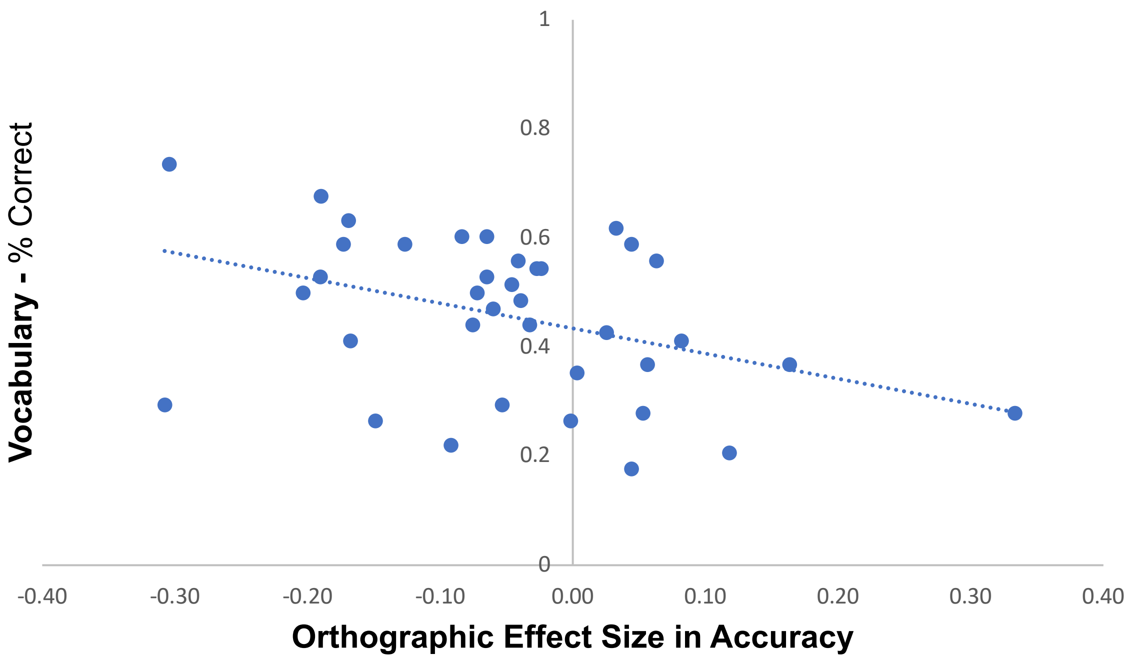


Figure 94. Correlation between the Size of the Orthographic Effect in Accuracy (x-axis), and Vocabulary Test (y-axis), in young deaf readers of Spanish.

In the masked orthographic priming experiment in this thesis (see section 6.2) only young deaf readers with large vocabulary size and the group of deaf adult skilled readers showed a strong orthographic effect, while the effect was not significant in the group of young deaf readers with smaller vocabulary. This suggests a developmental pattern in which differences in vocabulary size can influence on how young readers access to the sub lexical information of the words (e.g., phonological, or orthographic codes). Additionally, there is robust evidence that vocabulary is the main predictor of reading ability in deaf readers (Mayberry et al., 2011, Kyle & Harris, 2011; Kyle et al., 2016). Therefore, in order to better understand the process of single word recognition with fingerspelled words in developing readers, the group of young readers (n=37) was split in half, based on their vocabulary size: small vocabulary (n=18; Vocabulary Mean score = 34%, SD = 9) and large vocabulary (n=19; Vocabulary Mean score = 58%, SD = 6). The same analyses described above for the whole group were performed for each group separately (see Table 65 for Small Vocabulary group and Table 66 for Large Vocabulary group).

Small vocabulary group

Lexicality effect: No significant difference was found between response times to words and pseudowords; (3828.51ms vs 3982.77ms); $t_1(36) = -1.20$, $p = .236$; $t_2(166) = -1.04$, $p = .302$. There was significantly better accuracy for words than for pseudowords, for both subject and item analyses; (57% vs 48%); $t_1(36) = 2.78$, $p = .008$; $t_2(166) = 6.15$, $p < .001$.

Orthographic effects - There were no significant differences between TL and RL conditions in RT; (3997.41ms vs 3968.13ms); $t_1(18) = .245$, $p = .809$; $t_2(83) = -.276$, $p = .783$ (See Table 65 and Figures 95 and 96), nor in accuracy; (48% vs 49%), $t_1(18) = -.164$, $p = .871$; $t_2(83) = -.51$, $p = .613$.

Large vocabulary group

Lexicality effect – There was only a significant difference in RTs between words and pseudowords (3785.69ms vs 3950.49ms), in the item analysis; $t_1(34) = -.95$, $p = .349$; $t_2(166) = -2.31$, $p = .022$. There was a significant difference in accuracy between words and pseudowords in the analyses, for both subject and item analyses (67% vs 52%), $t_1(34) = 3.14$, $p = .004$; $t_2(166) = 3{,}16$, $p = .002$.

Orthographic effects – Participants were slower to reject as words the TL than the RL pseudowords, for both subject and item analyses; (4064.71ms vs 3836.26ms), $t_1(17) = 2.38$, $p = .030$; $t_2(83) = 2.54$, $p = .013$. Analysis of the accuracy data also showed a significant difference between conditions; participants made more errors for the TL than for the RL pseudowords, for both subject and item analyses; (49% vs 58%), $t_1(17) = -3.96$, $p < .001$; $t_2(83) = -2.96$, $p = .004$ (See Table 66 and Figures 95 and 96).

Table 65. Mean lexical decision times (RTs in ms, upper half), and percentage accuracy (lower half) for TL and RL control conditions, in young deaf readers of Spanish with Small Vocabulary Size.

	Orthographic Effect
Type of condition	RT Mean (SD)
Transposed letter (TL)	3997.41 (439.72)
Replaced letter (RL)	3968.13 (384.42)
difference	**29.28**
Type of condition	Accuracy Mean (SD)
Transposed letter (TL)	48% (11)
Replaced letter (RL)	49% (14)
difference	**1%**

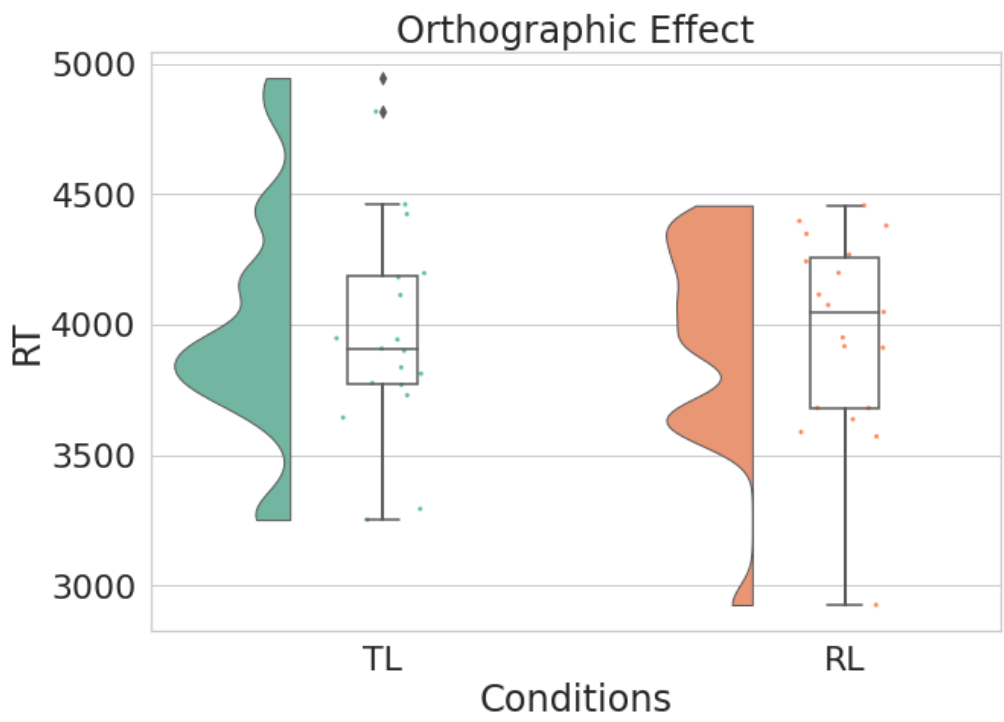


Figure 95. Response times (RT) for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in young deaf readers of Spanish with Small Vocabulary Size.

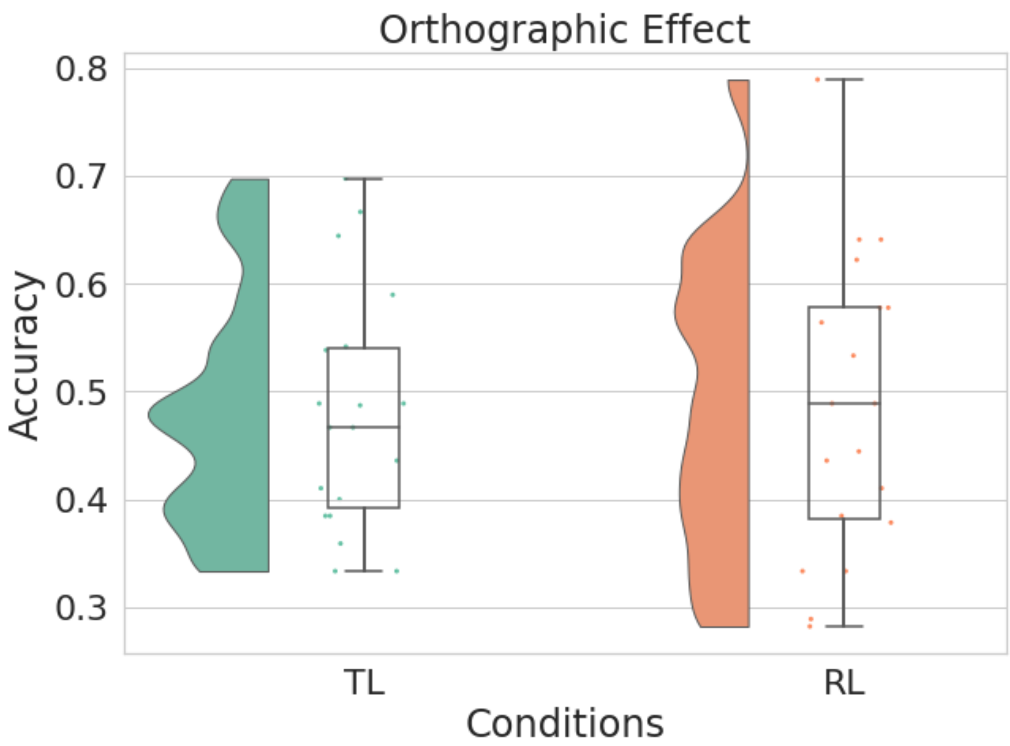


Figure 96. Response times (RT) for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in young deaf readers of Spanish with Small Vocabulary Size.

Table 66. Mean lexical decision times (RTs in ms, upper half), and percentage accuracy (lower half) for TL and RL control conditions, in young deaf readers of Spanish with Large Vocabulary Size.

	Orthographic Effect
	RT
Type of condition	Mean (SD)
Transposed letter (TL)	4064.71 (496.86)
Replaced letter (RL)	3836.26 (585.98))
difference	**228.45***
	Accuracy
Type of condition	Mean (SD)
Transposed letter (TL)	49% (12)
Replaced letter (RL)	58% (15)
difference	**-9%*** **

* $p < .05$, ** $p < .01$, *** $p < .001$

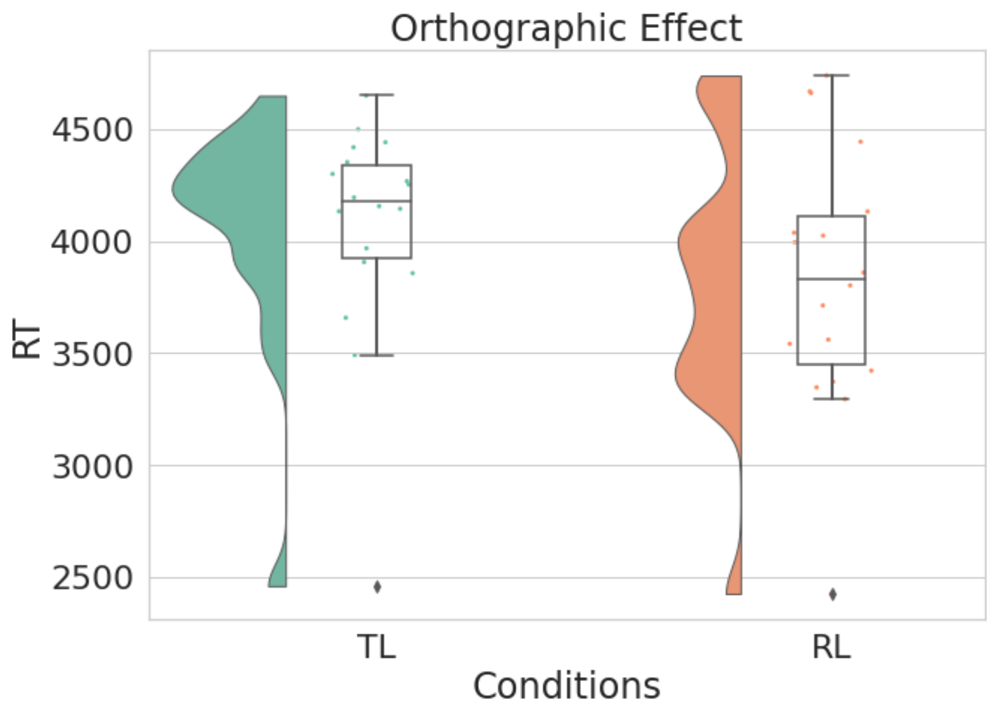


Figure 97. Response times (RT) for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in young deaf readers of Spanish with Large Vocabulary Size.

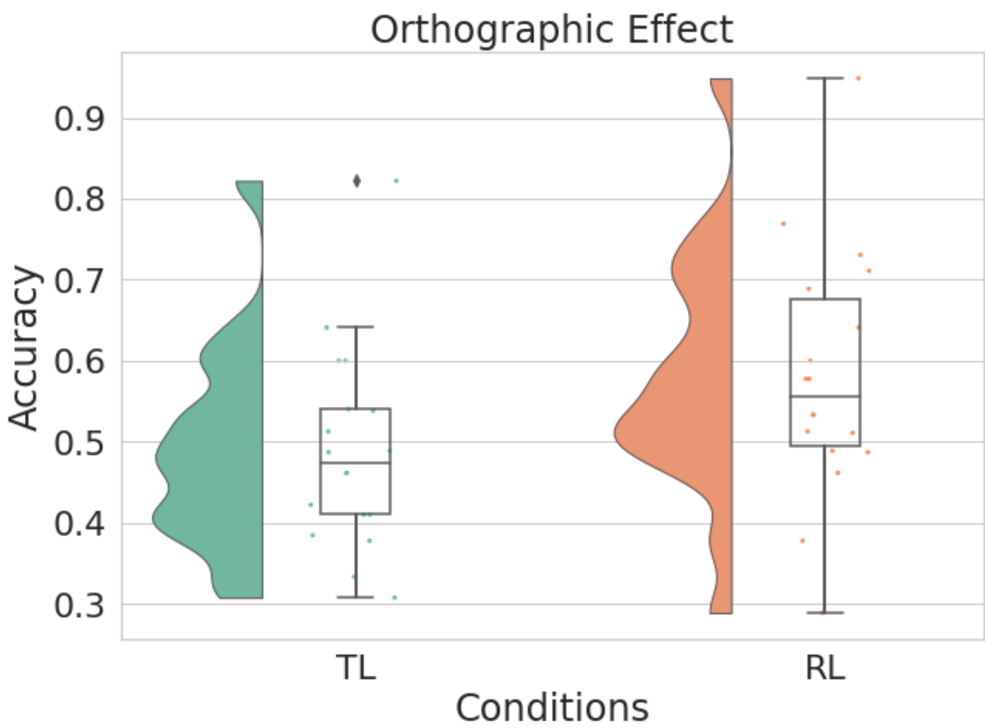


Figure 98. Accuracy of correct responses for Transposed-letter consonant (TL, left) and Replaced-letter consonant (RL, right) during the LDT, in young deaf readers of Spanish with Large Vocabulary Size.

The correlation analyses between the size of the orthographic effect (in RT and accuracy) and the behavioural measures were performed in the two groups: Small Vocabulary Size (see Table 67), and Large Vocabulary Size (see Table 68). No correlations were found between the size of the orthographic effect (in RT and accuracy) and the behavioural measures in the two groups of young deaf readers.

Table 67. Correlations with offline behavioural measures and the size of the orthographic effect in RT (left) and accuracy (right), in young deaf readers of Spanish with Small Vocabulary Size.

Offline measures		Size of the orthographic effect in:	
		RT	Accuracy
Sentence Reading (% correct)	r	.23	.13
	p	.337	.586
Reading Comprehension (% correct)	r	-.24	-.08
	p	.319	.749
Speechreading Ability Test (% correct)	r	.16	-.11
	p	.509	.669
Vocabulary Test (# correct answers; max = 68)	r	.35	-.16
	p	.142	.515
Fingerspelling Ability Test (% correct)	r	.06	-.01
	p	.815	.981
Phonological Processing (visual bias index)	r	.39	.26
	p	.100	.289

*(+) $p < .076$, * $p < .05$, ** $p < .01$, *** $p < .001$*

Note. Size of the orthographic effect (in RT and Accuracy) = Transposed letter - Replaced letter control condition, (TL-RL).

Table 68. Correlations with offline behavioural measures and the size of the orthographic effect in RT (left) and accuracy (right), in young deaf readers of Spanish with Large Vocabulary Size.

Offline measures		Size of the orthographic effect in:	
		RT	Accuracy
Sentence Reading (% correct)	r	.32	-.26
	p	.192	.304
Reading Comprehension (% correct)	r	.01	-.10
	p	.958	.687
Speechreading Ability Test (% correct)	r	.10	-.04
	p	.680	.879
Vocabulary Test (# correct answers; max = 68)	r	.02	-.21
	p	.925	.395
Fingerspelling Ability Test (% correct)	r	.11	-.16
	p	.667	.535
Phonological Processing (visual bias index)	r	-.03	.01
	p	.921	.966

* $p < .05$, ** $p < .01$, *** $p < .001$

Note. Size of the orthographic effect (in RT and Accuracy) = Transposed letter - Replaced letter control condition, (TL-RL).

7.2.4. Discussion

This subsection includes a brief discussion from the results from each experiment in section 7.2. For more detail see the General Discussion in Chapter 8.

Deaf adult readers of English

Deaf readers of English showed an influence of orthography in their performance of a LDT with fingerspelled items. They made more errors in response to TL than RL pseudowords. There was also a trend towards slower RTs to TL and RL items. This difference might suggest that the participants are encoding the letter identity of the fingerspelled word, and this information is influencing their RTs, showing a less precise orthographic representation of the words. This is also known as a flexibility of the readers, where they identify all the letters from the word and encode them, showing some flexibility on the letter positions within the word. This orthographic process seems to be similar when processing fingerspelled words and pseudowords (see Meade et al., 2020)

Deaf participants with larger effects of orthography (the way that TL and RL was subtracted participants showed less accuracy, e.g., negative numbers) had better fingerspelling abilities. This suggests that fingerspelling ability provides a good representation of orthographic codes. This finding is consistent with the results found in Ormel, et al (2022), where fingerspelling ability predicted better orthographic representation in deaf participants.

Not surprisingly, the participants were more accurate, and relatively faster, recognising fingerspelled words than pseudowords. The clear, but not entirely significant, trend towards a lexicality effect in the RTs is likely to be due to the low N, we would expect to find significant differences in RTs with a higher N. However, this could also be also explained by the nature of the stimuli where participants require more time to process the whole fingerspelled word or pseudoword than when it was presented in printed text. This extra time could allow participants to develop strategies to answer more efficiently and reduce the differences between both types of stimuli.

Deaf adult readers of Spanish

These deaf adult readers of Spanish had some variability in their reading scores (e.g., sentence reading test, M=91%, SD=10, range=69%-100%). However, most of them were skilled readers. As predicted, deaf adult readers of Spanish showed an orthographic effect in accuracy. This supports the notion that readers can show some flexibility to recognize the words, as long as they recognize all the letters that form the word. In terms of their RTs, deaf adult skilled readers showed a borderline difference between rejecting TL pseudowords (e.g., aminales) and RL pseudoword (e.g., arivales) and they also seem to respond slower (although not significantly) in the TL condition. The fact that the participants were slower and had more errors in the TL than in the RL condition reflects that they are indeed accessing the abstract letter representations for these words but keep a certain degree of flexibility regarding coding the position of those letters

There was a clear effect in accuracy and an almost significant difference in RT with a small sample size which supports those deaf readers of Spanish rely in orthographic processing even when the stimulus is presented in serial. It is not well understood which mechanisms of fingerspelling ability support word recognition, as the process is slightly different when a reader recognizes a printed word vs fingerspelled word. Given that fingerspelled words are presented letter by letter by a handshape the readers need time to see all the letters, remember their order and have lexical access to them. Whereas the process of recognizing printed words is faster with all the information immediately available for the participants. This extra time could also be used by deaf readers to develop different strategies when recognizing a fingerspelled word.

Young deaf readers of Spanish

The orthographic effects were found in the accuracy percentage, in the whole group of young readers as well in the group of Large Vocabulary. Developing readers had more errors to the transposed letter condition (e.g., aminales) than to the replaced letter control condition (e.g., arivales) when rejecting them as words (e.g., animales). This suggests that the orthographic effect in accuracy in the whole group might be driven by those young readers with a large vocabulary, who knew more words and relied on the orthographic information to recognize words. For example, they could identify all the letters from the words and showed some flexibility to those letters that were transposed. Possible reasons of why young deaf readers with small vocabulary did not show an orthographic effect are discussed in the General Discussion (Chapter 8) of this thesis.

In the whole group of young deaf readers, the size of the orthographic effect in RTs was correlated to reading ability. This may suggest that the larger the orthographic effect in RTs the better reading ability in the participants. In other words, participants that were affected by the orthographic information of the fingerspelled words seem to be better readers.
In terms of the size of the orthographic effect in accuracy, this was correlated to vocabulary. This correlation was negative (see table 61), meaning that the orthographic effect was the difference score of this subtraction: TL-RL. Therefore, if the difference score is negative, participants have better encoding flexibility of the letter identity. This suggests that the more errors participants had to reject the TL as words, the larger their word knowledge is.

The Lexicality Effect was found in the accuracy responses in the whole group of teenagers. This shows the advantage of knowing the words, which means that they have a quick lexical representation of them. When the group of developing deaf readers was split in 'small' and 'large' vocabularies, both groups continued to show a clear lexicality effect in accuracy.

8. General Discussion

The aim of this thesis was to explore to what extent phonological and orthographic information is used automatically during visual word processing by deaf readers. In addition to deaf adults, who are at the end point of reading development, this research also included deaf developing readers (11 to 21 years old) of Spanish with the aim to further our understanding of the interplay between phonological, orthographic and fingerspelling processing at different stages of literacy acquisition. That is, to determine whether the relative contribution of each type of processing to reading ability varies depending on the stage of literacy acquisition. In addition, adult readers of two languages with different orthographic depth (English – opaque and Spanish - transparent) were tested using the same experimental paradigms. First, a sandwich masked priming paradigm was used in combination with a lexical decision task using printed words. Second, an unprimed lexical decision task with fingerspelled words. Finally, a battery of behavioural tests was selected to explore participants' reading ability and other reading related skills and their relationships to the size of the phonological and orthographic effects.

This chapter provides a summary of the main findings of the experiments presented in this doctoral thesis as well as discussing the implications of the results and their limitations. Lastly, I propose suggestions for future work.

A summary of the findings is shown in table 69. Although there are a few exceptions, the results in general show a lexicality effect for both groups of adult readers and for the large vocabulary teenagers but not for the small vocabulary teenagers. More importantly, both the masked priming and the fingerspelling (unprimed lexical decision) experiment show significant phonological effects for the adult readers of English but not for the adult readers of Spanish. In the group of teenager readers of Spanish, the phonological effect seemed to be driven by the small vocabulary group. Regarding the orthographic (TL vs. RL) effect, both groups of adult readers show a typical TL effect. The young deaf readers of Spanish, however, showed the opposite pattern than the one that was found for the pseudohomophone conditions. That is, the orthographic effect was driven by the group with large vocabulary. The observed pattern on the lexicality effect is not surprising and it reflects the increased exposure to print (and increased orthographic knowledge) of larger vocabulary and adult readers. Therefore, below I will concentrate on the discussion of the phonological and orthographic effects in each of the groups as well as their possible relationships with reading related abilities.

Table 69. Overall summary of results for the lexicality (a) and Phonological and Orthographic (b) effects in all groups.

a) Summary of Experimental results (Lexicality Effect):

	Lexical Decision with Sandwich Masked Priming - Printed words		**Unprimed Lexical Decision - Fingerspelled words**	
	Lexicality Effect (words vs pseudowords)		**Lexicality Effect** (words vs pseudowords)	
	Phonology	**Orthography**	**Phonology**	**Orthography**
Adults-English	Exp 1 N= 14 RT= **W** < PS *p*< **.001** Acc **W** < PS *p*= **.003**	Exp: 4 N= 13 RT= **W** < PS *p*= **.048** Acc= W = PS *p*= .054	Exp 7 N= 12 RT= **W** < PS *p*= **.032** Acc W = PS *p*= .217	Exp: 10 N= 13 RT= W = PS *p*= .127 Acc= **W** > PS *p*= **.005**
Adults-Spanish	Exp 2 N= 16 RT= **W** < PS *p*= **.015** Acc W = PS *p*= .189	Exp: 5 N= 16 RT= **W** < PS *p*= **.044** Acc= W = PS *p*= .486	Exp 8 N= 15 RT= W = PS *p*= .211 Acc W = PS *p*= .695	Exp: 11 N= 12 RT= **W** < PS *p*= **.030** Acc= **W** > PS *p*= **.001**
Teenagers-Spanish (Whole group)	Exp 3 N= 55 RT= **W** < PS *p*= **.001** Acc W = PS *p*= .141	Exp: 6 N= 55 RT= W = PS *p*= .237 Acc= W = PS *p*= .158	Exp 9 N= 48 RT= **W** < PS *p*= **.017** Acc W = PS *p*= .905	Exp: 12 N= 37 RT= W = PS *p*= .136 Acc= **W** > PS *p*= **.001**
Teenagers-Spanish Small Vocabulary	Exp 3.1. N= 29 RT= W = PS *p*= .126 Acc W = PS *p*= .612	Exp: 6.1 N= 28 RT= TL = RL *p*= .960 Acc= TL = RL *p*= .119	Exp 9.1 N= 24 RT= W = PS *p*= .236 Acc W = PS *p*= .404	Exp: 12.1 N= 19 RT= W = PS *p*= .236 Acc= **W** > PS ***p*= .008**
Teenagers-Spanish Large Vocabulary	Exp 3.2 N= 26 RT= **W** < PS *p*< **.001** Acc W = PS *p*= .067	Exp: 6.2 N= 26 RT= **TL** < RL *p*= **.035** Acc= TL = RL *p*= .465	Exp 9.2 N= 24 RT= **W** < PS *p*= **.028** Acc W = PS *p*= .219	Exp: 12.2 N= 18 RT= W = PS *p*= .349 Acc= **W** > PS *p*= **.004**

Note: Exp = Experiment, , RT= Response Time, Acc = accuracy, W = words, PS = pseudowords

b) Summary of Experimental results (Phonological and Orthographic Effects):

	Lexical Decision with Sandwich Masked Priming - Printed words		Unprimed Lexical Decision - Fingerspelled words	
	Phonological Effect (PSH vs ORTH)	**Orthographical Effect (TL vs RL)**	**Phonological Effect (PSH vs ORTH)**	**Orthographical Effect (TL vs RL)**
Adults-English	Exp 1 N= 14 RT= **PSH** < ORTH *p*= **.048** Acc **PSH** > ORTH *p*= **.028** *Facilitatory effect in RT and Acc*	Exp: 4 N= 13 RT= **TL** < RL *p*= **.006** Acc: TL = RL *p*= .776 *Facilitatory effect in RT*	Exp 7 N= 12 RT= **PSH** < ORTH *p*= **.007** Acc **PSH** > ORTH *p*= **.044** *Facilitatory effect in RT and Acc*	Exp: 10 N= 13 RT= TL > RL *p*= .052 Acc: **TL** > RL *p*< **.001** *Inhibitory effect in Acc*
Adults-Spanish	Exp 2 N= 16 RT= PSH = ORTH *p*= .778 Acc PSH = ORTH *p*= .532	Exp: 5 N= 16 RT= **TL** < RL *p*= **.041** Acc: TL < **RL** *p*= **.039** *Facilitatory effect in RT* *Inhibitory effect in Acc*	Exp 8 N= 15 RT= PSH = ORTH *p*= .784 Acc PSH = ORTH *p*= .289	Exp: 11 N= 12 RT= TL = RL *p*= .077 Acc: **TL** < RL *p*= **.035** *Inhibitory effect in Acc*
Teenagers-Spanish (Whole group)	Exp 3 N= 55 RT= **PSH** < ORTH *p*= **.049** Acc PSH = ORTH *p*= .332 *Facilitatory effect in RT*	Exp: 6 N= 54 RT= TL = RL *p*= .199 Acc: TL = RL *p*= .392	Exp 9 N= 48 RT= **PSH** > ORTH *p*= **.007** Acc PSH = ORTH *p*= .242 *Inhibitory effect in RT*	Exp: 12 N= 37 RT= TL = RL *p*= .114 Acc: **TL** < RL *p*= **.029** *Inhibitory effect in Acc*
Teenagers-Spanish Small Vocabulary	Exp 3.1. N= 29 RT= **PSH** < ORTH *p*= **.031** Acc PSH = ORTH *p*= .165 *Facilitatory effect in RT*	Exp: 6.1 N= 28 RT= TL = RL *p*= .184 Acc: TL = RL *p*= .674	Exp 9.1 N= 24 RT= **PSH** > ORTH *p*= **.020** Acc PSH = ORTH *p*= .847 *Inhibitory effect in RT*	Exp: 12.1 N= 19 RT= TL = RL *p*= .809 Acc: TL = RL *p*= .871
Teenagers-Spanish Large Vocabulary	Exp 3.2 N= 26 RT= PSH = ORTH *p*= .827 Acc PSH = ORTH *p*= .731	Exp: 6.2 N= 26 RT= **TL** < RL *p*= **.002** Acc: TL = RL *p*= .407 *Facilitatory effect in RT*	Exp 9.2 N= 24 RT= PSH = ORTH *p*= .156 Acc PSH = ORTH *p*= .182	Exp: 12.2 N= 18 RT= **TL** > RL *p*= **.030** Acc: **TL** < RL *p*< **.001** *Inhibitory effect in RT and Acc*

Note: Facilitatory effect: Faster responses or/and better accuracy; Inhibitory effect: Slower responses or/and more errors in accuracy, RT = Response Time, Acc = accuracy, Exp = Experiment, PSH = pseudohomophones, ORTH = orthographic control, TL = Transposed Letter, RL= Replaced Letter

Processing of written words

8.1. Phonological processing of written words (Experiments 1-3)

Experiments 1, 2 and. 3 addressed two research questions in each group of participants:

(1) Do deaf readers use phonological codes automatically during visual word recognition?

(2) Is the size of any phonological priming effect correlated with reading, speechreading and fingerspelling skills?

This subsection will consider the findings reported in Chapter 6 (section 6.1), in the context of previous evidence to address these research questions.

Do deaf readers of English and Spanish use phonological codes automatically during visual word recognition?

Following the rationale presented in Chapter 3, it was predicted that if deaf readers use phonological codes automatically during word recognition, they should show faster RTs and less errors for words preceded by pseudohomophones than for those preceded by orthographic control masked primes (due to facilitation in the pseudohomophone prime condition).

This prediction is based on previous research in hearing readers (Rastle & Brysbaert, 2006), which can serve as a comparison point in the aim to understand word recognition and reading in people with an altered access to speech-based phonology. In the case of hearing readers, phonological processing is commonly recognized as one of the main contributors to visual word recognition in adult skilled readers (Frost, 1998). Furthermore, it has been suggested that the role of phonological processing is crucial at the early stages of reading development in hearing readers, (for a recent comprehensive review Castles et al., 2018). This is due to reading being 'parasitic' on spoken language and recycling and already built language comprehension network (Dehaene & Cohen, 2007). In other words, reading instruction allows hearing students to match letters to already existing phonological representations and understanding the phoneme to grapheme conversion rules. This allows developing readers to access an already built network for language processing. Therefore, in hearing readers word recognition is intrinsically related to developing an awareness of the phonemes that the word contains and accessing these representations during word recognition. Previous research strongly supports this view, showing phonological effects in a wide range of experiments that start early on during reading development and continue in adulthood , (for a recent comprehensive review see Castles et al., 2018).

Research into phonological effects in deaf readers has been more controversial than in hearing readers. On the one hand, there are studies that have shown that deaf adult readers can make use of phonological information across a range of tasks, most of them involving explicit phonological manipulations (e.g., decide whether two words rhyme or not) (e.g., Emmorey et al., 2013; Hanson & McGarr, 1989; MacSweeney et al., 2008, 2013). On the other hand, many recent studies investigating automatic activation of phonological codes during word recognition have failed to show an effect for deaf readers (Costello et al., 2021; Fariña et al., 2017) or have found evidence of coarser grained phonological processing in deaf than hearing people (Glezer et al., 2019).

Recent findings have shown that there is a variety of factors that contribute to good reading ability in deaf children and adults (see Dye et al., 2008; Mayberry et al., 2011; Musselman, 2000; Ye Wang et al., 2008). For deaf signers, those factors include sign language proficiency, sign vocabulary size and fingerspelling skill (see Mayberry et al., 2011; Ormel et al., 2022) as well as speechreading skill (Kyle et al., 2016; Arnold & Kopsel, 1996; Kyle & Harris, 2006, 2010).

In this thesis the role of phonology in SWR was investigated in deaf readers using a masked priming paradigm in experiments 1-3. However, phonological masked priming effects are small in nature (Rastle & Brysbaert, 2006). Therefore, there is a chance that this experimental paradigm would not be sensitive enough to isolate a small effect. In order to boost the effects in deaf readers, a sandwich masked priming paradigm (see Lupker & Davis, 2009) was used in this thesis (Experiments 1-6).

In Experiment 1, deaf adult readers of English showed a significant effect of phonology in RTs. This is despite that fact that, due to COVID-19, the sample size was small (n=13). The phonological effect was calculated in response time (RT) and accuracy as follows: pseudohomophones minus orthographic control. Since the difference score in RT was negative this means that participants were responding faster to targets preceded by pseudohomophones (e.g., kup - CUP) vs orthographic controls (e.g., fup, CUP). In terms of accuracy, the difference score was positive, meaning that participants had better accuracy for targets preceded by pseudohomophones vs orthographic controls. Therefore, this group of deaf adult readers of English, responded to targets preceded by pseudohomophones faster and better than targets preceded by orthographic controls. These findings are congruent with previous masked priming experiments that have found facilitatory phonological priming effects in an LDT in hearing readers of English (see Rastle & Brysbaert, 2006). This suggests that deaf adult readers of English were accessing phonological information of the prime automatically, and as result it facilitated lexical decision. These results also suggest that a more sensitive experimental paradigm, such as the sandwich masked priming used here, might be necessary to capture this type of phonological effect in deaf readers. These data clearly indicate that deaf adult readers of English (an opaque orthography) use phonological codes during visual word recognition.

Contrary to the significant phonological effect found in the deaf readers of English in the present study, deaf adult readers of Spanish (Experiment 2, section 6.1) showed no phonological effect. Participants responded similarly to the word targets preceded by pseudohomophones (e.g., kable, CABLE) than to the targets preceded by orthographic controls (e.g, lable, CABLE). It is tempting to attribute the difference in findings between deaf adult readers of Spanish and English to orthographic depth if we consider previous findings in hearing readers. Indeed, it is well established that hearing skilled readers of Spanish show stronger phonological effects than readers of English (Frost, 1994; Algeo & Butcher, 2013). However, studies with deaf readers of Spanish have shown mixed results and, in fact, the situation is likely to be more complicated and will be examined in further detail below. Furthermore, although the same experimental paradigm was used with both deaf adult readers of Spanish and English, it was not possible to contrast the groups directly.

This was because, while the sandwich masked priming settings were the same, important stimulus-related factors differed. For example, the degree of orthographic overlap between prime and target was all except one letter for Spanish items (e.g., kable CABLE) but much more variable for English (e.g., rhight WRITE). The position of the phonological overlap was in the initial syllable for Spanish but more variable—and often in the rhyme—for English. In addition, length, lexical frequency, age of acquisition and bigram frequency were taken into account within each language but not precisely matched across languages. That is, in both languages there was an aim to select highly frequent stimuli, with a low AoA, that was between 4 and 7 letters long. However, it was not possible to perfectly match all of these factors across the two languages. Since these are all factors known to have an effect on behavioural responses, it was considered that a direct comparison between the groups will not help to clarify the underlying factors behind any possible group differences. Possible causes for the apparent differences in patterns of results are discussed instead.

At first sight, the lack of a phonological priming in adult deaf readers of Spanish seem to support the studies that conclude that deaf readers do not use phonological information during word reading, or that its use is reduced compared to hearing readers (Costello et al., 2021; Fariña et al., 2017; Chamberlain, 2002; Bélanger et al., 2012; 2013; Hanson et al., 1983). However, it is important to note that in this thesis, the deaf adult readers of Spanish were skilled readers, similar to the deaf readers studied by Costello et al., (2021) and Fariña et al., (2017). As discussed above, here the phonological effect was significant in the adult readers of English included in Experiment 1. This small group of deaf readers of English had more variability in reading level than the highly skilled adult readers of Spanish. Similarly, the participants in Gutierrez-Sigut et al., (2017) study, had a much wider range of reading skills than the adult readers of Spanish studied here. As previously suggested by Costello et al. (2021), reading skill is likely to be a key factor to explain the differences between studies. One possibility is that the adult skilled readers of Spanish, due to their increased exposure to print, could rely on the visual information of the primes for word recognition without being influenced by the phonology of the primes (see Meade et al., 2020 for a similar argument with skilled readers of English).

The findings in the Spanish teenager group, who were still in the process of reading development (and hence of developing a larger reading ability), further inform our understanding of under which conditions deaf readers use phonological codes to facilitate word recognition. First, the group of teenagers (Experiment 3, section 6.1) indeed showed a phonological effect when considered as a whole. Similar results were also shown in a study with adult deaf readers of Spanish with a large variety of reading levels (Gutierrez -Sigut et al., 2017; 2018). Phonological effects in groups that include less skilled readers but not in groups of skilled readers seem to suggest that accessing the phonology of words is not only possible but also useful to deaf readers while they develop reading skill; and then much less useful when they are skilled, just as in hearing readers. This suggested developmental trajectory might be independent of the orthographic depth of the language in which they are reading. Although given that it was not possible to collect data from deaf teenagers reading English, due to COVID-19, this possibility could not be addressed in the current thesis.

This explanation is consistent with the Dual Route Cascaded (DRC) model that proposes two pathways for word recognition (Coltheart et al., 2011). The direct route: 'printed word' - orthography - word recognition, this route is usually used by skilled readers which recognize words by sight, particularly those more frequent (i.e., with higher exposure). Whereas the indirect phonological mediated route is used for less skilled readers (e.g., 'printed word'- orthography – phonology - word recognition) to recognise regular and low frequency words. The role of phonological processing is particularly essential at the early stages of reading development in hearing readers, (Rayner et al., 2012), it could also play an important role in the reading development of deaf readers. However, as readers gain expertise they rely more on orthography (visual information) to quickly recognize words. Hence, phonological processing seems to take a less important role for hearing readers (Castles et al., 2018) and for deaf readers, who might be able to use visual/orthographic information efficiently early on. The fact that phonological effects are not captured in highly skilled deaf readers, even using highly sensitive experimental paradigms such as sandwich masked priming, might indicate that phonological processing could take a less important role in deaf than in hearing skilled readers—who tend to show phonological effects even if they are small. Further research is needed to test this speculation.

Even if phonological processing is essential for deaf readers at initial stages of reading development, the relationship between the size of phonological effects and reading ability in deaf readers is not clear-cut. As opposed to findings in hearing readers, correlations between the use of phonology and reading ability are not as strong nor consistently found in adult or developing deaf readers (see e.g. Gutierrez-Sigut et al., 2017 of Mayberry et al., 2011 for a review), suggesting that the relationship might be more complex than for hearing readers.

One main contributory factor to reading ability that has been found to correlate with phonological processing is vocabulary size (see e.g. Gutierrez-Sigut. et al., 2018 for evidence with adults and Ormel et al., 2022 for evidence with children). In the study conducted by Gutierrez-Sigut et al., (2018), where the sandwich masked priming paradigm was also used, it was found that adult deaf readers of Spanish with smaller vocabularies had larger phonological effects (since there were no appropriate standardized vocabulary tests for adult readers, these authors use accuracy across several experimental tasks to determine knowledge of printed words as a measure of vocabulary size of adult deaf readers).

This thesis explored whether a phonological effect was present in deaf developing readers with small and large vocabulary size. The group of teenagers was subsequently split in half according to the group's median score in the vocabulary test: Small (n= 29, Vocabulary Mean score = 35%) and Large vocabulary (n=26, Vocabulary Mean score = 57%). In accordance with previous research in Spanish described above (Gutierrez-Sigut et al., 2018), phonological effects were only found in the group of young deaf readers with small vocabulary size but not for the young deaf readers with large vocabulary and the adult skilled readers. Even though neither age or reading ability were correlated with the size of the phonological effect, it is worth to note that the group of young deaf readers with Large vocabulary size was slightly older than the group of Small vocabulary (Mean age, Large voc., 17.6, and Small voc., 15.3). More importantly the large vocabulary group also had better reading skills (Sentence reading score: Large voc., 73%, Small voc., 52%). Indeed, vocabulary and reading skill were, not surprisingly, highly correlated. In summary, the pattern of correlations found here (i.e., significant correlation between the phonological effect and vocabulary size but not age nor reading level) suggest that vocabulary size might hold the strongest relationship with the use of phonology during word recognition. Further research is needed to specifically test that the use of phonology to recognize words is strongly related to vocabulary size above and beyond highly correlated variables.

Regardless of the possible interaction with these other variables (age and reading level) the present results show that increasing vocabulary as part of reading development can shape how phonology is accessed during VWR. As deaf readers of Spanish increase their vocabulary (and to a certain extent reading skills and age) they seem to use less or no phonology while processing words. This is in line with previous findings in hearing developing readers showing a more relevant role of phonology during earlier stages of reading development (see Castles et al., 2018 for an extensive review). Future research should include vocabulary measures.

Is the size of the phonological priming effect related to fingerspelling and speechreading skills?

Having considered that previous research with hearing skilled adult readers has consistently shown phonological effects during VWR tasks, it was therefore initially hypothesized that better speechreaders and those with better fingerspelling skills would show large phonological priming effects.
Therefore, the group of deaf adult readers of Spanish in the current thesis showed a significant correlation between the size of the phonological effect in the written word study and fingerspelling ability. This correlation was negative because a larger facilitation of pseudohomophone primes was expressed in negative numbers (Pseudohomophone's primes minus Orthographic control prime conditions). In other words, the better the fingerspelling abilities in the participants, the larger the size of the effect of phonology on RTs. This suggests that participants with better fingerspelling abilities use phonology to a greater extent during SWR than those with poorer fingerspelling skills. This is in line with the proposal that fingerspelling ability recruits or "taps on" phonological processing (Antia et al., 2020; Lederberg et al., 2019). Recently, Ormel et al., (2022) found that fingerspelling ability, and speech

based phonological knowledge, predicted word and text reading in deaf children from 8 to 13 years old. The authors suggested that fingerspelling can facilitate the construction of phonological representations of printed words. Similarly, Haptonstall-Nykaza & Schick, (2007) and Sehyr et al., (2017), suggested that fingerspelling can be used as a tool to provide phonological information about printed words, and therefore build up the development of speech-based phonological representations. However, it is important to keep in mind that the group showing this correlation was the adult readers of Spanish, which as a group did not have a significant phonological effect. A correlation with fingerspelling skill was not found in any of the other groups. Therefore, although the present results are intriguing, they highlight the importance to further explore the link of fingerspelling skill and phonological processing during word recognition.

Finally, speechreading ability was not correlated with phonological processing. In both Spanish adult and teenager readers, reading ability and speechreading ability were significantly correlated (a correlation was not found in the adult readers of English but due to COVID-19 this was the group with the smallest N). The better speechreading skills the better reading abilities participants showed. This is consistent with Arnold and Kopsel (1996), Kyle and Harris (2006, 2010) and Kyle et al., (2016), who also found speechreading to be correlated to reading ability. It has been suggested that speechreading ability may play a mediation role in building some phonological representations of the speech as it has been proposed that deaf readers can gain some access to the sublexical structure of words (e.g., phonology) through speechreading ability (Kyle & Harris, 2006, 2010). Hence, phonological information could be part of other reading related factors that all together contribute to develop better reading skills in deaf people.

8.2. Orthographic processing of written words (Experiments 4-6)

In addition to examining the role of phonology in reading in deaf people, this thesis also examined the role of orthographic processing during SWR in deaf readers. There have been surprisingly few studies that have addressed this previously. The paradigms allowed us to test whether the precision of the orthographic representations in deaf readers varied across reading development (adults and teenagers), and also languages with different degrees of transparency (i.e., English-Opaque and Spanish- Transparent).

The principal subcomponents of orthographic processing are ‘letter identification’ and ‘letter position identification’ (i.e., order identification; see Chapter 4 for more detail). Some theories (see Grainger and Ziegler, 2011 for recent review) have proposed that a precise orthographic representation requires letters be allocated to a specific position within the words. For the dual-route model this type of precise orthographic representation is necessary for a fine-grained route to lexical access. In addition, Grainger and Ziegler (2011) also propose an open bigrams route: the coarse-grained route, which allows access to the meaning of the word (semantics) through open bigrams, (e.g., CAT: CA, AT, CT). The most common way of exploring orthographic precision in readers has been through the manipulation of transposed letters (Comesaña et al., 2016; Ktori et al., 2014; Lupker et al., 2008; Perea and Carreiras, 2006, 2008; Perea and Lupker, 2004). In the orthographic experiments (4-6) conducted in this thesis, letter positions were manipulated in orthographic primes: TL prime (hostipal – hospital) and RL primes e.g., (hosfigal, hospital).

The research questions addressed in each of the groups of the deaf participants were:

1. To what extent do deaf readers use orthographic codes automatically during visual word recognition?

2. Is the size of the orthographic priming effect corelated with reading, speechreading and fingerspelling skills?

This subsection will examine the experimental findings reported in Chapter 6 (section 6.2).

To what extent do deaf readers of English and Spanish use orthographic codes automatically during visual word recognition?

In terms of orthographic effects in deaf readers our predictions (based on previous findings, see Chapter 4 for more detail) were that deaf readers would show faster RTs and less errors during lexical decision for words preceded by a masked prime which is a pseudoword in which two letters had been transposed (e.g., hostipal – hospital) than when preceded by a pseudoword including a replaced letter (e.g., hosfigal, hospital). It is argued that this would reflect facilitation due to the transposed letter pseudoword.

As predicted, deaf adult readers of English (Exp 4, section 6.2) showed a significant TL effect. Similar findings were found in the group of deaf adult readers of Spanish (Exp 5, a more transparent orthography) and in teenagers with large vocabulary size (but not the whole group of teenagers nor the teenagers with small vocabularies; Exp. 6). By benefiting from the TL primes, these readers showed some flexibility (as opposed to absolutely precise orthographic representations that include the exact letter position) in the associations of letter positions within the word. These findings replicated the standard TL priming effects (Meade et al., 2020, with deaf readers, and Andrews & Lo, 2012, with hearing readers).

In terms of the transparency of the language and orthographic effects, both groups of adults (readers of English and Spanish) showed a facilitatory orthographic effect in RT. Interestingly, the group of readers of Spanish also showed an inhibitory effect in their accuracy responses. That is, responses were faster but less accurate for the TL than for the RL condition. This effect on accuracy was not close to being significant in English readers. One possible explanation is that, as most readers in the Spanish adult group were skilled readers, they could indeed have a more precise orthographic representation of the words than the group of English readers.

In terms of reading development, the group of deaf adult readers of Spanish and the developing readers with large vocabulary showed a facilitatory orthographic effect in their RTs. However, no effect was observed in the group of developing readers with small vocabulary. From a developmental perspective, there is a transition from beginner readers that tend to show a slow word recognition process (using different tools, e.g., decoding) to fast and automatic word recognition, based on the words' orthography (Castles and Nation, 2006; Nation 2009). This transition can also be influenced by individual differences among the readers. These individual differences in the development of orthographic representations are likely to start during childhood and to continue in adulthood (see Perfetti, 1992). On the one hand, more reading experience or better spelling ability could allow readers to have a more precise orthographic representation. For example, Andrews and Hersch (2010) showed that hearing adults who were better spellers showed an inhibitory orthographic effect in a group of university hearing readers. Adult skilled readers develop a fully specified orthographic representations of the words, recognizing only targets as words when their letters are allocated to their specific positions. On the other hand, individual differences could provide readers with more flexibility (i.e. a less precise orthographic representation) when recognizing words (Frith, 1986; e.g., poorer spellers showed a facilitatory effect; in a group of university hearing readers, Andrews & Hersch; 2010). For instance, when some of the letters are not in their exact position within the word (e.g., hostipal, hospital), readers could be influenced by the letter identification from the real word (hospital) and recognizing (hostipal) as a word when it is not. Readers that show flexibility are thought to be less likely to develop a (stricter) fully specified orthographic representation. In other words, they might rely more on the context and might put less attention to the internal structure of the word.

In summary deaf adult readers of English and Spanish and developing readers with large vocabulary size all showed effects of TL during SWR, just as shown in hearing participants. Our next research question was whether the size of this effect related to other factors.

Is the size of the orthographic priming effect related to reading, speechreading and fingerspelling skills?

We hypothesized that reading, speechreading and fingerspelling skill would be associated with the size of the orthographic priming effect in deaf readers. The orthographic priming effect was defined as the difference, in either RTs or accuracy, between the TL and RL conditions.

In contrast to our predictions, no correlation was found between the measures of reading, speechreading and fingerspelling and the size of the priming orthographic effect (i.e., difference between the TL-C and RL-C conditions) in any of the groups. Nonetheless, the adult deaf readers of English and Spanish, and the teenagers with large vocabulary, showed a positive correlation between vocabulary and the size of the priming orthographic effect. Specifically, the group of deaf readers of English showed a positive correlation in accuracy and the group of adult readers of Spanish and the teenagers with large vocabulary showed a correlation in RTs. In terms of the whole group of teenagers, they showed a negative correlation in their RTs (size of the orthographic effect and vocabulary). Meaning that those with a small vocabulary showed a small orthographic effect. Which means that deaf participants with large vocabularies are more sensitive to the TL prime when recognizing target words.

Lexicality effect

The “lexicality effect” (i.e., advantage of processing real words over pseudowords) is also thought to reflect the increased precision of orthographic representations of words. According to Perfetti (2007), as readers integrate more written words into their vocabulary, the precision of their orthographic knowledge increases. In this thesis, a significant lexicality effect was found for both groups of adult readers and also for the young deaf readers with large vocabulary size. Nevertheless, the lexicality effect was not found in the teenagers with small vocabulary. These results replicated previous findings (Acha and Perea, 2008; Cattell, 1886; Paulesu et al., 2010; Reicher, 1969; Zoccolotti et al., 2008). The groups showing a lexicality effect had a large vocabulary and better reading ability than the group of teenagers with small vocabulary that did not show a lexicality effect. One possible reason why the deaf teenagers with a small vocabulary did not show the effect is that since they had less vocabulary in their lexicon, this could have a direct impact on how they process the words and pseudowords. For example, this may cause that some of the words might have been processed as pseudowords and they might not have recognized them as real words. This goes in line with the “Lexical Quality Hypothesis” (LQH) that recognizes the relevance of individual differences in reading ability (Perfetti, 2017). According to the LQH when recognizing single words readers activate their orthographic, phonological and semantic knowledge at the same time, and it is used to process the words. The group of small vocabulary might have had less activation in their semantic and orthographic (as they did not show priming orthographic effects either) knowledge when reading the words. Another possibility is that they might have been affected by the length of the words used in the experiment, as the words were between 7 and 12 letters long (M = 9.38, SD = 1.28). Perhaps teenagers with small vocabulary needed more time to recognize long words. Acha and Perea' (2008), showed that beginning readers of Spanish responded 114ms faster when the target was a short word (6-7 letters) than when it had a longer length (8-9 letters). This impact of the length of the word was not seen in skilled readers. Moreover, as we have seen, the groups of deaf adults and teenagers with large vocabulary seem to benefit differently from phonological and orthographic codes during SWR, compared to the group of teenagers with small vocabulary which seems to rely more on the phonological information during SWR. This may be due to their reading stage, which suggests that teenagers with small vocabulary are in their early stages of reading development, activating phonological codes during SWR. On the other hand, teenagers with large vocabulary and adult readers with also large vocabulary and better reading skills, are sensitive to the orthographic structure of the words. Since young deaf readers of English were not tested, we cannot establish this pattern across languages.

Processing of fingerspelled words

The following section discusses the processing of fingerspelled words in deaf readers during unprimed lexical decision (Experiments 7-12). It is important to remember that even when most of the participants were the same as previous experiments, the groups for the fingerspelling experiments were slightly smaller, as not all the participants had developed fingerspelling ability.

8.3. Phonological processing of fingerspelled words (Experiments 7-9)

The research questions for these series of experiments were the following:

1. Do deaf readers use speech phonology during recognition of fingerspelled words?

2. Is the size of a speech phonological effect during fingerspelling perception related to reading, speechreading and fingerspelling skills?

This subsection will consider previous evidence and contrast them with the findings reported in Chapter 7, section 7.1.

<u>Fingerspelling</u>

Deaf signers can use fingerspelling, the manual representation of the alphabet, to represent written words. Fingerspelling can serve as a link between the semantic and the orthographic representation of words (Padden & Ramsey 2000). According to Ormel et al., (2022) fingerspelling ability may play an important role in facilitating the creation of the orthographic and phonological representations of the written words in deaf readers. This thesis presented a series of experiments examining the role of orthography and phonology during SWR of fingerspelled words, (See Chapter 7).

Do deaf readers use speech phonology during recognition of fingerspelled words?

In line with previous studies with deaf (e.g., Gutierrez-Sigut et al., 2018) and hearing adults (e.g., Rastle and Brysbaert; 2006) it was predicted that if deaf readers use speech phonology during recognition of fingerspelled words (e.g., clue), participants should show slower lexical decision response times and more errors to pseudohomophones (e.g., klue) than to the orthographic control (e.g., plue).
Our results in the fingerspelled experiments seem to show a trend that is consistent with the results from the phonological masked priming experiments. While deaf adult readers of English showed a phonological effect in both RTs (facilitatory) and accuracy (inhibitory), no effect was found in the group of deaf adult readers of Spanish, nor in the group of teenagers with large vocabulary. However, the group of teenagers as a whole and the subset of teenagers with a small vocabulary showed phonological effects, as predicted.

These results with fingerspelled stimuli, largely parallel those found in the phonological masked priming experiments with printed words in this thesis. Deaf readers of English during the unprimed LDT were actually faster in their responses and showed less errors to pseudohomophones (e.g., kable) than to orthographic control (e.g, lable) conditions. Thus, despite the shared phonology of the pseudohomophones with their base word, deaf readers of English rejected the pseudohomophones faster than the orthographic controls. One possibility, albeit speculative, is that English signers are more frequently exposed to potential phonetic errors in fingerspelled words (either seen in others or receiving corrections from other signers when they produce such errors). In other words, when signers learn the correct orthography for fingerspelled words, they may have an enhanced awareness of possible phonological errors that they should avoid and that are commonly associated with this word, which gets reinforced by the interaction with other experienced (more skilled) signers. This could explain how phonological pseudohomophones are rejected faster than pseudowords (which are less frequently encountered), as they would not occur naturally. However further research is needed to test this interpretation.

As discussed previously, no direct comparisons between the two groups of deaf adult readers of English and Spanish were conducted. Even though in both languages the selection of the stimuli were based on similar factors (e.g., AoA, frequency, length), it is unfeasible to have a perfect parameter match due to fundamental differences in language and measurements. Importantly, the production of fingerspelling in BSL is two-handed vs the one-handed fingerspelling system in the LSM. This may also affect the word processing of the participants while doing the LDT, and the production of the fingerspelled word. However, the influence of these potential confounds need to be tested to be able to standardise cross-linguistic fingerspelling tasks.

In terms of our findings in deaf readers of Spanish, our unprimed lexical decision experiments with deaf adult skilled readers of Spanish and teenagers with large vocabulary participants, showed results that are consistent to what has been reported in previous studies (Costello et al., 2021 & Fariña et al., 2017). The results from our fingerspelling study are also consistent with what we found in our masked priming experiments described in Chapter 6, where no significant differences were found between pseudohomophones and orthographic controls in their RT's nor in their accuracy. Even though the paradigm that was used in the Costello et al., (2021) & Fariña et al., (2017) studies was the same as that used here, the current stimuli were also presented in fingerspelled words and pseudowords. Therefore, irrespective of the modality of the stimuli presentations (e.g., printed vs fingerspelling) adult readers of Spanish and teenagers with large vocabulary, showed no sensitivity to the pseudohomophones and treated them equally than the orthographic controls. This suggests that in this experiment the fingerspelled words were processed by the deaf readers in a similar way than they processed printed words. On the other hand, the group of teenagers with small vocabulary did show phonological effects in our fingerspelled version of the task. Fingerspelling can provide visual access to phonology; which can carry phonological information (representation of the speech) in its production (see Haptonstall-Nykaza & Schick, 2007; Sehyr et al., 2916). The production of the stimuli in fingerspelling might have influenced the participant's word processing with phonological information, to recognize the pseudohomophones as pseudowords and reject them slower.

From a developmental point of view, there seem to be a developmental trajectory in deaf readers of Spanish across different age groups (teenagers and adults), as deaf readers with smaller vocabulary were affected by the phonological information of the pseudohomophones while the teenagers with larger vocabulary and adults skilled readers did not show difference between both conditions (pseudohomophones and orthographic controls) in the LDT.

Overall, the findings from our fingerspelling studies suggest that the use of phonology by deaf readers is similar, irrespective of whether the word is presented in print or fingerspelled.

Is the size of a speech phonological effect related to reading, speechreading and fingerspelling skills?

Given that it has been found that deaf readers can access phonology through different reading related tools, such as fingerspelling and speechreading ability. In this thesis, it was also originally hypothesized that better readers, speechreaders and those with better fingerspelling skills would show a larger phonological priming effect.

However, none of the groups of adult deaf readers of English and Spanish showed correlations between the size of the phonological effect in fingerspelled perception and the reading ability (and reading related measures). This is consistent with previous research that similarly did not find correlations between phonological processing and reading ability in deaf readers (e.g., Hanson & Fowler; 1987, Kyle & Harris 2006; Mayberry et al., 2011; Meade et al., 2020; Miller & Clark; 2011).

However, there is always a possibility that a correlation was not found due to the small numbers of participants in the adult groups. Nevertheless, the group of young deaf readers of Spanish did show significant correlations between the size of the phonological effect in RT and reading, speechreading ability and vocabulary. Moreover, there was a correlation between phonological awareness and the size of phonological effect in accuracy.

The participants with lower reading skills had a larger phonological size effect, which may suggest that the use of phonology might be greater when reading skill is in the early stage of development. The other correlations between speechreading and vocabulary, and the phonological size, also support the view that reading related factors may influence the use of phonological information when recognizing fingerspelled words.

8.4. Orthographic processing of fingerspelled words (Experiments 10-12)

Similar to the masked priming experiments with printed words, here, the role of orthography was explored in deaf readers with unprimed LDT experiments using fingerspelled words and pseudowords. The research questions addressed in these experiments (10-12) were the following:

1 How precisely do deaf readers use orthographic codes during visual recognition of fingerspelled words?

2 Is the size of an orthographic effect related to reading, speechreading, and fingerspelling skills?

How precisely do deaf readers use orthographic codes during visual recognition of fingerspelled words?

Standard TL effects have been reported in deaf readers (Meade et al., 2020). Therefore, it was predicted that if deaf readers use orthographic codes during recognition of fingerspelled words (e.g., chocolate), they should show slower lexical decision times and more errors to nonwords with transposed letters (e.g., cholocate) than to nonwords with a replaced letter (e.g., chofonate). As the lexical representation of the real word would be more likely to be activated by the nonword with transposed letters than nonwords with replaced letters.

Deaf adult readers of English and Spanish, as well as the group of teenagers with large vocabulary, showed some degree of flexibility in the association of the transposed letter positions within the fingerspelled items (i.e., significant TL effect), replicating previous findings (Meade et al., 2020). Not only did the participants make more errors in response to TL than RL pseudowords, but there was also a trend towards slower RTs to TL and RL items. This difference might suggest that the participants are encoding the letter identity of the fingerspelled word, and this information is influencing their RTs, showing a less precise orthographic representation of the words. There is very little research available exploring orthographic effects in deaf readers using fingerspelling stimuli. However, these results were consistent with previous findings with hearing readers (e.g., Comesaña et al., 2016; Lupker et al., 2008), and deaf readers (Meade et al., 2020), using printed words. For example, participants showed more errors when rejecting the TL pseudoword 'fwoler' as a word (flower), than rejecting the RL control 'fvoter'. This shows some flexibility in the orthographic processing in deaf readers, as they are able to identify all the letters from the word and encode them but show less precision in their positions within the word. Interestingly the same trend of results was found in our previous experiments with a masked orthographic priming paradigm using printed words. Adult skilled readers and teenagers with large vocabulary seem to be more affected by this orthographic manipulation than readers with small vocabulary who are still developing their reading skills. This orthographic processing found in deaf readers with printed stimuli seems to be similar when processing fingerspelled words and pseudowords, as the results show the same orthographic effects.

Is the size of an orthographic effect related to reading, speechreading, and fingerspelling skills?

It was hypothesized that better readers, speechreaders and those with better fingerspelling skills should show a larger orthographic effect (defined as the difference between the TL and the RL control condition in either RTs or accuracy). As predicted, deaf readers of English who showed larger effects of orthography in accuracy (TL minus RL, e.g., negative numbers indicate more errors for TL condition than for the RL), had better fingerspelling abilities. This supports the proposal that fingerspelling ability might provide a representation of orthographic codes in deaf readers. This finding is consistent with the results found in Ormel, et al., (2022), where fingerspelling ability predicted better orthographic representation in deaf participants. The other groups of Spanish readers did not show any correlations with the size of the orthographic effects and the reading related measures. Except for the whole group of teenagers that showed a significant correlation between the size of the orthographic effect and sentence reading in RT (the larger the orthographic effect size the better reading skills) and with vocabulary in accuracy (the larger the orthographic effect size the better the vocabulary). These correlations support the role of fingerspelling building orthographic representation in deaf readers, particularly during reading development, linking the representation of the printed word to the fingerspelled words.

8.5. **Summary and Implications**

The results reported in this thesis have important implications for our understanding of how deaf readers from different stages of reading development and deaf readers who are at the end point of reading development (i.e., adult readers), recognize single words. The main aim of this thesis was to explore the role of phonology and orthography during word recognition (printed and fingerspelled words). An important methodological contribution from these studies is that phonology and orthography appear to play a very similar role in single word recognition of written words and fingerspelled words in deaf readers.

Our findings from both phonological and orthographic experiments (masked priming with printed words and LDT with fingerspelled words), seem to show similar patterns in how participants process printed and fingerspelled words. On the one hand, deaf teenagers from different stages of reading development (the whole group and the group with small vocabulary), showed phonological effects during processing of both written and fingerspelled words. On the other hand, deaf adult readers of Spanish who are at the end point of reading, as well as the group of teenagers with large vocabulary size, showed orthographic effects in both, written and fingerspelled experiments. Finally, deaf adult readers of English showed effects of both phonology and orthography, during both written and fingerspelled SWR.

In summary, the results suggest that deaf readers of Spanish seem to benefit from phonological information at early stages of reading development. However, when their vocabulary and reading experience increases, they seem to rely more on the visual, orthographic information of the word.

In the case of deaf adult readers of English (opaque orthography), they showed phonological and orthographic effects during both written and fingerspelled word recognition. This group had more variability in the reading skills levels. They might use both phonological and orthographic codes to recognize words.

The abundance of mixed results in the literature studying phonological effects in hearing and deaf readers, suggest the need for future studies that systematically control and assess the impact and influence of a wider range of variables (e.g., methodological differences, individual differences). Our findings underline the importance of studying phonological and orthographic effects in languages with different transparency and across different stages of reading development. They also lend strong support to the suggestion that fingerspelling can play an important role in reading development in deaf children.

Appendix A
Set of stimuli used in the Rhyme Judgement task

CRY	HIGH	R
FATE	WEIGHT	R
GREW	CLUE	R
BRUISE	SNOOZE	R
HOE	SNOW	R
PHONE	KNOWN	R
GLUE	SHOE	R
WHITE	RIGHT	R
FRAIL	SCALE	R
BLOWN	STONE	R
BREAK	LAKE	R
CHEF	DEAF	R
JAIL	WHALE	R
BEER	HEAR	R
TOES	BLOWS	R
COT	BUY	NR
CHIP	THROUGH	NR
HIDE	FOOD	NR
SWERVE	PLEASE	NR
BEG	KEY	NR
BEAD	MAID	NR
COAT	PUT	NR
CARD	STAIR	NR
WORK	ROAR	NR
TOWED	GOOD	NR
VOICE	WISE	NR
DART	HATE	NR
LOAD	SAID	NR
SKIN	CHAIN	NR
COOL	TOLL	NR
PIE	SKY	R
RULE	POOL	R
NONE	RUN	R
SPOON	JUNE	R
KITE	LIGHT	R
STUFF	TOUGH	R
FREE	TEA	R
CARE	FAIR	R
FLOAT	QUOTE	R
RARE	SWEAR	R
PEARL	GIRL	R
SOAK	JOKE	R
SIGN	LINE	R
POOR	STORE	R
ROOM	TOMB	R

POT	FLY	NR
NAME	THUMB	NR
FINE	DAWN	NR
PLEAT	SHOOT	NR
BED	KNEE	NR
GUARD	FLAIR	NR
COAL	BULL	NR
CALM	SNAIL	NR
BOMB	FOAM	NR
SPEAK	FLAKE	NR
SHALL	CRAWL	NR
BROAD	WOOD	NR
TIED	BREAD	NR
LOOP	POPE	NR
SOON	CROWN	NR
CHOOSE	NEWS	R
SOME	HUM	R
CONE	SEWN	R
MOOSE	JUICE	R
FIGHT	BITE	R
THERE	HAIR	R
TRUE	FLEW	R
FADE	RAID	R
TRAIN	CANE	R
SHEET	MEAT	R
HAIL	SALE	R
FOUR	MORE	R
LOAN	BONE	R
MEET	EAT	R
CHAIR	PEAR	R
TOOTH	PLOUGH	NR
WINE	BUN	NR
BOOTH	NO	NR
SPILL	CRUEL	NR
SHINE	LOSS	NR
PART	BOOT	NR
CHIN	PRUNE	NR
HALF	NAIL	NR
CLOCK	SPOKE	NR
CHEAT	DATE	NR
CART	LATE	NR
YAWN	PLANE	NR
FOIL	HOLE	NR
MESS	NOSE	NR
TERM	DREAM	NR

Appendix B

Fingerspelling ability task, first (a) the list of words in English and second, (b) the list of words in Spanish.

a) Words in English, presented in fingerspelling videos by a British Sign Language (BSL) signer.

1 bay
2 ice
3 mud
4 pie
5 pit
6 pot
7 rug
8 toe
9 wig
10 pole
11 pond
12 vest
13 horse
14 skull
15 straw
16 camel
17 tiger
18 badger
19 barrel
20 bucket
21 forest
22 walrus
23 bedroom
24 blanket
25 cabbage
26 chicken
27 hamster
28 laundry
29 panther
30 whiskey

b) Words in Spanish, presented in fingerspelling videos by a Mexican Sign Language (LSM) signer.

1 pie
2 oro
3 gel
4 ron
5 paz
6 red
7 gol
8 río
9 oso
10 taxi
11 golf
12 gota
13 cinta
14 turno
15 drama
16 bolas
17 polen
18 maldad
19 textos
20 pastor
21 toldos
22 bosque
23 función
24 cristal
25 cálculo
26 troncos
27 ranchos
28 lección
29 disfraz
30 crucero

Appendice C

Set of stimuli used in Experiment 1 with deaf adult readers of English

Word targets (practice):

No.	Target Word	Identity priming	Phonological Priming	Orthographic control priming	Unrelated priming
1	**COPS**	cops	kops	yops	yeye
2	**CLUMP**	clump	klump	flump	frine
3	**SOWN**	sown	soan	soin	vond
4	**SKI**	ski	skee	skey	glu
5	**FIN**	fin	phin	slin	jux
6	**CRIB**	crib	krib	frib	floy
7	**DUES**	dues	dooze	deaps	jelf

Pseudoword targets (practice):

	Target Word	Identity priming	Phonological Priming	Orthographic control priming	Unrelated priming
8	**CLOG**	clog	klog	tlog	sark
9	**CICE**	cice	sise	n/a	rars
10	**CLOB**	clob	klob	xlob	slue
11	**CLUFF**	cluff	kluff	xluff	sourt
12	**PESS**	pess	n/a	daich	bram
13	**CALT**	calt	n/a	talt	carn
14	**CUDE**	cude	kude	tude	paps
15	**ANSY**	ansy	n/a	anvy	cume
16	**KIVE**	kive	n/a	fove	grue

160 Target 'words' and their 4 primes used in Experiment 1:

No.	Target	Identity priming	Phonological Priming	Orthographic control priming	Unrelated priming
1	**DUES**	dues	dooze	deaps	jelf

2	**TOWED**	towed	tode	toye	ritch
3	**BAYS**	bays	beize	broak	veth
4	**ROARS**	roars	rauze	narts	vourt
5	**SEAM**	seam	ceme	relm	goos
6	**BREW**	brew	brue	bree	snaz
7	**CLAW**	claw	kloar	plarc	snoc
8	**WADE**	wade	whayed	wreach	julk
9	**CONE**	cone	koan	voon	vift
10	**FLAW**	flaw	phloar	gleare	snoz
11	**FIN**	fin	phin	slin	jux
12	**CRANE**	crane	krain	drauv	swimp
13	**FLU**	flu	phlue	slaur	cri
14	**BLUR**	blur	blirr	blorr	gluy
15	**VAT**	vat	vatt	vath	ven
16	**WEB**	web	whebb	wrell	fuy
17	**SKI**	ski	skee	skey	glu
18	**NUT**	nut	knutt	thund	kep
19	**FADE**	fade	phayed	dearch	jurg
20	**COIN**	coin	koign	noich	vert
21	**PORK**	pork	porque	porthe	nudg
22	**HORN**	horn	hawn	hemn	vors
23	**FAME**	fame	phame	thame	jusk
24	**COARSE**	coarse	korce	roipe	reaths
25	**LACE**	lace	lais	larc	veng
26	**FAN**	fan	phan	chan	wip
27	**FRY**	fry	phrye	throy	scy
28	**NAIL**	nail	gnale	koarl	kuse
29	**RAID**	raid	reighed	roigues	valf
30	**HAZE**	haze	hays	haff	velk
31	**TOMB**	tomb	toom	toid	sact
32	**CHASE**	chase	chaice	chauze	slirk
33	**SAUCE**	sauce	sorce	sonce	rigns
34	**CORE**	core	korr	borz	veft
35	**FOLK**	folk	phoak	thoik	jeng

36 **GAZE**	gaze	heighs	nolled	bach
37 **JUICE**	juice	jooce	jeece	nealm
38 **FORD**	ford	phawed	droith	jeph
39 **HONEY**	honey	hunni	henma	ribid
40 **CHEQUE**	cheque	chec	chem	shulfs
41 **ROOT**	root	wrute	chert	veem
42 **FILE**	file	phyle	cheal	jarn
43 **FEARED**	feared	pheared	sleared	jought
44 **PHASE**	phase	faze	yade	gnond
45 **NURSE**	nurse	nerse	oinse	kunch
46 **WISE**	wise	whyes	wrees	domp
47 **FAIL**	fail	phail	chail	jurs
48 **TIED**	tied	tighed	tirque	gean
49 **FLOW**	flow	phlo	gloy	quey
50 **RAISE**	raise	wraze	berne	vands
51 **CIRCLE**	circle	sercle	norcle	shombs
52 **QUEEN**	queen	kween	treen	snean
53 **NOISE**	noise	gnoys	chons	kulpt
54 **FARM**	farm	pharm	gharm	juch
55 **BASE**	base	baice	barle	nell
56 **SKY**	sky	skigh	skorr	wro
57 **SEAT**	seat	cete	dest	voom
58 **PHONE**	phone	foan	jorn	gnunk
59 **HORSE**	horse	hauce	heale	mulks
60 **FAT**	fat	phat	wrat	guc
61 **PEACE**	peace	peese	pethe	wooch
62 **DRY**	dry	drigh	drair	swo
63 **WEIGHT**	weight	wate	weat	dounce
64 **BALL**	ball	borl	bewl	nure
65 **SHOWED**	showed	shoad	shons	critch
66 **WALK**	walk	whauk	wraik	juse
67 **WRITE**	write	rhight	moight	knird
68 **WALL**	wall	whawl	wraig	jung
69 **RATE**	rate	rait	nart	vanc

70 **GOES**	goes	ghoze	gnopp	heav
71 **WAYS**	ways	wheeze	wreets	jurt
72 **FORCE**	force	phorse	thorde	jempt
73 **FREE**	free	phrea	thref	trou
74 **CALL**	call	kawl	tarl	vimp
75 **MONEY**	money	munni	menro	riscs
76 **FACE**	face	phaice	plauce	jawl
77 **USE**	use	yuice	douke	ach
78 **OLD**	old	oaled	oulch	ern
79 **WORK**	work	whirque	wribbed	jern
80 **WITH**	with	whyth	wruth	daff
81 **RIP**	rip	ryp	rop	guf
82 **PUPPY**	puppy	puppi	puppa	sitwo
83 **CRAB**	crab	krab	frab	flom
84 **CORK**	cork	kork	nork	nauz
85 **CREST**	crest	krest	frest	flont
86 **CLING**	cling	kling	pling	prood
87 **CLAN**	clan	klan	tlan	sorp
88 **CRUST**	crust	krust	lrust	smeck
89 **SHINE**	shine	shyne	shune	crast
90 **COPS**	cops	kops	yops	yeye
91 **CLICK**	click	klick	tlick	doart
92 **CRUSH**	crush	krush	hrush	spork
93 **KNOT**	knot	gnot	jlot	skym
94 **DAME**	dame	daim	darm	wirt
95 **CORD**	cord	kord	pord	plof
96 **SHIELD**	shield	sheeld	sheuld	crourt
97 **CART**	cart	kart	yart	yeys
98 **CULT**	cult	kult	yult	yoem
99 **COUCH**	couch	kouch	mouch	seels
100 **RIPE**	ripe	rype	rupe	saff
101 **CANS**	cans	kans	zans	zelt
102 **COINS**	coins	koins	doins	daurg
103 **CAPS**	caps	kaps	waps	woog

104 **CRISP**	crisp	krisp	trisp	teant
105 **CLUE**	clue	klue	plue	proy
106 **CAGE**	cage	kage	lage	lowp
107 **CREEK**	creek	kreek	preek	plors
108 **NERVE**	nerve	nurve	narve	kurch
109 **CRAFT**	craft	kraft	praft	plirp
110 **CLIFF**	cliff	kliff	sliff	spomp
111 **CUPS**	cups	kups	nups	norf
112 **CRASH**	crash	krash	prash	plice
113 **CRUDE**	crude	krude	drude	deags
114 **CLAY**	clay	klay	blay	beld
115 **SKIRT**	skirt	skert	skart	whimp
116 **CRACK**	crack	krack	drack	deyst
117 **CAKE**	cake	kake	yake	verg
118 **CREW**	crew	krew	frew	fliz
119 **CLERK**	clerk	klerk	plerk	prown
120 **CROWN**	crown	krown	wrown	weert
121 **CORN**	corn	korn	norn	nawp
122 **RUBBER**	rubber	rubbur	rubbir	shucts
123 **CATS**	cats	kats	yats	yolb
124 **CROP**	crop	krop	wrop	woem
125 **CHEESE**	cheese	cheeze	cheede	scouil
126 **CUTS**	cuts	kuts	vuts	vern
127 **CLOUD**	cloud	kloud	floud	frafe
128 **CREAM**	cream	kream	tream	bourt
129 **CLOCK**	clock	klock	slock	steeg
130 **COAL**	coal	koal	noal	guin
131 **CARD**	card	kard	zard	pouz
132 **GAIN**	gain	gane	garn	beth
133 **CAST**	cast	kast	yast	yowm
134 **CASH**	cash	kash	xash	werp
135 **CHOOSE**	choose	chooze	choone	scounc
136 **CROSS**	cross	kross	tross	thend
137 **LEADER**	leader	leeder	leuder	shumph

138 **CATCH**	catch	katch	ratch	roups
139 **CAMP**	camp	kamp	zamp	zoun
140 **WON**	won	wun	wan	dep
141 **NOSE**	nose	noze	nove	kurg
142 **CARS**	cars	kars	yars	yowt
143 **CLUB**	club	klub	flub	freb
144 **GROW**	grow	groe	groy	snuz
145 **CHOICE**	choice	choise	choife	shixth
146 **ARMY**	army	armi	armo	yuge
147 **SUMMER**	summer	summur	summor	lancad
148 **COURT**	court	kourt	nourt	neeps
149 **PAID**	paid	pade	pard	wirl
150 **WINDOW**	window	windoe	windou	garrix
151 **COST**	cost	kost	dost	daug
152 **CHURCH**	church	cherch	chorch	shobes
153 **COLD**	cold	kold	dold	drof
154 **CLASS**	class	klass	tlass	whike
155 **LINE**	line	lyne	lene	vost
156 **KNOWN**	known	knoan	knoin	swink
157 **SET**	set	cet	fet	mut
158 **CASE**	case	kase	zase	zown
159 **SIDE**	side	cide	jide	guss
160 **YEAR**	year	yeer	yeor	isth

160 Target 'pseudowords' and their primes used in Experiment 1:

161 **ANSY**	ansy	n/a	anvy	cume
162 **BAVE**	bave	n/a	bawn	comp
163 **BEASH**	beash	n/a	baish	crast
164 **BEVE**	beve	n/a	cheve	cres
165 **BUP**	bup	n/a	meep	sno
166 **CADE**	cade	n/a	tade	coss
167 **CAGS**	cags	n/a	xags	rall
168 **CAIL**	cail	n/a	xail	lats
169 **CALED**	caled	n/a	taled	cangs

170	**CALS**	cals	n/a	xals	swip
171	**CALT**	calt	n/a	talt	carn
172	**CAWL**	cawl	n/a	lawl	hoil
173	**CHUPE**	chupe	n/a	vaip	brust
174	**CLERN**	clern	n/a	tlern	grust
175	**CLINT**	clint	n/a	tlint	gring
176	**CLONS**	clons	n/a	tlons	spock
177	**COND**	cond	n/a	xond	cabe
178	**COOB**	coob	n/a	coom	hars
179	**CORT**	cort	n/a	xort	flab
180	**CRAFF**	craff	n/a	lraff	preed
181	**CRANS**	crans	n/a	lrans	brack
182	**CRAY**	cray	n/a	lray	luts
183	**CREG**	creg	n/a	freg	trew
184	**CRIRP**	crirp	n/a	trirp	grest
185	**CROLT**	crolt	n/a	trolt	soach
186	**CROWL**	crowl	n/a	hrowl	hoach
187	**CRUE**	crue	n/a	frue	cluk
188	**CRULE**	crule	n/a	frule	grush
189	**CUNS**	cuns	n/a	xuns	muts
190	**DARRED**	darred	n/a	deighed	teaker
191	**DERD**	derd	n/a	coib	prip
192	**DOBE**	dobe	n/a	dode	dall
193	**FREW**	frew	n/a	bleigh	cors
194	**GOWD**	gowd	n/a	sowd	hoil
195	**HADE**	hade	n/a	hoinn	baws
196	**HILE**	hile	n/a	jairl	carm
197	**HOREP**	horep	n/a	horew	craws
198	**JARK**	jark	n/a	soub	crip
199	**JASS**	jass	n/a	jeeth	clow
200	**JAVE**	jave	n/a	yave	coff
201	**JONE**	jone	n/a	chone	grop
202	**JUILD**	juild	n/a	juite	crums
203	**KOLL**	koll	n/a	xoll	prot

204 **KORS**	kors	n/a	xors	duts
205 **KRANG**	krang	n/a	hrang	grane
206 **LECK**	leck	n/a	dack	cald
207 **LERGE**	lerge	n/a	serne	courn
208 **LOURER**	lourer	n/a	teater	sheald
209 **MEEM**	meem	n/a	mairt	coze
210 **MIB**	mib	n/a	hib	joc
211 **MOME**	mome	n/a	hoarm	brog
212 **NIM**	nim	n/a	thipp	gle
213 **NONT**	nont	n/a	nond	nise
214 **NUSH**	nush	n/a	naid	faps
215 **PAIM**	paim	n/a	paith	clep
216 **PESS**	pess	n/a	daich	bram
217 **PETCH**	petch	n/a	hetch	sauns
218 **PUMPER**	pumper	n/a	purmer	chield
219 **RUDSER**	rudser	n/a	rudper	cedcle
220 **RUMPY**	rumpy	n/a	doppy	crars
221 **RUNEY**	runey	n/a	peney	clale
222 **SAIRE**	saire	n/a	sayer	rourt
223 **SARES**	sares	n/a	searth	clane
224 **SHAN**	shan	n/a	knin	cupe
225 **SHEED**	sheed	n/a	shad	clemp
226 **SHIEZE**	shieze	n/a	shieks	pommer
227 **SHOG**	shog	n/a	klag	noss
228 **SKILD**	skild	n/a	skift	crare
229 **SLOUD**	sloud	n/a	yloud	croad
230 **SNEEN**	sneen	n/a	sween	sawes
231 **TEIN**	tein	n/a	peith	cong
232 **VART**	vart	n/a	seight	cluv
233 **VIG**	vig	n/a	vib	nat
234 **WINDIC**	windic	n/a	wintom	russer
235 **YARM**	yarm	n/a	poarb	crel
236 **YBES**	ybes	n/a	ybed	clis
237 **YEARED**	yeared	n/a	meared	cibsce

238	**YINE**	yine	n/a	woin	coys
239	**YOME**	yome	n/a	chope	coll
240	**ZILE**	zile	n/a	zel	cail
241	**BERGE**	berge	burdge	n/a	fleam
242	**BICK**	bick	bique	n/a	wans
243	**CAND**	cand	kand	n/a	whot
244	**CANG**	cang	kang	n/a	rast
245	**CANK**	cank	kank	n/a	fash
246	**CATH**	cath	kath	n/a	grap
247	**CAUTCH**	cautch	korch	n/a	shiefs
248	**CEPS**	ceps	keps	n/a	cawn
249	**CESH**	cesh	sesh	n/a	spog
250	**CICE**	cice	sise	n/a	rars
251	**CIG**	cig	sig	n/a	jeb
252	**CLAFF**	claff	klaff	n/a	queep
253	**CLAG**	clag	klag	n/a	suts
254	**CLEAM**	cleam	kleam	n/a	saird
255	**CLEST**	clest	klest	n/a	sancs
256	**CLIGS**	cligs	kligs	n/a	spick
257	**CLILT**	clilt	xlilt	n/a	wheen
258	**CLUP**	clup	klup	n/a	stap
259	**COFS**	cofs	kofs	n/a	flot
260	**COFT**	coft	koft	n/a	haps
261	**CORGE**	corge	korge	n/a	grerk
262	**CORGUE**	corgue	kaugg	n/a	brield
263	**COTH**	coth	koth	n/a	brap
264	**COULS**	couls	kouls	n/a	sapse
265	**CRALT**	cralt	kralt	n/a	grick
266	**CRON**	cron	kron	n/a	quap
267	**CRUB**	crub	krub	n/a	ythe
268	**CRUBS**	crubs	krubs	n/a	gramp
269	**CRURS**	crurs	krurs	n/a	jeace
270	**CUDS**	cuds	kuds	n/a	bame
271	**CURN**	curn	kurn	n/a	shap

272 **DEAK**	deak	deck	n/a	cass
273 **FEB**	feb	phebb	n/a	spu
274 **FEEK**	feek	pheak	n/a	nase
275 **FEEN**	feen	phean	n/a	capt
276 **FET**	fet	phet	n/a	orn
277 **FID**	fid	phidd	n/a	cru
278 **FOWN**	fown	phown	n/a	cace
279 **FUCH**	fuch	phutch	n/a	nole
280 **FURVE**	furve	pherve	n/a	sleed
281 **GERT**	gert	jert	n/a	cack
282 **GOME**	gome	goam	n/a	baps
283 **GOPE**	gope	ghoap	n/a	blap
284 **HASE**	hase	haiss	n/a	noke
285 **JUFF**	juff	juph	n/a	clim
286 **KNIDE**	knide	nighed	n/a	coult
287 **LOD**	lod	lodd	n/a	wel
288 **LOYS**	loys	loize	n/a	cluh
289 **LUM**	lum	lumb	n/a	que
290 **NEAF**	neaf	kneeph	n/a	clas
291 **NURCH**	nurch	knirch	n/a	skipe
292 **NURK**	nurk	gnurk	n/a	rans
293 **PHEASE**	phease	feece	n/a	windax
294 **PHICK**	phick	fique	n/a	clipe
295 **PHOF**	phof	foff	n/a	clum
296 **PODE**	pode	poad	n/a	cras
297 **PUM**	pum	pumb	n/a	sli
298 **RAUCE**	rauce	rhawse	n/a	crand
299 **RAUSE**	rause	ourse	n/a	queeg
300 **REACE**	reace	wreese	n/a	crems
301 **REAT**	reat	rhete	n/a	bams
302 **RIBE**	ribe	rhybe	n/a	shap
303 **RIN**	rin	rhinn	n/a	wol
304 **ROID**	roid	wroid	n/a	clin
305 **SECH**	sech	setch	n/a	cren

306	**SHICK**	shick	shique	n/a	juile
307	**SHOOF**	shoof	shuiff	n/a	cliss
308	**SLEE**	slee	slea	n/a	dans
309	**SOYS**	soys	soize	n/a	clux
310	**THALE**	thale	thail	n/a	crant
311	**VEAM**	veam	vemer	n/a	spib
312	**WABE**	wabe	waib	n/a	cank
313	**WEFF**	weff	wheph	n/a	crer
314	**WERCH**	werch	whurch	n/a	croom
315	**WHEAM**	wheam	weemb	n/a	skith
316	**WONE**	wone	whone	n/a	dall
317	**ZAKE**	zake	zaick	n/a	bage
318	**ZANE**	zane	zain	n/a	cose
319	**ZAYS**	zays	zaize	n/a	cate
320	**ZEAT**	zeat	zeet	n/a	cund

Appendix D

For completeness of reporting the data in addition to the *t-tests*, the results of ANOVAs are included here for deaf adult readers of English, Spanish and young deaf readers of Spanish.

1.1. We conducted Analyses of Variance (ANOVAs) in the visual word phonological processing experiment with deaf adult readers of English.

One-way repeated measures ANOVA were performed separately for the response times and accuracy data including type of prime as the within subjects factor (Prime conditions: Pseudohomophone, Orthographic control, Identity and Unrelated). These ANOVAs were conducted over the subject ($F1$) and items ($F2$) means per condition.

Responses to words were significantly faster than to pseudowords; $F1(1,13) = 35.77$, $p < .001$ (M = 752.58ms vs M = 970.44ms); $F2(1,318) = 218.56$, $p < .001$ (756.37ms vs 953.49ms). The analyses in the accuracy data also showed a significant lexicality effect, $F1(1,13) = 13.89$, $p = .003$ (M = 98% vs M = 88%); $F2(1,318) = 49.55$, $p < .001$ (M = 97% vs M = 88%).

Analysis of the response times showed a significant effect of type of prime, $F1(3, 39) = 11.27$, $p < .001$; $F2(3, 477) = 7.03$, $p < .001$. Planned pairwise comparisons showed significantly faster responses for the identity than for the unrelated condition; analyses by-subject: $p < .001$ (M = 714ms, SD = 134.44 and M = 768.25, SD = 134.71 respectively), by-item: $p < .001$ (M = 712ms, SD = 163.13 and M = 785.17, SD = 177.59 respectively). Only in the analyses by-subject, responses were significantly faster for the phonological than for the orthographic prime condition p = .048, (M = 751.69, SD = 123.85, M = 776.35ms, SD = 124.36, respectively); analyses by-item, p = 1.66 (M = 752.40, SD = 147.78, M = 775.99ms, SD = 158.23, respectively).

Analysis of accuracy of responses showed a significant effect of type of prime in the analyses by-subject, $F1(3, 39) = 3.79$, $p = .018$; but not in the analyses by-item, $F2(2.406, 382.539) = 2.45$, $p = .077$. Planned pairwise comparisons showed no significant differences between identity and unrelated conditions in the by-subject analyses; $p = 1$ (M = 98%, SD = 2.28, M = 98%, SD = 2.68), nor between the phonological and orthographic condition, $p = .168$; (M = 98%, SD = 2.23 and M = 96%, SD = 4.13 respectively). No differences found in the analyses by-item: between identity and unrelated, $p = .634$ (M = 98%, SD = 7.55, M = 98%, SD = 8.47), nor between the phonological and orthographic condition, $p = .055$; (M = 98%, SD = 7.76 and M = 96%, SD = 12.50 respectively)

1.2. Analyses of Variance (ANOVAs) in the visual word phonological processing experiment with deaf adult readers of Spanish.

The same analyses than in the adult deaf readers of English was performed here with adult deaf readers of Spanish.

Responses to words were significantly faster than to pseudowords; $F1(1,15) = 7.59$, $p = .015$ (M = 805.85ms vs M = 1003.04ms); $F2(1,306) = 160.58$, $p < .001$ (M=797.01ms vs M= 951.48ms). The accuracy data only showed a significant lexicality effect in the analyses by-item; $F1(1,15) = 1.90$, $p = .189$ (M = 94% vs M = 88%); $F2(1,306) = 25.26$, $p < .001$ (M=93% vs M=88%).

Analyses on the response times showed only a significant main effect type of prime condition in the by-item analysis; $F1(3, 45) = 2.07$, $p = .117$; $F2(3,459) = 3.4$, $p = .018$. Planned pairwise comparisons showed significantly faster responses for the identity than for the unrelated condition in both analyses; by-subject: $p = .012$; (M = 777.32ms, SD = 170.36 and M = 824.67ms, SD = 160.17 respectively); by-item: $p = .004$; (M = 765.07ms, SD = 179 and M = 817.24ms, SD = 149.1).
No differences between the phonological and orthographic control prime conditions in RTs: by-subject analyses; $p = .778$; (M = 813.49ms, SD = 209.55 and M = 807.92ms, SD = 167.75 respectively); by-item analyses $p = .716$ (M = 806.14ms, SD = 176.71 and M = 799.59ms, SD = 157.21 respectively).

Analysis of accuracy of responses showed no effect of type of prime $F1(3, 45) = 1.41$, $p = .254$; $F2(2.663,407.510) = 1.21$ $p = .303$. Planned pairwise comparisons showed significant differences between identity and unrelated condition in the by-subject analyses; $p = .019$ (M = 95%, SD = 6.20, M = 92%, SD = 8.55), but not in the by-item analyses: $p = .158$ (M = 94%, SD = 13.86, M = 92%, SD = 15.84), nor between the phonological and orthographic condition; by-subject analyses: $p = .532$ (M = 93%, SD = 6.94, M = 94%, SD = 6.87); by-item analyses : $p = .494$ (M = 93%, SD = 1.1, M = 94%, SD = 1.1, respectively).

1.3. Analyses of Variance (ANOVAs) in the visual word phonological processing experiment with young deaf readers of Spanish.

The same analyses than in the deaf adults readers of English was performed here with deaf young readers of Spanish.

Responses to words were significantly faster than to pseudowords; $F1(1,54) = 18.98$, $p < .001$ (M = 946.96ms vs M = 1069.74ms); $F2(1,216) = 153.63$, $p < .001$ (M=916.05ms vs M= 1059.68ms). The analyses in the accuracy data also showed a significant lexicality effect The accuracy data only showed a significant lexicality effect in the analyses by-item; $F1(1,54) = 2.23$, $p = .141$ (M = 75% vs M = 69%); $F2(1,216) = 39.17$, $p < .001$ (M=76% vs M=67%).

Analysis of the response times showed a significant effect of type of prime; $F1(3,162) = 5.37$, $p = .002$; $F2(3,324) = 6.50$, $p < .001$. Planned pairwise comparisons showed significantly faster responses for the identity than for the unrelated condition in both analyses: by-subject , $p = .011$; (M = 932.93ms, SD =

274.03 and M = 986.69, SD = 255.11 respectively); and by-item $p < .001$ (M = 896.40, SD = 141.25 and M = 955.27, SD = 140.92) . Responses were significantly faster for the phonological than for the orthographic prime condition in the by-subject analyses, $p = .049$, (M = 919.16, SD = 229.68 and M = 949.07ms, SD = 274.47, respectively), but not in the by-item analyses; p = .309 (M = 898.72, SD = 111.06 and M = 913.79, SD = 120.59, respectively).

Analysis of accuracy of responses showed no main effect of type of prime, F1(3, 162 = 2.03, $p = .113$; F2(3, 324) = 8.71, $p = .456$. Planned pairwise comparisons showed no significant differences between identity and unrelated; by-subject analyses, $p =$ .055 (M = 77%, SD = 19.56 and M = 74%, SD = 20.46, respectively); by-item analyses, $p = .211$ (M = 77%, SD = 13.12 and M = 75%, SD = 13.68), nor between the phonological and orthographic condition: by-subject: $p = .332$; (M = 75%, SD = 21.99 and M = 74%, SD= 21.56, respectively), by-item analyses, $p = .304$ (M = 77%, SD = 13.39 and M = 75%, SD = 13.3, respectively).

1.4. Analyses of Variance (ANOVAs) in the visual word phonological processing experiment with young deaf readers of Spanish: 'Small vocabulary and Large vocabulary size' groups.

The same analyses than in the adult deaf readers of English was performed here with the two groups of the deaf young readers of Spanish: 'Small Vocabulary Size' and 'Large Vocabulary Size'.

In the ‘Small Vocabulary Size’ group, responses to words were faster than to pseudowords but only in the analysis by-item; $F1(1,28) = 2.45$, $p = .126$ (M = 1062.03ms vs M = 1116.16ms), $F2(1,216) = 11.03$, $p = .001$ (M = 1040.70ms vs M = 1102.62ms respectively). The analyses in the accuracy data did not show a lexicality effect, $F1(1,28) = .26$, $p = .612$ (M = 66% vs M = 63%); $F2(1,216) = .77$, $p = .383$ (M = 64% vs M = 63%, respectively).

In the analysis of the response times this group showed a significant effect of type of prime only in the analyses by-subject, $F1(3,84) = 3.40$, $p = .022$; $F2(1,108) = 1.07$, $p = .304$. Planned pairwise comparisons showed no difference in responses for the identity than for the unrelated condition; by-subject analyses, $p = .625$ (M = 1078.96ms, SD = 225.88 and M = 1096.72ms, SD = 219.54 respectively), by-item analyses, $p = .316$ (M = 1079.69ms, SD = 287.18 and M = 1036.75ms, SD = 351.92 respectively) .

Responses showed only in the by-subject analyses, significantly faster for the phonological than for the orthographic prime condition; $p = .031$, M = 1009.45ms, SD = 197.78 and M = 1062.99ms, SD = 249.95, respectively), but not difference in the analyses by-item, $p = .131$, M = 993.76ms, SD = 27.07 and M = 1052.59ms, SD = 28.97, respectively).

Analysis of accuracy of responses showed no main effect of type of prime, $F1(3, 84) = 1.32$, $p = .274$; $F2(3, 324) = .82$, $p = .486$. Planned pairwise comparisons showed no differences between identity and unrelated, by-subject analyses; $p = .181$ (M =

68%, SD = 20.35 and M = 65%, SD = 20.38 respectively); nor by-item analyses, p = .215 (M = 66%, SD = 20.88 and M = 62%, SD = 22.53 respectively). There is a significant difference between the phonological and orthographic condition in the analyses by-subject; p = .023 (M = 68%, SD=21.93 and M = 65%, SD = 21.99 respectively), but no difference was showed in the analyses by-item, p = .361 (M = 66%, SD=22.23 and M = 64, SD = 20.04 respectively).

In the ‘Large Vocabulary Size’ group, responses to words were faster than to pseudowords; $F1(1,25) = 23.22$, $p < .001$ (818.62ms vs 1017.96ms); $F2(1,216) = 151.97$, $p < .001$ (M = 804.60ms vs M = 1015.44ms). The accuracy data only showed a significant lexicality effect in the analyses by-item; $F1(1,25) = 3.68$, p = .067, (85% vs 75%); $F2(1,216) = 90.1$, $p < .001$ (M = 88% vs M = 72%).

In the analysis of the response times this group showed a significant effect of type of prime, F1(3,75) = 9.70, $p < .001$, $F2(3,324) = 9.17$, $p < .001$. Planned pairwise comparisons showed significantly difference in responses for the identity than for the unrelated condition in both analyses: by-subject $p < .001$ (M = 770.05ms, SD = 229.63 and M = 863.97ms, SD = 238.51 respectively); and by-item analyses, $p <$ .001 (M = 753.32ms, SD = 167.68 and M = 860.83ms, SD = 174.98 respectively). No difference was showed between the phonological and the orthographic prime conditions; by-subject analyses, p = .827 (M = 818.45ms, SD = 223.91 and M = 822.01ms, SD = 246.79, respectively), nor by-item analyses; p = .375 (M =792.93ms, SD = 144.70 and M = 811.33ms, SD = 174.55, respectively)

Analysis of accuracy of responses showed no main effect of type of prime, $F1(3, 75) = 2.64$, $p = .056$; $F2(3, 324) = .92$, $p = .431$. Planned pairwise comparisons showed no differences between identity and unrelated conditions; by-subject analyses, $p = .152$ (M = 88%. SD = 11.74 and M = 86%, SD = 14.12, respectively), neither by-item analyses, $p = .139$ (M = 90%. SD = 13.60 and M = 87%, SD = 15.29, respectively). No difference was showed for the phonological and orthographic condition; by-subject analyses, $p = .731$ (M = 83%, SD = 19.17 and M = 84%, SD = 15.79, respectively); by-item analyses, $p = .816$ (M = 88%, SD = 15.70 and M = 87%, SD = 15.82, respectively).

Appendix E

Below are the Everyday questions' extension of the "Test of Child Speechreading" (ToCS, Kyle et al., 2013). First, in English and then, the Spanish adaptation.

a) English version:

1 How old are you?
2 Where do you live?
3 Have you got brothers or sisters?
4 What did you eat for breakfast?
5 What is your favourite food?
6 What colour is your bedroom?
7 What's the time?
8 When is your birthday?
9 What football teams do you like?
10 What is your favourite colour?
11 Do you live in a house or a flat?
12 What is your favourite book?

b) Spanish Version:

1 ¿Cuántos años tienes?
2 ¿Tu dónde vives?
3 ¿Tienes algun hermano o hermana?
4 ¿Qué desayunaste esta mañana?
5 ¿Cuál es tu comida favorita?
6 ¿De qué color es tu cuarto?
7 ¿Qué hora es?
8 ¿Cuándo es tu cumpleaños?
9 ¿Qué equipos de football te gustan?
10 ¿Cuál es tu color favorito?
11 ¿Vives en una casa o en un departamento?
12 ¿Cuál es tu libro favorito?

Appendix F

Set of stimuli used in Experiments 2 and 3 with deaf adult and young deaf readers of Spanish.
On the right side of the columns a (*) indicates that the target and its conditions were removed from the analyses, as they had less than 58% accuracy overall.

Word targets (practice):

No.	Target Word	Identity priming	Phonological Priming	Orthographic control priming	Unrelated priming
1	CAMARA	cámara	kamara	tamara	selaco
2	COFUNO	cofuno	kofuno	tofuno	bocila
3	CONUJA	conuja	konuja	donuja	burata
4	GENERAL	general	jeneral	peneral	pivisol
5	CALDO	caldo	kaldo	taldo	burta
6	VUNCE	vunce	bunce	zunce	surro
7	BISTEC	bistec	vistec	zistec	varian

Pseudoword targets (practice):

No.	Target Word	Identity priming	Phonological Priming	Orthographic control priming	Unrelated priming
8	COLTE	colte	kolte	lolte	talba
9	GISOZOL	gisozol	jisozol	pisozol	ferulis
10	BELLOTA	bellota	vellota	tellota	jeneral
11	VARFAC	varfac	barfac	carfac	tepres
12	VENDER	vender	bender	fender	tisron
13	CADENA	cadena	kadena	dadena	firusa
14	BILETO	bileto	vileto	tileto	pusani
15	BEBIDA	bebida	vebida	tevida	fisute
16	VICHETO	vicheto	bicheto	ticheto	crerrisu

160 Target 'words' and their 4 primes used in the Experiment:

						Items excluded from the analyses (*).	
No.	Target	Identity priming	Phonological Priming	Orthographic control priming	Unrelated priming	Experiment 2. Adults	Experiment 3. Young reaers
1	BURRO	burro	vurro	nurro	saeca		
2	COMIDA	comida	komida	tomida	bucelo		
3	CAMPO	campo	kampo	fampo	fusga		
4	BOCINA	bocina	vocina	nocina	sinoza		(*)
5	CANARIO	canario	kanario	tanario	lemecia		(*)
6	BATA	bata	vata	sata	cilo		

7	VERDE	verde	berde	ferde	tinlo		
8	BABA	baba	vaba	naba	sifa		(*)
9	BASURA	basura	vasura	casura	roniso		
10	CAPA	capa	kapa	fapa	tego		
11	CABRA	cabra	kabra	tabra	focho		(*)
12	COCINA	cocina	kocina	locina	tamuco		
13	CUEVA	cueva	kueva	tueva	lioro		
14	COCO	coco	koco	hoco	fisa		
15	BUZO	buzo	vuzo	nuzo	rano		(*)
16	BICHO	bicho	vicho	richo	nucha		(*)
17	CARIÑOS	cariños	kariños	tariños	fasonac		
18	CINTA	cinta	zinta	rinta	nosfo		
19	BALCÓN	balcón	valcón	nalcón	rilzás		(*)
20	CUERPO	cuerpo	kuerpo	buerpo	liosgo		
21	CURA	cura	kura	tura	bina		(*)
22	BALA	bala	vala	nala	cofa		(*)
23	CARETA	careta	kareta	lareta	fineto	(*)	(*)
24	BOLLO	bollo	vollo	nollo	rello	(*)	(*)
25	CARNE	carne	karne	tarne	larco		
26	CORRAL	corral	korral	lorral	tanol		(*)
27	CAÑA	caña	kaña	faña	huco		
28	BOBO	bobo	vobo	cobo	nita		(*)
29	COLA	cola	kola	fola	heto		
30	CURVA	curva	kurva	lurva	tesna		(*)
31	CABALLO	caballo	kaballo	laballo	fotocha		
32	BANDERA	bandera	vandera	candera	sintero		
33	VESTIDO	vestido	bestido	lestido	benlata		
34	CARTA	carta	karta	larta	fisfo		
35	BIBERÓN	biberón	viberón	ciberón	natusán		(*)
36	BONITO	bonito	vonito	ronito	cemata		
37	CIRCO	circo	zirco	nirco	cesna		
38	CARBÓN	carbón	karbón	tarbón	lisfán		
39	BAÑERA	bañera	vañera	rañera	cesumo		
40	CASCO	casco	kasco	fasco	linza		(*)
41	BARRA	barra	varra	zarra	serro		
42	CAMINO	camino	kamino	famino	losama		
43	COPA	copa	kopa	lopa	bugo		
44	CONEJO	conejo	konejo	fonejo	larafa		
45	VELERO	velero	belero	telero	fatira	(*)	(*)
46	GIRASOL	girasol	jirasol	pirasol	punical		(*)
47	CERRADO	cerrado	zerrado	nerrado	virreta		
48	JIRAFA	jirafa	girafa	piraja	pegope		
49	BÚHO	búho	vúho	rúho	cifa		(*)
50	CUCHARA	cuchara	kuchara	tuchara	felloro		
51	CORONA	corona	korona	torona	lisamo		
52	JEFE	jefe	gefe	pefe	pifo		
53	CASILLA	casilla	kasilla	tasilla	fimollo		(*)
54	CARTERO	cartero	kartero	lartero	fislara		(*)

55	CAPITÁN	capitán	kapitán	lapitán	lorefón		
56	CASETA	caseta	kaseta	taseta	lisofo		(*)
57	BIGOTE	bigote	vigote	rigote	cepula		(*)
58	CUBO	cubo	kubo	lubo	tama		(*)
59	CALAMAR	calamar	kalamar	falamar	tofocer		
60	CAZA	caza	kaza	laza	tiso		
61	CAZUELA	cazuela	kazuela	lazuela	lacieta		(*)
62	GENIO	genio	jenio	yenio	yacea		
63	BOTÓN	botón	votón	notón	cutás		
64	CABAÑA	cabaña	kabaña	fabaña	tiremo		
65	CEPILLO	cepillo	zepillo	repillo	vegecha		
66	VIENTO	viento	biento	hiento	liusfa		
67	CAPILLA	capilla	kapilla	lapilla	balerra		
68	BAÑO	baño	vaño	zaño	rira		
69	COCHE	coche	koche	toche	furro		
70	VISITA	visita	bisita	tisita	fesepa		
71	CIELO	cielo	zielo	vielo	seota		
72	CEREZAS	cerezas	zerezas	nerezas	ramocan		(*)
73	BARRIO	barrio	varrio	carrio	norrea		
74	VAGÓN	vagón	bagón	lagón	fojís		(*)
75	COFRE	cofre	kofre	tofre	latra		(*)
76	BAÚL	baúl	vaúl	naúl	caíl		(*)
77	CIRUELA	ciruela	ziruela	niruela	sevielo		(*)
78	CARACOL	caracol	karacol	banacol	henasal		(*)
79	BORDE	borde	vorde	norde	sasto		(*)
80	GIGANTE	gigante	jigante	pigante	puganla		
81	CAZO	cazo	kazo	fazo	tiso	(*)	(*)
82	COPIA	copia	kopia	lopia	tugeo		
83	CARTÓN	cartón	kartón	lartón	faslís		
84	CEBRA	cebra	zebra	rebra	nofro		
85	BANDEJA	bandeja	vandeja	nandeja	nostigo		(*)
86	BOTELLA	botella	votella	rotella	saficha		
87	BARBA	barba	varba	sarba	nisfo		
88	CAMA	cama	kama	tama	fosi		
89	VERANO	verano	berano	herano	fanera		
90	BARRO	barro	varro	rarro	nerra		
91	CAMISA	camisa	kamisa	lamisa	teneco		
92	CORAZÓN	corazón	korazón	lorazón	tamirés		
93	VIOLÍN	violín	biolín	liolín	faosán		(*)
94	CORAL	coral	koral	toral	fisol		(*)
95	BOLSA	bolsa	volsa	nolsa	cilna		
96	VIRGEN	virgen	birgen	lirgen	lasjos		
97	BOCA	boca	voca	noca	cezo		
98	BARCO	barco	varco	rarco	morza		
99	GENTE	gente	jente	pente	yasle		
100	BALAZOS	balazos	valazos	nanazos	cevolar		(*)
101	BUZÓN	buzón	vuzón	nuzón	samás		
102	VIOLETA	violeta	bioleta	tioleta	feutalo		(*)

103	CENIZA	ceniza	zeniza	reniza	saceno		(*)
104	CABLE	cable	kable	lable	fucho		
105	CINE	cine	zine	rine	nero		
106	CALOR	calor	kalor	falor	bahan		
107	CARTEL	cartel	kartel	lartel	tesfol		(*)
108	COMEDOR	comedor	komedor	tomedor	fomilas		
109	CALLE	calle	kalle	lalle	tucho		
110	BALÓN	balón	valón	nalón	refas		
111	CAMBIO	cambio	kambio	fambio	tisleo		
112	BAILE	baile	vaile	caile	teita		
113	CUENTO	cuento	kuento	luento	biesla		
114	VOLANTE	volante	bolante	tolante	fitosla		
115	BOLSO	bolso	volso	colso	carza		
116	VECINA	vecina	becina	lecina	ficoso		
117	CAFÉ	café	kafé	tafé	buta		
118	BOLA	bola	vola	zola	sifo		
119	CORO	coro	koro	horo	teza	(*)	(*)
120	BARRIL	barril	varril	narril	sirrel		(*)
121	VIVO	vivo	bivo	livo	tuza		
122	BALLENA	ballena	vallena	nallena	richaco		
123	BATIDO	batido	vatido	natido	solora		(*)
124	BESO	beso	veso	neso	muno		
125	CEBOLLA	cebolla	zebolla	rebolla	sitecho		
126	VERDAD	verdad	berdad	ferdad	nertol		
127	COHETE	cohete	kohete	tohete	fatola		(*)
128	CENA	cena	zena	rena	vimo		
129	CUNA	cuna	kuna	funa	bemo		(*)
130	CERDO	cerdo	zerdo	verdo	nisto		
131	COLEGIO	colegio	kolegio	folegio	tilenao		(*)
132	GENIAL	genial	jenial	penial	joreor		
133	CAJÓN	cajón	kajón	lajón	figás		
134	COLOR	color	kolor	folor	hetas		
135	GITANA	gitana	jitana	pijana	pagena		(*)
136	CABEZA	cabeza	kabeza	tabeza	lofaco		
137	CAZADOR	cazador	kazador	bazador	necetin		
138	VENTANA	ventana	bentana	hentana	lambeco		
139	VIÑA	viña	biña	fiña	luco		(*)
140	VIAJE	viaje	biaje	tiaje	feofa		
141	BUFANDA	bufanda	vufanda	nufanda	catisto		(*)
142	BOXEO	boxeo	voxeo	noxeo	tonea		
143	CARRERA	carrera	karrera	tarrera	lichana		
144	CAMELLO	camello	kamello	lamello	finacha		
145	BOSQUE	bosque	vosque	nosque	nampea		
146	COSA	cosa	kosa	hosa	luca		
147	VIEJO	viejo	biejo	tiejo	laipa		
148	COLETA	coleta	koleta	foleta	tatilo	(*)	(*)
149	CARO	caro	karo	laro	bino		
150	BELLEZA	belleza	velleza	nelleza	cichono		

151	CAJA	caja	kaja	taja	huga		
152	CAMIÓN	camión	kamión	tamión	feneás		
153	BARRIGA	barriga	varriga	narriga	corrupa		(*)
154	CASO	caso	kaso	faso	luno		
155	CASA	casa	kasa	fasa	lono		
156	VIDA	vida	bida	tida	leto		
157	CARRO	carro	karro	larro	ticha		
158	BARCA	barca	varca	narca	zosmo		
159	BANCO	banco	vanco	sanco	cesna		
160	BEBÉ	bebé	vebé	mebé	rado		

No.	Target	Identity priming	Phonological Priming	Orthographic control priming	Unrelated priming
162	VESCADO	vescado	bescado	tescado	firnoba
163	BULMA	bulma	vulma	culma	zilno
164	BULMO	bulmo	vulmo	fulmo	dilca
165	BETÓN	betón	vetón	hetón	lifás
166	CILGO	cilgo	zilgo	vilgo	rista
167	CACITRO	cacitro	kacitro	hacitro	bonebra
168	CAFO	cafo	kafo	lafo	duta
169	CACAPO	cacapo	kacapo	facapo	herago
170	BALLERO	ballero	vallero	mallero	sichama
171	VUTO	vuto	buto	futo	teli
172	CACI	caci	kaci	daci	ture
173	BARRAZA	barraza	varraza	sarraza	carrino
174	VIBÁN	vibán	bibán	tibán	hatós
175	CECIDOR	cecidor	zecidor	vecidor	ciraler
176	CACIAL	cacial	kacial	tacial	horeol
177	CARIZAR	carizar	karizar	tarizar	benecos
178	CURNA	curna	kurna	durna	lisno
179	GESÍA	gesía	jesía	pesía	giría
180	CUENZO	cuenzo	kuenzo	luenzo	tiesca
181	CAUBA	cauba	kauba	fauba	liuco
182	CUVE	cuve	kuve	fuve	hico
183	BONJO	bonjo	vonjo	nonjo	sasga
184	VENCAD	vencad	bencad	tencad	disrod
185	BASDÓN	basdón	vasdón	casdón	zorlás
186	BAKIDOR	bakidor	vakidor	nakidor	mitaher
187	VACHO	vacho	bacho	hacho	lilla
188	CECERE	cecere	zecere	vecere	nivema
189	CANZÓN	canzón	kanzón	banzón	lescás
190	CAPIBA	capiba	kapiba	tapiba	dugada
191	BENSERA	bensera	vensera	zensera	viscome
192	BAOL	baol	vaol	raol	ceal
193	BUPO	bupo	vupo	nupo	zijo
194	CERAL	ceral	zeral	veral	cisol

195	CACEPO	cacepo	kacepo	bacepo	tiraga
196	GICINA	gicina	jicina	picina	purivo
197	GICISOL	gicisol	jicisol	picisol	paranel
198	VENANA	venana	benana	denana	busoco
199	CECECA	cececa	zececa	sececa	nivase
200	CIESTO	ciesto	kiesto	biesto	launfa
201	BACIDO	bacido	vacido	zacido	remote
202	BICEROS	biceros	viceros	siceros	varucan
203	CULBA	culba	kulba	dulba	tilto
204	VORENTE	vorente	borente	forente	tisasfa
205	CABI	cabi	kabi	labi	zole
206	VUMA	vuma	buma	tuma	hina
207	CICO	cico	zico	sico	naze
208	BENSEJA	benseja	venseja	renseja	viszapo
209	VEFO	vefo	befo	tefo	liho
210	GIVENTE	givente	jivente	pivente	gacenla
211	BIRRO	birro	virro	nirro	zerra
212	GEVO	gevo	jevo	pevo	pima
213	BACURO	bacuro	vacuro	nacuro	vizane
214	BADO	bado	vado	zado	rute
215	COCEPA	cocepa	kocepa	tocepa	lemigo
216	CENCO	cenco	zenco	renco	rasva
217	CUFA	cufa	kufa	hufa	difo
218	BOPO	bopo	vopo	ropo	zega
219	BOCERRA	bocerra	vocerra	cocerra	nivurro
220	CAVI	cavi	kavi	tavi	deno
221	VUESTO	vuesto	buesto	fuesto	hienla
222	CANVERA	canvera	kanvera	fanvera	lincase
223	CACARO	cacaro	kacaro	lakaro	fetina
224	CEMO	cemo	zemo	femo	huva
225	CABU	cabu	kabu	labu	fiha
226	COBIO	cobio	kobio	tobio	hifea
227	VIRTA	virta	birta	dirta	lusbo
228	VEURETA	veureta	beureta	heureta	fiucado
229	CERRAL	cerral	zerral	nerral	nirras
230	CONIR	conir	konir	bonir	tuvas
231	CACIROR	caciror	kaciror	laciror	dunasas
232	GIRTE	girte	jirte	pirte	gosla
233	VIEVO	vievo	bievo	lievo	taija
234	COCORO	cocoro	kocoro	locoro	fisana
235	BACHO	bacho	vacho	zacho	sicha
236	CEMI	cemi	zemi	nemi	niha
237	CIFO	cifo	zifo	vifo	zaha
238	VIZA	viza	biza	hiza	lase
239	BUHA	buha	vuha	suha	nafo
240	CEFRE	cefre	zefre	nefre	sitra
241	BIALE	biale	viale	niale	veuta
242	BAFERO	bafero	vafero	nafero	ritusa

243	CILO	cilo	zilo	rilo	nafa
244	VUJO	vujo	bujo	hujo	lepa
245	CADACA	cadaca	kadaca	fadaca	lateno
246	BUTO	buto	vuto	ruto	sahe
247	CECORRO	cecorro	zecorro	secorro	zanerra
248	BUJÓN	bujón	vujón	sujón	zagás
249	BUJA	buja	vuja	nuja	roge
250	BUNCA	bunca	vunca	sunca	zasva
251	CALLI	calli	kalli	lalli	fache
252	BETREMA	betrema	vetrema	setrema	cabrizo
253	VEMINO	vemino	bemino	temino	diraca
254	BUJENDA	bujenda	vujenda	zujenda	sapista
255	VAIBE	vaibe	baibe	laibe	teufa
256	CUNSE	cunse	kunse	hunse	bisra
257	BARGO	bargo	vargo	nargo	cespa
258	CABÓN	cabón	kabón	fabón	tités
259	CACNO	cacno	kacno	facno	lisza
260	CECHE	ceche	zeche	veche	nella
261	COZADO	cozado	kozado	tozado	hicoba
262	VELGEN	velgen	belgen	delgen	bilpas
263	CAVATAS	cavatas	kavatas	havatas	fitebes
264	GIRRE	girre	jirre	perri	purra
265	CUGA	cuga	kuga	luga	fipo
266	BONANA	bonana	vonana	ronana	viseno
267	BUVA	buva	vuva	zuva	caze
268	CACERRA	cacerra	kacerra	dacerra	lenirro
269	CACIRA	cacira	kacira	hacira	lunemo
270	CAURO	cauro	kauro	lauro	teuna
271	CECEZOL	cecezol	kecezol	fecezol	bicosal
272	VINATA	vinata	binata	tinata	deroha
273	GESIAL	gesial	jesial	pesial	piruel
274	BULQUE	bulque	vulque	rulque	salguo
275	CAMPEA	campea	kampea	dampea	lingae
276	BEJE	beje	veje	neje	repo
277	CECARRO	cecarro	zecarro	vecarro	sinorra
278	BIXEO	bixeo	vixeo	rixeo	casea
279	JETI	jeti	geti	peti	puha
280	BURÓN	burón	vurón	murón	nisús
281	CULLIRO	culliro	kulliro	tulliro	dachena
282	CASIRIA	casiria	kasiria	lasiria	tanosie
283	CARTE	carte	karte	barte	hisfa
284	CACARRA	cacarra	kacarra	lacarra	tuderro
285	BALLEL	ballel	vallel	nallel	zechal
286	CIRTE	cirte	kirte	tirte	lasbo
287	CACIR	cacir	kacir	lacir	benos
288	CEPE	cepe	zepe	nepe	zija
289	VEPO	vepo	bepo	tepo	duge
290	BUCOTE	bucote	vucote	nucote	vizado

291	VEIRÓN	veirón	beirón	teirón	feucás
292	BORRIA	borria	vorria	zorria	nurrai
293	COREMIA	coremia	koremia	loremia	hivocio
294	CAQUISA	caquisa	kaquisa	daquisa	tiquere
295	VESCE	vesce	besce	tesce	lorfa
296	CARTOL	cartol	kartol	bartol	desbal
297	VINTINA	vintina	bintina	lintina	fashomo
298	VEZERA	vezera	bezera	fezera	dacuso
299	CUCHA	cucha	kucha	fucha	hulli
300	CIRIOSA	ciriosa	ziriosa	niriosa	vereozo
301	CUTA	cuta	kuta	duta	bafu
302	CONTÓN	contón	kontón	dontón	lasbás
303	JICIHA	jiciha	giciha	piciha	gasalo
304	CELLIDA	cellida	zellida	nellida	cocheta
305	CAZICA	cazica	kazica	bazica	deruno
306	BULLO	bullo	vullo	nullo	cicha
307	COSARO	cosaro	kosaro	bosaro	hinavo
308	BEDÍ	bedí	vedí	zedí	vité
309	CESAMA	cesama	zesama	vesama	cinevo
310	CIRTE	cirte	zirte	sirte	vosdo
311	CALLETO	calleto	kalleto	halleto	bichude
312	CONFO	confo	konfo	tonfo	hesta
313	CERRI	cerri	zerri	nerri	carra
314	CACARRA	cacarra	kacarra	facarra	lisurro
315	BANCE	bance	vance	cance	rismo
316	VUBI	vubi	bubi	fubi	hale
317	BOMO	bomo	vomo	zomo	ruva
318	COCIJÓN	cocijón	kocijón	tocijón	darepás
319	JENCO	jenco	genco	penco	pisza
320	BOMATO	bomato	vomato	nomato	visoba

Appendix G

Set of stimuli used in experiment 4. TL = Transposed letter, RL = Replaced letter.
On the right columns of the stimuli used in the Experiment, a (*) indicates that that one and its conditions were removed the analyses.

Word targets (practice):

No.	**Word Target**	**TL-prime**	**RL-prime**	**unrelated-prime**
1	BASEBALL	babesall	badenall	toficher
2	FIREWORKS	fiweroks	fimenorks	cegarolds
3	FIREMAN	fimeran	finesan	pawrass
4	SOMETIMES	sotemites	sofewites	tripolate
5	SOMEBODY	sobemody	sodenody	retalave
6	HOMEWORK	howemork	hovenork	decilion

Pseudoword targets (practice):

	Pseudoword Target	**TL-prime**	**RL-prime**	**unrelated-prime**
7	BANETALL	batenall	balemall	tofinker
8	FIREGARKS	figerarks	fijenarks	cegaroise
9	FARKMAN	famkran	fanksan	pawract
10	SONETIVES	sotenives	solemives	doxotelia
11	SONESUDY	sosenudy	soremudy	retalime
12	HOSEWORN	howesorn	hoverorn	decicion

120 Target 'words' and their 4 primes used in the Experiment:

	Target	**TL-prime**	**RL-prime**	**unrelated-prime**
1	ABOVE	avobe	anode	gloir
2	ALIVE	avile	anife	tholt
3	ANIMAL	aminal	asiral	midery
4	BANDAGE	bangade	banpabe	witafun
5	BEFORE	berofe	benote	gasays
6	BINOCULARS	biconulars	bisorulars	virebision
7	BROKEN	bkoren	bhosen	sulpty
8	CAMERA	carema	casena	tarble
9	CELERY	cerely	cesefy	pisard

10	CIGARETTE	ciragette	cinapette	tregolate
11	CRIMINAL	crinimal	crisiwal	plameton
12	DELIVER	deviler	dewifer	machand
13	DIFFERENT	diffenert	diffemect	amalomive
14	EMPTY	etpmy	efpny	knizz
15	FAMILIES	falimies	fatinies	stiletin
16	FLEXIBLE	flebixle	flezijle	whiveton
17	FROWN	fworn	fmosn	stoze
18	GLOBE	gbole	ghofe	storl
19	HOLIDAY	hodilay	hobyfay	suyical
20	IMAGINE	imanige	imaripe	helband
21	KNIFE	kfine	ktime	engry
22	LOVELY	lolevy	lofewy	pronen
23	MAGICAL	macigal	maripal	squirch
24	MINUTE	mitune	mifuve	tacent
25	NATURE	narute	nacufe	sunflu
26	PAVEMENT	pamevent	panewert	niffbook
27	PLANT	pnalt	pmaht	snish
28	POPULAR	polupar	potugar	turtlid
29	PROMISE	prosime	proniwe	mustire
30	RELIGION	regilion	repifion	upshulla
31	SAFETY	satefy	saleky	bomeri
32	SEVENTH	senevth	serewth	witason
33	SKIRT	srikt	sniht	plure
34	SPAGHETTI	sgaphetti	sbazhetti	mustmerns
35	STOLEN	sloten	skofen	brivel
36	STRETCH	stterch	stfench	pilerns
37	TINKLE	tilkne	tifkme	pucost
38	TOMORROW	toromrow	tonovrow	ibtexity
39	UMBRELLA	umblerla	umbsetla	lolonare
40	VOLCANO	volnaco	volmaro	hamidoy
41	ACTIVITY	acvitity	acwifity	dilktate
42	ALLIGATOR	allitagor	allifajor	docatelia

43	APOLOGISE	apolosige	apolojive	sortticed
44	BASEMENT	bamesent	banecent	supazine
45	BEHAVE	bevahe	bewate	natops
46	BLANKET	bnalket	bmafket	chisfat
47	CABINET	canibet	caridet	imemize
48	CANDLE	caldne	cafdme	fotalo
49	CHILD	clihd	cfind	froil
50	COCONUT	conocut	comorut	redband
51	CROCODILE	crodocile	crobosile	impisator
52	DENTIST	densitt	dencift	sturays
53	DINOSAUR	disonaur	dizomaur	stinklit
54	ENVELOPE	enlevope	enfewope	mokedent
55	FEMALE	felame	fetane	stular
56	FLOWER	fwoler	fvoter	atipul
57	FURNITURE	furtinure	furlimure	cegarombs
58	GLOVE	gvole	gnofe	eshry
59	HOSPITAL	hostipal	hosfigal	seticism
60	INVITATION	intivation	infiwation	bolicylter
61	LEMONADE	lenomade	lerowade	grolinal
62	MACHINE	macnihe	macrike	costods
63	MAGICIAN	macigian	marijian	envenics
64	MOVEMENT	momevent	mowerent	sontsudy
65	PALACE	pacale	parafe	tolkly
66	PIRATE	pitare	piface	spanel
67	POLICE	pocile	ponife	retoil
68	PRESENT	pserent	pcenent	bambals
69	PUMPKIN	pukpmin	puhpwin	rirtbud
70	RETURN	rerutn	resufn	finthe
71	SCARF	sracf	snasf	kninx
72	SILENCE	sinelce	sirefce	mevesce
73	SMALL	slaml	sfanl	abern
74	SPINACH	snipach	srigach	wemcano
75	STOMACH	smotach	snofach	domslin

76	TANGLE	talgne	tafgme	pirift
77	TOGETHER	toteghe r	tofepher	envenirm
78	TONIGHT	toginht	topimht	calltul
79	VEGETABLE	vetegable	vefepable	sowntives
80	WATERY	warety	wanefy	demeld
81	AIRPORT	airropt	airnogt	kanchen
82	ANGRY	argny	acgmy	wrine
83	AWAKE	akawe	ahave	theng
84	BEAUTIFUL	beaufitul	beaulidul	stigolate
85	BEHIND	benihd	becind	sinkfa
86	BRACELET	bralecet	brafenet	stiftlin
87	CAFETERIA	cateferia	caleberia	boaptisul
88	CAREFUL	caferul	catenul	flinape
89	CHOCOLATE	cholocate	chofonate	booftisul
90	COSTUME	cosmute	cosnufe	namcano
91	DELICIOUS	decilious	denifious	impimator
92	DESERT	derest	denect	molind
93	DOLPHIN	dohplin	dokptin	strekes
94	EVENING	eneving	emewing	rirtsod
95	FINISH	fisinh	firimh	suncru
96	FOREST	fosert	fonect	spilen
97	GARAGE	gagare	gajane	sungty
98	HELICOPTER	helipocter	heligonter	onmisition
99	HUSBAND	husnabd	husmahd	pilerts
100	KITCHEN	kihcten	kifclen	mibinep
101	LEOPARD	leorapd	leosagd	imemide
102	MAGAZINE	mazagine	maxavine	retalict
103	MEDICINE	mecidine	mesibine	phacible
104	MUSTARD	musratd	musnafd	clisuce
105	PARENT	panert	pamest	calscu
106	PLANET	pnalet	prafet	shonen
107	POLITE	potile	pofike	sunscu
108	PRIVATE	pritave	prifawe	fexagid

109	RELATIVE	retalive	refakive	pakedent
110	RIDING	rinidg	rimibg	temarm
111	SECOND	senocd	semosd	moding
112	SKELETON	sketelon	skefehon	decidion
113	SMILE	slime	sfine	yuthu
114	STICK	scitk	snifk	frope
115	STORM	srotm	snofm	thesh
116	TELEVISION	tevelision	tenefision	glurtroods
117	TOMATO	totamo	tofano	walage
118	TRAMPOLINE	tramlopine	tramfogine	onmihition
119	VITAMIN	vimatin	viwalin	pawrect
120	WHOLE	wlohe	wfobe	stids
121	AFUKE	akufe	ahute	thinx
122	ARBLY	albry	atbsy	twove
123	ATIPOL	apitol	agifol	migera
124	BEGOTE	betoge	befope	sinkla
125	BENTAST	bensatt	benraft	stopaks
126	BRIFELET	brilefet	britehet	gromital
127	CEGAROIRE	ceragoire	cenapoire	trixolate
128	CLACIBLE	clabicle	claridle	tsameton
129	CRUGODIPS	crudogips	crubojips	impidator
130	DEGNERENT	degnenert	degnemest	amalomism
131	DINOMOIS	dimonois	diwohois	stiftlit
132	ELFRY	erfly	enfhy	kniud
133	FALATO	fatalo	fakaho	signpa
134	FESMITURE	festimure	feshinure	cegarorms
135	FLINANK	fnilank	fmitank	gurcano
136	FROLD	flord	fhosd	snite
137	GLORE	grole	gsohe	ewsry
138	HIVERY	hirevy	hisewy	demeon
139	IBTEFITY	ibfetity	iblekity	dishbate
140	JILTHEN	jihtlen	jibtken	mitinet
141	LIREBISION	liberision	lidecision	glurtroose

142 MASCITE	mastice	masfire	costoil
143 MITERY	mirety	misefy	pilack
144 NALORE	narole	nasote	fomali
145 PASAKE	pakase	pahare	minond
146 PILECTS	picelts	pirelts	mevechs
147 PLAWS	pwals	pmafs	snast
148 POTIVE	povite	poxife	retoid
149 PUTICINE	pucitine	purifine	thacible
150 RETOPE	repote	regofe	tortly
151 SANUTE	satune	safume	tacant
152 SHINATE	shitane	shifame	facagon
153 SMOLE	slome	sfone	uncri
154 SPARET	srapet	snaget	shoten
155 STIGS	sgits	spifs	froge
156 STRUTCH	stturch	stfunch	clisurl
157 TARPLE	talpre	tafpne	piriss
158 TOFIRMER	torifmer	tonitmer	envenill
159 UTCRULLA	utclurla	utcfusla	lolonasm
160 WASAGE	wagase	wapare	sucety
161 AIRBOME	airmobe	airnohe	jutchen
162 ASOKE	akose	afoce	phive
163 BAREDENT	baderent	babesent	magahals
164 BEJITE	betije	befige	sinkro
165 BINOTURYTE	bitonuryte	bifomuryte	virefision
166 CARGLE	calgre	cafgne	trirel
167 CHIRK	crihk	cnilk	scown
168 COCOLOY	colocoy	cotoroy	redbaft
169 DECIGIAN	degician	depirian	upsculla
170 DEMEGS	degems	depens	molird
171 DOCEMELIA	domecelia	donerelia	boaftisul
172 ENVENIME	ennevime	enmexime	momedent
173 FAVELY	falevy	fatewy	senstu
174 FINSLE	filsne	fitsme	pucoss

175 FOLIDOX	fodilox	fobitox	sepulir
176 FURPITAL	furtipal	furfigal	seticide
177 HEREST	hesert	hecent	sencru
178 HOBELABLE	holebable	hofedable	sownticed
179 IMEMITS	imetims	imefins	tushtid
180 KNISM	kmirm	kwism	slart
181 LONIVES	lovines	loximes	corolot
182 MIBIMET	mimibet	minidet	konchen
183 MOSEDENT	modesent	moberent	solksudy
184 ONMIBITION	onbimition	ondinition	bolicytter
185 PASEDENT	padesent	paberent	dirtbate
186 PISAND	pinasd	pimard	slinet
187 PLIVETON	plitevon	plifewon	devigeen
188 PROLENT	plorent	pfosent	buntist
189 RARETE	ratere	rafese	caltru
190 ROVENTH	ronevth	romexth	witafid
191 SAPULIR	salupir	safugir	tuselid
192 SHOJEN	sjohen	sgoken	sulkty
193 SOSTARD	sosratd	soscafd	clisulg
194 SPARHONTI	sraphonti	snaghonti	mullmerks
195 STOPAFF	spotaff	sgokaff	domquin
196 SUNETY	suteny	sufemy	boceri
197 TEMACS	tecams	terans	stirir
198 TOSICOLTER	tosilocter	tosiforter	onmifition
199 VITASAD	visatad	vinafad	pastact
200 WHODE	wdohe	wboke	stips
201 AMILOMIVE	amilovime	amiloxine	sorttives
202 ATILE	alite	afihe	quess
203 BASHAYS	basyahs	basgaks	vitafod
204 BEJOVE	bevoje	beyoge	natose
205 BOAXTISUL	boaxsitul	boaxriful	stipolate
206 CASETUL	catesul	caherul	tonains
207 CHONEN	cnohen	cmoken	flivel

208 COSTORM	cosrotm	cosnofm	natcano
209 DEDECER	deceder	dereber	mascise
210 DERIFLOOS	defirloos	deticloos	impivator
211 DOTBRIN	dorbtin	dosbfin	squench
212 ERTMING	emtring	entsing	rirtwud
213 FELONAYS	fenolays	femotays	gramital
214 FLIMER	fmiler	fniter	atifac
215 FOLINIES	fonilies	fomities	stiletit
216 GLOCS	gcols	grofs	stofs
217 HINISE	hisine	hirime	sunbru
218 HULBANT	hulnabt	hulfamt	putault
219 IMPIGATOL	impitagol	impifapol	docameria
220 LELFACK	lelcafk	lelratk	imecits
221 MAGAKALS	makagals	mahapals	retalilk
222 MITERA	mireta	misefa	fargle
223 MUCOND	munocd	murosd	soding
224 PAFICEEN	pacifeen	pariteen	envenile
225 PIDEKIN	pikedin	pihebin	rirthad
226 PLAMITAL	platimal	plafinal	plaveton
227 POTIND	ponitd	pocifd	sunstu
228 PROPIRE	proripe	prosige	mestand
229 RETALIRM	relatirm	refakirm	parfdent
230 RUSING	runisg	rumicg	bisish
231 SCAFE	sface	stare	knisp
232 SKIME	smike	snihe	plund
233 SPANJET	snapjet	smagjet	chanjat
234 STAMMOLITS	stamlomits	stamfonits	glurtrooms
235 STOWL	swotl	svofl	prosh
236 SUPICAL	sucipal	susigal	strents
237 TOCARROG	toracrog	tonasrog	ibtezity
238 TRUGOLATE	trulogate	trufopate	fubcituse
239 VURPANO	vurnapo	vurmago	hamigay
240 WRALL	wlarl	wtanl	aberk

Appendix H

Set of stimuli in Spanish used for the Masked Orthographic prime Experiments with deaf adult and young deaf readers of Spanish. (Exps. 5-6)

TL_C = Transposed letter Consonant, RL_C = Replaced letter Consonant.
TL_V = Transposed letter Vowel, RL_V = Replaced letter Vowel.

On the right side of the columns a (*) indicates that the target and its conditions were removed from the analyses, as they had less than 58%

Word targets (practice):

No.	Target Word	TL_C prime	RL_C prime	TL_V prime	RL_C prime
1	SACAPUNTAS	sacanuptas	sacaructas	sacupantas	sacopentas
2	ESTUFA	esfuta	escuba	estafu	estefo
3	PROFESORA	prosefora	pronetora	profosera	profisura
4	ACONDICIONADOR	acondiciodanor	acondiciolavor	acondicionodar	acondicionidur
5	BICICLETA	bicictela	bicicfeba	biciclate	bicicluti
6	ABRELATAS	abretalas	abrefabas	abraletas	abrolitas

Pseudoword targets (practice):

7	CARITELA	catirela	cafisela	caretila	carutala
8	FORISANTO	fosiranto	fonivanto	forasinto	forusento
9	TACODINO	tadocino	talovino	tocadino	ticudino
10	NARCODOR	nardocor	narlosor	norcador	nercudor
11	PETEBUZÓN	pebetuzón	pelefuzón	petebozón	petebizón
12	NERGAFO	nerfago	nertavo	nergofa	nergufe

120 Target 'words' and their 4 primes used in the Experiment:

						Items excluded from the analyses	
No.	Target Word	TL_C prime	RL_C prime	TL_V prime	RL_C prime	Exp. 5. Adults	Exp 6. Young reaers
1	INCUBADORA	incudabora	inculatora	incabudora	incobedora		(*)
2	INTELIGENTE	inletigente	indebigente	intilegente	intolagente		
3	CADUCIDAD	cacudidad	canubidad	cadicudad	cadecodad		(*)
4	REMOLACHA	relomacha	retozacha	remalocha	remilucha	(*)	(*)
5	FORTALEZA	forlateza	forbadeza	fortelaza	fortuloza		
6	SOLIDARIDAD	soliradidad	solinatidad	soladiridad	soleduridad		
7	PERSONAJE	pernosaje	pervomaje	persanoje	persuneje		
8	TARTAMUDO	tarmatudo	tarzaludo	tartumado	tartimedo		(*)

9	DESAYUNO	deyasuno	degavuno	desuyano	desiyeno		
10	MACEDONIA	madeconia	mabezonia	macodenia	macudinia		(*)
11	ZANAHORIA	zahanoria	zafasoria	zanoharia	zanehuria		
12	CONGELADO	conlegado	conbepado	congoledo	congalido		
13	DESPEDIDA	desdepida	deslegida	despideda	despoduda		
14	CONVOCATORIA	convotacoria	convolazoria	convacotoria	convecutoria		(*)
15	TOBOGANES	togobanes	topolanes	tobagones	tobigunes		(*)
16	DECORADO	derocado	denozado	decarodo	decurido		(*)
17	ORDENADORES	ordedanores	ordezatores	ordanedores	ordinudores		
18	MARINERO	manirero	masivero	mareniro	marunaro		
19	CAMISETA	casimeta	caniveta	camesita	camasuta		
20	LABORATORIO	labotarorio	labofanorio	labarotorio	laberitorio		
21	COMUNICACIÓN	comucinación	comuviración	cominucación	comenocación		
22	CONTAMINADO	contanimado	contavinado	contimanado	contemonado		
23	ALBARICOQUE	albaciroque	albanivoque	albiracoque	alberucoque	(*)	(*)
24	AMANECER	anamecer	asavecer	amenacer	aminocer		
25	RESUCITADO	resuticado	resufinado	resicutado	resecatado		
26	ESCALERILLA	escarelilla	escanetilla	escelarilla	escilorilla		
27	PRIMAVERA	privamera	prisarera	primevara	primovura		
28	FLORECITA	flocerita	flovenita	floriceta	floracuta		
29	FAVORECIDA	favocerida	favosenida	faverocido	favirucido		
30	EVAPORADO	evaropado	evanogado	evoparado	evuperado		(*)
31	ALAMEDA	amaleda	anateda	alemada	alimuda		(*)
32	FENOMENAL	femonemal	fecoremal	fenemonal	fenimanal		
33	MALHUMORADO	malhuromado	malhusozado	malhomurado	malhemarado		(*)
34	COLADERAS	colaredas	colasebas	coladares	coladuris		
35	GENEROSIDAD	genesoridad	genevonidad	genoresidad	genurasidad		
36	UNIDADES	udinades	utisades	unadides	unedodes		
37	TOSTADORA	tosdatora	toslafora	tostodara	tostudera		
38	ABSOLUTO	ablosuto	abconuto	absuloto	abselato		
39	NATURALEZA	natulareza	natufaveza	nataruleza	naterileza		
40	PODEROSO	poredoso	pometoso	podoreso	podiraso		
41	ESPINACAS	esnipacas	esvigacas	espanicas	esponecas		(*)
42	SEPARADORES	sepadarores	sepalanores	separodares	separidures		
43	ITINERARIO	itirenario	itisevario	itenirario	itunorario		(*)
44	AMARILLO	aramillo	asavillo	amirallo	amorullo		
45	COLORADO	corolado	covotado	colarodo	colerido		
46	HELADERÍA	hedalería	hetabería	heledaría	heludoría		
47	FOGONAZO	fonogazo	fovojazo	foganozo	fogunizo	(*)	(*)
48	COMISARÍA	cosimaría	covinaría	comasiría	comusoría		(*)
49	COLABORACIÓN	colarobación	colanofación	colobaración	coluberación		
50	PREFERIDO	prerefido	presetido	prefiredo	prefurodo		
51	ACANTILADO	acanlitado	acanbifado	acantalido	acantuledo		(*)
52	MARAVILLA	mavarilla	mazasilla	marivalla	marevolla		
53	LITERATURA	litetarura	litebanura	litaretura	litorutura		
54	CACEROLA	carecola	casevola	carocela	caracila		(*)
55	FINALIZAR	filanizar	fitacizar	finilazar	finelozar		
56	TULIPANES	tupilanes	tugifanes	tulapines	tulepunes		(*)

57	ABOGADO	agobado	apotado	abagodo	abegudo		
58	MALEDUCADA	malecudada	malevutada	maudecada	malidocada		(*)
59	COMPETIDORES	compeditores	compelibores	compitedores	computodores		
60	PREPARATIVO	prepatarivo	prepafasivo	preparitavo	preparetuvo		
61	GELATINA	getalina	gebafina	gelitana	gelutona		
62	FEMENINO	fenemino	fesecino	femineno	femanuno		
63	CRISTALINA	crislatina	crisbafina	cristilana	cristeluna		
64	INVITACIÓN	intivación	indisación	invatición	invetoción		
65	MINIFALDA	mifinalda	mitiralda	minafilda	minefulda		(*)
66	ORGANIZADO	orgazinado	orgasirado	orginazado	orgenuzado		
67	CALIFICATIVO	califitacivo	califibanivo	calificitavo	calificetuvo		
68	APARECIDO	apacerido	apanesido	aperacido	apirucido		
69	ENAMORADO	enaromado	enasozado	enomarado	enumirado		
70	TELEVISIÓN	tevelisión	teredisión	telivesión	telavusión		
71	ASPIRADORAS	aspidaroras	aspilanodas	asparidoras	asporedoras		(*)
72	LABERINTO	larebinto	lanefinto	labirento	laburanto		(*)
73	EXPOSICIÓN	exsopición	exnogición	expisoción	expesución		
74	ILUMINADO	ilunimado	ilucirado	ilimunado	ilemanado		
75	VELOCIDAD	vecolidad	venotidad	velicodad	velacedad		
76	PARALIZADOS	parazilados	paranifados	parilazados	parelozados		
77	GOLOSINA	gosolina	gocofina	golisona	golesuna		
78	DELICADEZA	delidaceza	delibaneza	delacideza	delocedeza		
79	INVITADO	intivado	inlizado	invatido	invutedo		
80	PATINADORA	patidanora	patilasora	patanidora	patenodora		
81	MUSCULATURA	muscutalura	muscufabura	musculutara	musculotera		(*)
82	ACELERACIÓN	acelecarión	acelenasión	acelericaón	acelerecuón		
83	DESTINATARIO	destitanario	destilazario	destanitario	destonetario		
84	APETITO	atepito	alejito	apiteto	apotuto		(*)
85	ENEMIGO	emenigo	eserigo	enimego	enamogo		
86	ABEJORRO	ajeborro	agetorro	abojerro	abajirro	(*)	(*)
87	DIMINUTO	dinimuto	disivuto	dimunito	dimenato		(*)
88	CARAMELO	camarelo	cavaselo	caremalo	carimulo		
89	LUMINOSO	lunimoso	lusiroso	lumoniso	lumenaso		
90	SOLITARIO	sotilario	sobidario	solatirio	soleturio		
91	AUTOCINEMAS	autonicemas	autorivemas	autocenimas	autocunamas	(*)	
92	GASOLINERA	gasonilera	gasovitera	gasilonera	gaselunera		
93	CAPACIDAD	cacapidad	canagidad	capicadad	capocudad		
94	VETERINARIA	veteniraria	vetesizaria	vetirenaria	veturonaria		
95	DORMITORIO	dortimorio	dorlirorio	dormotirio	dormaturio		
96	RINOCERONTE	rinoreconte	rinosezonte	rinecoronte	rinacuronte		(*)
97	ESCENARIO	esnecario	esrevario	escanerio	esconirio		
98	CALABOZO	cabalozo	cafatozo	calobazo	calebizo		
99	VITAMINAS	vimatinas	vicalinas	vitimanas	vitemunas		
100	EMPERADORES	empedarores	empelanores	emperodares	emperidures		
101	MANDARINA	manradina	manvatina	mandirana	manderona		
102	SEGURIDAD	serugidad	sezupidad	segirudad	segerodad		
103	HABITACIÓN	hatibación	halifación	habatición	haboteción		
104	TITULADO	tilutado	tibufado	titaludo	titelido		(*)

105	DESHABITADO	deshatibado	deshalifado	deshibatado	deshebutado		
106	ALFABETO	albafeto	altaleto	alfebato	alfibuto		(*)
107	REGADERA	redagera	relapera	regedara	regidura		(*)
108	TESORITO	terosito	tenovito	tesiroto	teseruto		
109	SAXOFONISTA	saxonofista	saxovotista	saxofinosta	saxofunesta	(*)	(*)
110	RELOJERO	rejolero	regofero	relejoro	relajuro		
111	AZUCARERO	azuracero	azunavero	azacurero	azecorero		
112	DEDICATORIA	deditacoria	dedilasoria	dedacitoria	dedocetoria		
113	TEMPERATURA	tempetarura	tempebamura	tempaterura	tempotirura		
114	GANADERO	gadanero	galavero	ganedaro	ganiduro		
115	CAMARERO	caramero	cazanero	cameraro	camoriro		
116	PASAJEROS	pasarejos	pasanegos	pasejaros	pasijuros		
117	RECUPERADO	recurepado	recusegado	recepurado	reciparado		
118	JABONERA	janobera	jacotera	jabenora	jabunira		
119	ANIMALES	aminales	arivales	anamiles	anemoles		
120	SALPICADO	salcipado	salnigado	salpacido	salpocedo		(*)

120 Target 'pseudowords' and their 4 primes used in the Experiment:

121	AMIFACADA	amicafada	amisalada	amaficada	amufecada
122	IRGAFICIÓN	irfagición	irtajición	irgifación	irgefución
123	DAMASONO	dasamono	darazono	damosano	damiseno
124	BAMODILLO	badomillo	batorillo	bamidollo	bamedullo
125	ESLERACIÓN	esrelación	esnetación	eslareción	esluroción
126	HENABIGIÓN	hebanigión	hetavigión	henibagión	henubegión
127	ADMOCUSO	adcomuso	adnoruso	admucoso	admacaso
128	SOLORENONTE	soloneronte	solozesonte	soleronte	solurinonte
129	COMOCILLO	cocomillo	corozillo	comicollo	comacullo
130	DENLOCAVORIO	denlovacorio	denlonasorio	denlacovorio	denlicuvorio
131	NANOPINIGIDO	nanonipigido	nanocijigido	naniponigido	nanepunigido
132	TAGOCAZORIA	tagozacoria	tagoraxoria	tagacozoria	tagucezoria
133	BUSEROSO	buresoso	bunecoso	busoreso	busiruso
134	BOMOSICO	bosomico	bovorico	bomisoco	bomesuco
135	AVULOTACIÓN	avutolación	avufobación	avolutación	aviletación
136	PASABILLA	pabasilla	patarilla	pasiballa	pasebolla
137	BEMOVECALO	bemocevalo	bemoresalo	bemevocalo	bemuvicalo
138	PEMODACO	pedomaco	petonaco	pemadoco	pemiduco
139	TIBONERA	tinobera	tisolera	tibenora	tibunara
140	TALECADOCA	taledacoca	talefaroca	talacedoca	talocudoca
141	POLENARIA	ponelaria	pocetaria	polaneria	polinuria
142	BIMARICAN	biramican	bisazican	bimiracan	bimerocan
143	AGUCAMOCA	agumacoca	agusaroca	agacumoca	agocemoca
144	PEMOBERA	pebomera	pelocera	pemebora	pemibura
145	PALIMORAJE	paliromaje	palisovaje	palomiraje	palumeraje
146	CAFARENEZA	cafanereza	cafasemeza	caferaneza	caforuneza
147	TOLECAPURA	tolepacura	tolejazura	tolacepura	tolucipura
148	CACEGUSA	cagecusa	capenusa	cacugesa	cacogisa

149	DIMIRADO	dirimado	disivado	dimarido	dimerudo
150	CASMILEDAR	caslimedar	castiredar	casmelidar	casmoludar
151	DARMELORIO	darlemorio	darterorio	darmolerio	darmulario
152	LICALONACIÓN	licanolación	licazofación	licolanoción	licolenución
153	ANLAJESO	anjaleso	anpafeso	anlejaso	anlijuso
154	PEMBUNORADO	pemburonado	pembusocado	pembonurado	pembenarado
155	CILOMICENA	cilocimena	cilovirena	cilimocena	cilamucena
156	IGUJEMADA	igumejada	igurepada	igejumada	igejumoda
157	TALUCANOZA	talunacoza	talusaroza	talacunoza	talicuneza
158	FRICABERO	fribacero	fritasero	fricebaro	fricoburo
159	BOFOCAVO	bocofavo	bonodavo	bofacovo	boficuvo
160	CAMASELA	casamela	cavarela	camesala	camisula
161	ECIDOPO	edicopo	elinopo	ecodipo	ecudapo
162	RIMUDADA	ridumada	ritusada	rimaduda	rimedoda
163	DEGECAROCIE	degeracocie	degesanocie	degacerocie	degucirocie
164	TEPECIRARIO	tepericario	tepenisario	tepicerario	tepocurario
165	CAVURIDAD	caruvidad	casunidad	cavirudad	caverodad
166	ONLECIPADO	onlepicado	onlegisado	onlicepado	onlucopado
167	TASIFUTADA	tasitufada	tasidulada	tasufitada	tasofetada
168	TOLEJAMIA	tojelamia	topefamia	tolajemia	tolojumia
169	LEBARIDAD	lerabidad	lezatidad	lebiradad	leboredad
170	CAMILOTERIA	camitoleria	camidoferia	camoliteria	camulateria
171	BAMOCERO	bacomero	basovero	bamecoro	bamicuro
172	ALATOVIDO	alavotido	alarofido	alotavido	alutevido
173	ANLOZADOZAS	anlodazozas	anlotacozas	anlazodozas	anlezoduzas
174	BISARIVAR	birasivar	bivanivar	bisiravar	bisurevar
175	CAMAGOPA	cagamopa	cajazopa	camogapa	camegupa
176	ANLECISEQUE	anlesiceque	anleriveque	anliceseque	anlucaseque
177	BEMATICO	betamico	befavico	bemitaco	bemutoco
178	REMOCADA	recomada	revorada	remacoda	remiceda
179	MACISOCIO	masicocio	maxinocio	macosicio	macusecio
180	PASECIRO	pacesiro	paxeniro	pasicero	pasucoro
181	APIBORRO	abiporro	adigorro	apobirro	apuberro
182	CALIPATURIA	calitapuria	califaguria	calapituria	calupeturia
183	PALURICADO	palucirado	palusizado	palirucado	palorecado
184	ESPICARIO	escipario	esmijario	espacirio	espocerio
185	ZASPIRENA	zasripena	zasvijena	zasperina	zaspurona
186	TALORINOCA	taloniroca	talozisoca	talironoca	talerunoca
187	ALICONARIA	alinocaria	alizosaria	alocinaria	alucenaria
188	TETABOLIA	tebatolia	teladolia	tetobalia	tetubelia
189	ASTEROLILLA	astelorilla	astebonilla	astorelilla	asturalilla
190	ZASCURAFENO	zascufareno	zascudaveno	zascarufeno	zascorifeno
191	TASCULADEZO	tascudalezo	tascufatezo	tascaludezo	tascolidezo
192	CAMINOVA	canimova	carizova	camoniva	camuneva
193	CARCASENA	carsacena	carmarena	carcesana	carcisuna
194	SITEBALIDAD	sitelabidad	sitedafidad	sitabelidad	sitobulidad
195	CARMANUDO	carnamudo	carsaxudo	carmunado	carmenodo
196	BICAJUVÓN	bijacuvón	bigaruvón	bicujavón	bicojevón

Appendix H

197	MOLUVANICA	molunavica	moluxasica	molavunica	molevonica
198	CAMPIFENERA	campinefera	campiselera	campefinera	campofunera
199	BOSMACEZA	boscameza	bosraseza	bosmecaza	bosmicoza
200	ALENIRADO	alerinado	alexicado	alinerado	alunorado
201	ZAMOCIDAD	zacomidad	zaronidad	zamicodad	zamecudad
202	TEGERACIÓN	teregación	tecejación	tegareción	tegurición
203	AMITOVA	atimova	alirova	amotiva	amuteva
204	ALOCETIDA	alotecida	aloderida	alecotida	alicutida
205	RESMODIDA	resdomida	reslovida	resmidoda	resmaduda
206	DESLEVANARIO	deslenavario	deslesacario	deslavenario	deslivunario
207	ALEDICIÁN	adelicián	atefición	alidecián	aludocián
208	ELECENADO	elenecado	elexerado	elecanedo	elecunido
209	HELIDANIO	hedilanio	hetifanio	heladinio	heludonio
210	ESETIRALE	eseritale	esenifale	esiterale	esoturale
211	BILESOSA	biselosa	binetosa	bilosesa	bilusisa
212	GELAMESO	gemaleso	gezafeso	gelemaso	gelimuso
213	ACADIPALA	acapidala	acagibala	acidapala	acedupala
214	DROSCARINA	drosracina	drosnavina	droscirana	droscurena
215	MALENUSA	manelusa	maredusa	malunesa	malanisa
216	FANCIRATURA	fancitarura	fancidazura	fancaritura	fancerotura
217	MOLENARIA	monelaria	mosefaria	molaneria	molunoria
218	CAMARIDAD	caramidad	cavazidad	camiradad	camerodad
219	NAVOLECACIÓN	navocelación	navorefación	navelocación	navulicación
220	MEMUCIDAD	mecumidad	mesuridad	memicudad	memacodad
221	AMABODO	abamodo	alasodo	amobado	amibedo
222	INCUDASA	inducasa	inlunasa	incadusa	incedosa
223	BAMASERA	basamera	baxarera	bamesara	bamisora
224	BAMUSOTE	basumote	barucote	bamosute	bamisate
225	IMCATOGULA	imcagotula	imcajofula	imcotagula	amcetugula
226	ANARENIR	ananerir	anacezir	aneranir	anuronir
227	ZAMERATO	zaremato	zavesato	zamareto	zamiruto
228	MOFIROTO	morifoto	mociloto	moforito	mofureto
229	DELERANOTA	delenarota	delezacota	delarenota	delurinota
230	HECORINO	herocino	hexosino	hecirono	heceruno
231	TELECOGIDAD	telegocidad	telejoridad	telocegidad	telicugedad
232	PREMASERA	presamera	prexavera	premesara	premusira
233	CLIFORACERA	clifocarera	clifonasera	clifarocera	cliferucera
234	APICAZÓN	acipazón	anigazón	apacizón	apocezón
235	INMEDADA	indemada	inlerada	inmadeda	inmudoda
236	ZAVATERIA	zataveria	zalaneria	zavetaria	zavutoria
237	DEMAGUMO	degamumo	dejanumo	demugamo	demigomo
238	ESBARIGENTE	esbagirente	esbajivente	esbiragente	esburogente
239	DICERUSO	direcuso	dinexuso	dicureso	dicaroso
240	CONLEBITADO	conletibado	conledifado	conlibetado	conlobutado

Appendix I

Set of stimuli used in Experiment 7 with deaf adult readers of English. This list was presented in videos with fingerspelled words and pseudowords.

On the right side of the columns a (*) indicates that the target and its conditions were removed from the analyses, as they had less than 58% accuracy overall.

Practice (presented in videos of fingerspelling)

1 **DUES**
2 **KLUMP**
3 **SOWN**
4 **SLIN**
5 **SKI**
6 **FRIB**
7 **COPS**
8 **KLOG**

Set of stimuli used in Expeiment 7 (480 fingerspelled words and pseudowords)

No.	Word	Pseudohomophone	Orthographic control	Items excluded from the analyses (*).
1	**DUES**	dooze	deaps	
2	**TOWED**	tode	toye	
3	**BAYS**	beize	broak	(*)
4	**ROARS**	rauze	narts	
5	**SEAM**	ceme	relm	
6	**BREW**	brue	bree	
7	**CLAW**	kloar	plarc	
8	**WADE**	whayed	wreach	
9	**CONE**	koan	voon	
10	**FLAW**	phloar	gleare	
11	**FIN**	phin	slin	
12	**CRANE**	krain	drauv	
13	**FLU**	phlue	slaur	
14	**BLUR**	blirr	blorr	

15 **VAT**	vatt	vath	
16 **WEB**	whebb	wrell	
17 **SKI**	skee	skey	
18 **NUT**	knutt	thund	
19 **FADE**	phayed	dearch	
20 **COIN**	koign	noich	
21 **PORK**	porque	porthe	
22 **HORN**	hawn	hemn	
23 **FAME**	phame	thame	
24 **COARSE**	korce	roipe	
25 **LACE**	lais	larc	
26 **FAN**	phan	chan	
27 **FRY**	phrye	throy	
28 **NAIL**	gnale	koarl	
29 **RAID**	reighed	roigues	
30 **HAZE**	hays	haff	
31 **TOMB**	toom	toid	
32 **CHASE**	chaice	chauze	
33 **SAUCE**	sorce	sonce	(*)
34 **CORE**	korr	borz	
35 **FOLK**	phoak	thoik	
36 **GAZE**	heighs	nolled	
37 **JUICE**	jooce	jeece	
38 **FORD**	phawed	droith	
39 **HONEY**	hunni	henma	
40 **CHEQUE**	chec	chem	
41 **ROOT**	wrute	chert	
42 **FILE**	phyle	cheal	
43 **FEARED**	pheared	sleared	
44 **PHASE**	faze	yade	
45 **NURSE**	nerse	oinse	
46 **WISE**	whyes	wrees	
47 **FAIL**	phail	chail	
48 **TIED**	tighed	tirque	

49	**FLOW**	phlo	gloy	
50	**RAISE**	wraze	berne	
51	**CIRCLE**	sercle	norcle	(*)
52	**QUEEN**	kween	treen	
53	**NOISE**	gnoys	chons	(*)
54	**FARM**	pharm	gharm	
55	**BASE**	baice	barle	
56	**SKY**	skigh	skorr	
57	**SEAT**	cete	dest	
58	**PHONE**	foan	jorn	
59	**HORSE**	hauce	heale	
60	**FAT**	phat	wrat	
61	**PEACE**	peese	pethe	
62	**DRY**	drigh	drair	
63	**WEIGHT**	wate	weat	
64	**BALL**	borl	bewl	
65	**SHOWED**	shoad	shons	
66	**WALK**	whauk	wraik	
67	**WRITE**	rhight	moight	
68	**WALL**	whawl	wraig	
69	**RATE**	rait	nart	
70	**GOES**	ghoze	gnopp	(*)
71	**WAYS**	wheeze	wreets	
72	**FORCE**	phorse	thorde	
73	**FREE**	phrea	thref	
74	**CALL**	kawl	tarl	
75	**MONEY**	munni	menro	
76	**FACE**	phaice	plauce	
77	**USE**	yuice	douke	
78	**OLD**	oaled	oulch	
79	**WORK**	whirque	wribbed	
80	**WITH**	whyth	wruth	
81	**RIP**	ryp	rop	
82	**PUPPY**	puppi	puppa	

83	**CRAB**	krab	frab	
84	**CORK**	kork	nork	
85	**CREST**	krest	frest	
86	**CLING**	kling	pling	
87	**CLAN**	klan	tlan	
88	**CRUST**	krust	lrust	
89	**SHINE**	shyne	shune	
90	**COPS**	kops	yops	
91	**CLICK**	klick	tlick	
92	**CRUSH**	krush	hrush	
93	**KNOT**	gnot	jlot	
94	**DAME**	daim	darm	
95	**CORD**	kord	pord	(*)
96	**SHIELD**	sheeld	sheuld	
97	**CART**	kart	yart	
98	**CULT**	kult	yult	
99	**COUCH**	kouch	mouch	
100	**RIPE**	rype	rupe	
101	**CANS**	kans	zans	
102	**COINS**	koins	doins	
103	**CAPS**	kaps	waps	
104	**CRISP**	krisp	trisp	
105	**CLUE**	klue	plue	
106	**CAGE**	kage	lage	
107	**CREEK**	kreek	preek	
108	**NERVE**	nurve	narve	
109	**CRAFT**	kraft	praft	
110	**CLIFF**	kliff	sliff	
111	**CUPS**	kups	nups	
112	**CRASH**	krash	prash	
113	**CRUDE**	krude	drude	
114	**CLAY**	klay	blay	
115	**SKIRT**	skert	skart	
116	**CRACK**	krack	drack	

117 **CAKE**	kake	yake	
118 **CREW**	krew	frew	
119 **CLERK**	klerk	plerk	
120 **CROWN**	krown	wrown	
121 **CORN**	korn	norn	
122 **RUBBER**	rubbur	rubbir	
123 **CATS**	kats	yats	
124 **CROP**	krop	wrop	
125 **CHEESE**	cheeze	cheede	
126 **CUTS**	kuts	vuts	
127 **CLOUD**	kloud	floud	(*)
128 **CREAM**	kream	tream	
129 **CLOCK**	klock	slock	
130 **COAL**	koal	noal	
131 **CARD**	kard	zard	
132 **GAIN**	gane	garn	
133 **CAST**	kast	yast	
134 **CASH**	kash	xash	
135 **CHOOSE**	chooze	choone	
136 **CROSS**	kross	tross	
137 **LEADER**	leeder	leuder	
138 **CATCH**	katch	ratch	
139 **CAMP**	kamp	zamp	
140 **WON**	wun	wan	
141 **NOSE**	noze	nove	
142 **CARS**	kars	yars	
143 **CLUB**	klub	flub	
144 **GROW**	groe	groy	
145 **CHOICE**	choise	choife	(*)
146 **ARMY**	armi	armo	
147 **SUMMER**	summur	summor	
148 **COURT**	kourt	nourt	
149 **PAID**	pade	pard	
150 **WINDOW**	windoe	windou	

151	**COST**	kost	dost	
152	**CHURCH**	cherch	chorch	
153	**COLD**	kold	dold	(*)
154	**CLASS**	klass	tlass	
155	**LINE**	lyne	lene	
156	**KNOWN**	knoan	knoin	
157	**SET**	cet	fet	
158	**CASE**	kase	zase	
159	**SIDE**	cide	jide	
160	**YEAR**	yeer	yeor	

Appendix J

Set of stimuli used in Experiments 8 and 9, with adult and young deaf readers of Spanish. This list was presented in videos with fingerspelled words and pseudowords.

On the right side of the columns a (*) indicates that the target and its conditions were removed from the analyses, as they had less than 58% accuracy overall.

Practice (presented in videos of fingerspelling)

1	CAMARA
2	GENERAL
3	CALDO
4	BISTEC
5	VELLOTA
6	BENDER
7	DADENA
8	TEVIDA

Set of stimuli used in Expeiments 8 and 9 (480 fingerspelled words and pseudowords)

				Items excluded from the analyses (*).	
No.	Word	Pseudohomophone	Orthographic control	Experiment 2. Adults	Experiment 3. Young reaers
1	BURRO	vurro	nurro		
2	COMIDA	komida	tomida		
3	CAMPO	kampo	fampo		
4	BOCINA	vocina	nocina		
5	CANARIO	kanario	tanario		(*)
6	BATA	vata	sata		
7	VERDE	berde	ferde		
8	BABA	vaba	naba		(*)
9	BASURA	vasura	casura		
10	CAPA	kapa	fapa		
11	CABRA	kabra	tabra		
12	COCINA	kocina	locina		
13	CUEVA	kueva	tueva		
14	COCO	koco	hoco		
15	BUZO	vuzo	nuzo		
16	BICHO	vicho	richo		
17	CARIÑOS	kariños	tariños		
18	CINTA	zinta	rinta		
19	BALCÓN	valcón	nalcón		
20	CUERPO	kuerpo	buerpo		
21	CURA	kura	tura		

22	BALA	vala	nala		
23	CARETA	kareta	lareta		(*)
24	BOLLO	vollo	nollo	(*)	(*)
25	CARNE	karne	tarne		
26	CORRAL	korral	lorral		(*)
27	CAÑA	kaña	faña		
28	BOBO	vobo	cobo		(*)
29	COLA	kola	fola		
30	CURVA	kurva	lurva		(*)
31	CABALLO	kaballo	laballo		
32	BANDERA	vandera	candera		
33	VESTIDO	bestido	lestido		
34	CARTA	karta	larta		
35	BIBERÓN	viberón	ciberón		(*)
36	BONITO	vonito	ronito		
37	CIRCO	zirco	nirco		
38	CARBÓN	karbón	tarbón		
39	BAÑERA	vañera	rañera		
40	CASCO	kasco	fasco		
41	BARRA	varra	zarra		
42	CAMINO	kamino	famino		
43	COPA	kopa	lopa		
44	CONEJO	konejo	fonejo		
45	VELERO	belero	telero		(*)
46	GIRASOL	jirasol	pirasol		(*)
47	CERRADO	zerrado	nerrado		
48	JIRAFA	girafa	piraja		
49	BÚHO	vúho	rúho		(*)
50	CUCHARA	kuchara	tuchara	(*)	
51	CORONA	korona	torona		
52	JEFE	gefe	pefe		
53	CASILLA	kasilla	tasilla		
54	CARTERO	kartero	lartero		(*)
55	CAPITÁN	kapitán	lapitán		
56	CASETA	kaseta	taseta		
57	BIGOTE	vigote	rigote		
58	CUBO	kubo	lubo		
59	CALAMAR	kalamar	falamar		
60	CAZA	kaza	laza		
61	CAZUELA	kazuela	lazuela		
62	GENIO	jenio	yenio		
63	BOTÓN	votón	notón		
64	CABAÑA	kabaña	fabaña		
65	CEPILLO	zepillo	repillo		
66	VIENTO	biento	hiento		
67	CAPILLA	kapilla	lapilla		
68	BAÑO	vaño	zaño		
69	COCHE	koche	toche		

70	VISITA	bisita	tisita		
71	CIELO	zielo	vielo		
72	CEREZAS	zerezas	nerezas		
73	BARRIO	varrio	carrio		
74	VAGÓN	bagón	lagón	(*)	(*)
75	COFRE	kofre	tofre		
76	BAÚL	vaúl	naúl		(*)
77	CIRUELA	ziruela	niruela		
78	CARACOL	karacol	banacol		(*)
79	BORDE	vorde	norde		(*)
80	GIGANTE	jigante	pigante		
81	CAZO	kazo	fazo	(*)	(*)
82	COPIA	kopia	lopia		
83	CARTÓN	kartón	lartón		
84	CEBRA	zebra	rebra		(*)
85	BANDEJA	vandeja	nandeja		
86	BOTELLA	votella	rotella		
87	BARBA	varba	sarba		
88	CAMA	kama	tama		
89	VERANO	berano	herano		
90	BARRO	varro	rarro		
91	CAMISA	kamisa	lamisa		
92	CORAZÓN	korazón	lorazón		
93	VIOLÍN	biolín	liolín		
94	CORAL	koral	toral		
95	BOLSA	volsa	nolsa		
96	VIRGEN	birgen	lirgen		
97	BOCA	voca	noca		
98	BARCO	varco	rarco		
99	GENTE	jente	pente		
100	BALAZOS	valazos	nanazos		(*)
101	BUZÓN	vuzón	nuzón		
102	VIOLETA	bioleta	tioleta		
103	CENIZA	zeniza	reniza		(*)
104	CABLE	kable	lable		
105	CINE	zine	rine		
106	CALOR	kalor	falor		
107	CARTEL	kartel	lartel		
108	COMEDOR	komedor	tomedor		
109	CALLE	kalle	lalle		
110	BALÓN	valón	nalón		
111	CAMBIO	kambio	fambio		
112	BAILE	vaile	caile		
113	CUENTO	kuento	luento		
114	VOLANTE	bolante	tolante		
115	BOLSO	volso	colso	(*)	
116	VECINA	becina	lecina		
117	CAFÉ	kafé	tafé		

118	BOLA	vola	zola		
119	CORO	koro	horo		
120	BARRIL	varril	narril		
121	VIVO	bivo	livo		
122	BALLENA	vallena	nallena		
123	BATIDO	vatido	natido		(*)
124	BESO	veso	neso		
125	CEBOLLA	zebolla	rebolla		
126	VERDAD	berdad	ferdad		
127	COHETE	kohete	tohete		(*)
128	CENA	zena	rena		
129	CUNA	kuna	funa		
130	CERDO	zerdo	verdo		
131	COLEGIO	kolegio	folegio		
132	GENIAL	jenial	penial		
133	CAJÓN	kajón	lajón		
134	COLOR	kolor	folor		
135	GITANA	jitana	pijana		(*)
136	CABEZA	kabeza	tabeza		
137	CAZADOR	kazador	bazador		
138	VENTANA	bentana	hentana		
139	VIÑA	biña	fiña	(*)	(*)
140	VIAJE	biaje	tiaje		
141	BUFANDA	vufanda	nufanda		
142	BOXEO	voxeo	noxeo		
143	CARRERA	karrera	tarrera		
144	CAMELLO	kamello	lamello		
145	BOSQUE	vosque	nosque		
146	COSA	kosa	hosa		
147	VIEJO	biejo	tiejo		
148	COLETA	koleta	foleta		(*)
149	CARO	karo	laro		
150	BELLEZA	velleza	nelleza		
151	CAJA	kaja	taja		
152	CAMIÓN	kamión	tamión		
153	BARRIGA	varriga	narriga		
154	CASO	kaso	faso		
155	CASA	kasa	fasa		
156	VIDA	bida	tida		
157	CARRO	karro	larro		
158	BARCA	varca	narca		(*)
159	BANCO	vanco	sanco		
160	BEBÉ	vebé	mebé		

Appendix K

Set of stimuli used in experiment 10, with deaf adult of English.
TL = Transposed letter, RL = Replaced letter.
On the right columns of the stimuli used in the Experiment, a (*) indicates that the word and the TL, and RL conditions were removed the analyses, as they had less than 58% accuracy overall.

Practice (presented in videos of fingerspelling)

1 BASEBALL
2 FIREWORKS
3 FIREMAN
4 SOMETIMES
5 SOBEMODY
6 HOVENORK
7 STOPAVE
8 NOBETOOK

Set of stimuli used in Expeiments 10 (360 fingerspelled words and pseudowords)

				Items excluded from the analyses (*).
	Word	**TL**	**RL**	**Experiment 2. Adults**
1	ABOVE	avobe	anode	
2	ALIVE	avile	anife	
3	ANIMAL	aminal	asiral	
4	BANDAGE	bangade	banpabe	
5	BEFORE	berofe	benote	
6	BINOCULARS	biconulars	bisorulars	
7	BROKEN	bkoren	bhosen	
8	CAMERA	carema	casena	
9	CELERY	cerely	cesefy	
10	CIGARETTE	ciragette	cinapette	
11	CRIMINAL	crinimal	crisiwal	
12	DELIVER	deviler	dewifer	
13	DIFFERENT	diffenert	diffemect	

14 EMPTY	etpmy	efpny		
15 FAMILIES	falimies	fatinies		
16 FLEXIBLE	flebixle	flezijle		
17 FROWN	fworn	fmosn		
18 GLOBE	gbole	ghofe		
19 HOLIDAY	hodilay	hobyfay		
20 IMAGINE	imanige	imaripe		
21 KNIFE	kfine	ktime		
22 LOVELY	lolevy	lofewy		
23 MAGICAL	macigal	maripal		
24 MINUTE	mitune	mifuve	(*)	
25 NATURE	narute	nacufe		
26 PAVEMENT	pamevent	panewert	(*)	
27 PLANT	pnalt	pmaht		
28 POPULAR	polupar	potugar		
29 PROMISE	prosime	proniwe		
30 RELIGION	regilion	repifion		
31 SAFETY	satefy	saleky		
32 SEVENTH	senevth	serewth	(*)	
33 SKIRT	srikt	sniht		
34 SPAGHETTI	sgaphetti	sbazhetti		
35 STOLEN	sloten	skofen	(*)	
36 STRETCH	stterch	stfench		
37 TINKLE	tilkne	tifkme	(*)	
38 TOMORROW	toromrow	tonovrow		
39 UMBRELLA	umblerla	umbsetla		
40 VOLCANO	volnaco	volmaro		
41 ACTIVITY	acvitity	acwifity		
42 ALLIGATOR	allitagor	allifajor		
43 APOLOGISE	apolosige	apolojive		
44 BASEMENT	bamesent	banecent		
45 BEHAVE	bevahe	bewate		
46 BLANKET	bnalket	bmafket		

47 CABINET	canibet	caridet		
48 CANDLE	caldne	cafdme		
49 CHILD	clihd	cfind		
50 COCONUT	conocut	comorut		
51 CROCODILE	crodocile	crobosile	(*)	
52 DENTIST	densitt	dencift		
53 DINOSAUR	disonaur	dizomaur	(*)	
54 ENVELOPE	enlevope	enfewope		
55 FEMALE	felame	fetane		
56 FLOWER	fwoler	fvoter		
57 FURNITURE	furtinure	furlimure	(*)	
58 GLOVE	gvole	gnofe		
59 HOSPITAL	hostipal	hosfigal		
60 INVITATION	intivation	infiwation		
61 LEMONADE	lenomade	lerowade		
62 MACHINE	macnihe	macrike		
63 MAGICIAN	macigian	marijian		
64 MOVEMENT	momevent	mowerent		
65 PALACE	pacale	parafe		
66 PIRATE	pitare	piface	(*)	
67 POLICE	pocile	ponife		
68 PRESENT	pserent	pcenent		
69 PUMPKIN	pukpmin	puhpwin		
70 RETURN	rerutn	resufn	(*)	
71 SCARF	sracf	snasf		
72 SILENCE	sinelce	sirefce	(*)	
73 SMALL	slaml	sfanl		
74 SPINACH	snipach	srigach		
75 STOMACH	smotach	snofach		
76 TANGLE	talgne	tafgme		
77 TOGETHER	totegher	tofepher		
78 TONIGHT	toginht	topimht	(*)	
79 VEGETABLE	vetegable	vefepable		

80 WATERY	warety	wanefy	
81 AIRPORT	airropt	airnogt	
82 ANGRY	argny	acgmy	
83 AWAKE	akawe	ahave	
84 BEAUTIFUL	beaufitul	beaulidul	(*)
85 BEHIND	benihd	becind	
86 BRACELET	bralecet	brafenet	
87 CAFETERIA	cateferia	caleberia	
88 CAREFUL	caferul	catenul	
89 CHOCOLATE	cholocate	chofonate	(*)
90 COSTUME	cosmute	cosnufe	
91 DELICIOUS	decilious	denifious	(*)
92 DESERT	derest	denect	
93 DOLPHIN	dohplin	dokptin	
94 EVENING	eneving	emewing	(*)
95 FINISH	fisinh	firimh	
96 FOREST	fosert	fonect	
97 GARAGE	gagare	gajane	
98 HELICOPTER	helipocter	heligonter	
99 HUSBAND	husnabd	husmahd	(*)
100 KITCHEN	kihcten	kifclen	
101 LEOPARD	leorapd	leosagd	(*)
102 MAGAZINE	mazagine	maxavine	
103 MEDICINE	mecidine	mesibine	
104 MUSTARD	musratd	musnafd	
105 PARENT	panert	pamest	
106 PLANET	pnalet	prafet	
107 POLITE	potile	pofike	
108 PRIVATE	pritave	prifawe	
109 RELATIVE	retalive	refakive	
110 RIDING	rinidg	rimibg	
111 SECOND	senocd	semosd	(*)
112 SKELETON	sketelon	skefehon	

113	SMILE	slime	sfine	
114	STICK	scitk	snifk	
115	STORM	srotm	snofm	
116	TELEVISION	tevelision	tenefision	
117	TOMATO	totamo	tofano	
118	TRAMPOLINE	tramlopine	tramfogine	
119	VITAMIN	vimatin	viwalin	(*)
120	WHOLE	wlohe	wfobe	

Appendix L

Set of stimuli in Spanish for the LDT - Orthographic fingerspelled word processing Experiment (Exps. 11-12), used with deaf adult and young deaf readers of Spanish.

TL_C = Transposed letter Consonant, RL_C = Replaced letter Consonant.

Practice (presented in videos of fingerspelling)

No.	Target Word	TL_C prime	RL_C prime
1	SACAPUNTAS	sacanuptas	sacaructas
2	ESTUFA	esfuta	escuba
3	PROFESORA	prosefora	pronetora
4	ACONDICIONADOR	acondiciodanor	acondiciolavor
5	BICICLETA	bicictela	bicicfeba
6	ABRELATAS	abretalas	abrefabas
7	CARITELA	catirela	cafisela
8	FORISANTO	fosiranto	fonivanto
9	TACODINO	tadocino	talovino
10	NARCODOR	nardocor	narlosor
11	PETEBUZÓN	pebetuzón	pelefuzón
12	NERGAFO	nerfago	nertavo

Set of stimuli used in Expeiments 11 -12 (360 fingerspelled words and pseudowords)

No.	Target Word	TL_C prime	RL_C prime
1	INCUBADORA	incudabora	inculatora
2	INTELIGENTE	inletigente	indebigente
3	CADUCIDAD	cacudidad	canubidad
4	REMOLACHA	relomacha	retozacha
5	FORTALEZA	forlateza	forbadeza
6	SOLIDARIDAD	soliradidad	solinatidad
7	PERSONAJE	pernosaje	pervomaje
8	TARTAMUDO	tarmatudo	tarzaludo
9	DESAYUNO	deyasuno	degavuno
10	MACEDONIA	madeconia	mabezonia
11	ZANAHORIA	zahanoria	zafasoria
12	CONGELADO	conlegado	conbepado
13	DESPEDIDA	desdepida	deslegida
14	CONVOCATORIA	convotacoria	convolazoria
15	TOBOGANES	togobanes	topolanes
16	DECORADO	derocado	denozado
17	ORDENADORES	ordedanores	ordezatores
18	MARINERO	manirero	masivero
19	CAMISETA	casimeta	caniveta
20	LABORATORIO	labotarorio	labofanorio
21	COMUNICACIÓN	comucinación	comuviración
22	CONTAMINADO	contanimado	contavinado
23	ALBARICOQUE	albaciroque	albanivoque
24	AMANECER	anamecer	asavecer
25	RESUCITADO	resuticado	resufinado
26	ESCALERILLA	escarelilla	escanetilla

27	PRIMAVERA	privamera	prisarera
28	FLORECITA	flocerita	flovenita
29	FAVORECIDA	favocerida	favosenida
30	EVAPORADO	evaropado	evanogado
31	ALAMEDA	amaleda	anateda
32	FENOMENAL	femonemal	fecoremal
33	MALHUMORADO	malhuromado	malhusozado
34	COLADERAS	colaredas	colasebas
35	GENEROSIDAD	genesoridad	genevonidad
36	UNIDADES	udinades	utisades
37	TOSTADORA	tosdatora	toslafora
38	ABSOLUTO	ablosuto	abconuto
39	NATURALEZA	natulareza	natufaveza
40	PODEROSO	poredoso	pometoso
41	ESPINACAS	esnipacas	esvigacas
42	SEPARADORES	sepadarores	sepalanores
43	ITINERARIO	itirenario	itisevario
44	AMARILLO	aramillo	asavillo
45	COLORADO	corolado	covotado
46	HELADERÍA	hedalería	hetabería
47	FOGONAZO	fonogazo	fovojazo
48	COMISARÍA	cosimaría	covinaría
49	COLABORACIÓN	colarobación	colanofación
50	PREFERIDO	prerefido	presetido
51	ACANTILADO	acanlitado	acanbifado
52	MARAVILLA	mavarilla	mazasilla
53	LITERATURA	litetarura	litebanura
54	CACEROLA	carecola	casevola
55	FINALIZAR	filanizar	fitacizar
56	TULIPANES	tupilanes	tugifanes
57	ABOGADO	agobado	apotado
58	MALEDUCADA	malecudada	malevutada
59	COMPETIDORES	compeditores	compelibores
60	PREPARATIVO	prepatarivo	prepafasivo
61	GELATINA	getalina	gebafina
62	FEMENINO	fenemino	fesecino
63	CRISTALINA	crislatina	crisbafina
64	INVITACIÓN	intivación	indisación
65	MINIFALDA	mifinalda	mitiralda
66	ORGANIZADO	orgazinado	orgasirado
67	CALIFICATIVO	califitacivo	califibanivo
68	APARECIDO	apacerido	apanesido
69	ENAMORADO	enaromado	enasozado
70	TELEVISIÓN	tevelisión	teredisión
71	ASPIRADORAS	aspidaroras	aspilanodas
72	LABERINTO	larebinto	lanefinto
73	EXPOSICIÓN	exsopición	exnogición
74	ILUMINADO	ilunimado	ilucirado
75	VELOCIDAD	vecolidad	venotidad
76	PARALIZADOS	parazilados	paranifados
77	GOLOSINA	gosolina	gocofina
78	DELICADEZA	delidaceza	delibaneza
79	INVITADO	intivado	inlizado
80	PATINADORA	patidanora	patilasora
81	MUSCULATURA	muscutalura	muscufabura
82	ACELERACIÓN	acelecarión	acelenasión

83	DESTINATARIO	destitanario	destilazario
84	APETITO	atepito	alejito
85	ENEMIGO	emenigo	eserigo
86	ABEJORRO	ajeborro	agetorro
87	DIMINUTO	dinimuto	disivuto
88	CARAMELO	camarelo	cavaselo
89	LUMINOSO	lunimoso	lusiroso
90	SOLITARIO	sotilario	sobidario
91	AUTOCINEMAS	autonicemas	autorivemas
92	GASOLINERA	gasonilera	gasovitera
93	CAPACIDAD	cacapidad	canagidad
94	VETERINARIA	veteniraria	vetesizaria
95	DORMITORIO	dortimorio	dorlirorio
96	RINOCERONTE	rinoreconte	rinosezonte
97	ESCENARIO	esnecario	esrevario
98	CALABOZO	cabalozo	cafatozo
99	VITAMINAS	vimatinas	vicalinas
100	EMPERADORES	empedarores	empelanores
101	MANDARINA	manradina	manvatina
102	SEGURIDAD	serugidad	sezupidad
103	HABITACIÓN	hatibación	halifación
104	TITULADO	tilutado	tibufado
105	DESHABITADO	deshatibado	deshalifado
106	ALFABETO	albafeto	altaleto
107	REGADERA	redagera	relapera
108	TESORITO	terosito	tenovito
109	SAXOFONISTA	saxonofista	saxovotista
110	RELOJERO	rejolero	regofero
111	AZUCARERO	azuracero	azunavero
112	DEDICATORIA	deditacoria	dedilasoria
113	TEMPERATURA	tempetarura	tempebamura
114	GANADERO	gadanero	galavero
115	CAMARERO	caramero	cazanero
116	PASAJEROS	pasarejos	pasanegos
117	RECUPERADO	recurepado	recusegado
118	JABONERA	janobera	jacotera
119	ANIMALES	aminales	arivales
120	SALPICADO	salcipado	salnigado

References

Acha, J., & Perea, M. (2008). The effects of length and transposed-letter similarity in lexical decision: Evidence with beginning, intermediate, and adult readers. British Journal of Psychology, 99(2), 245–264. https://doi.org/10.1348/000712607X224478

Algeo, J., & Butcher, C. A. (2013). The origins and development of the English language. Cengage Learning.

Andrews, S. (1996). Lexical Retrieval and Selection Processes: Effects of Transposed-Letter Confusability. Journal of Memory and Language, 35(6), 775–800. https://doi.org/10.1006/jmla.1996.0040

Andrews, S., & Hersch, J. (2010). Lexical precision in skilled readers: Individual differences in masked neighbor priming. Journal of Experimental Psychology: General, 139(2), 299–318. https://doi.org/10.1037/a0018366

Andrews, S., & Lo, S. (2012). Not all skilled readers have cracked the code: Individual differences in masked form priming. Journal of Experimental Psychology: Learning, Memory, and Cognition, 38(1), 152–163. https://doi.org/10.1037/a0024953

Anthony, J. L., & Francis, D. J. (2005). Development of Phonological Awareness. Current Directions in Psychological Science, 14(5), 255–259. https://doi.org/10.1111/j.0963-7214.2005.00376.x

Antia, S. D., Lederberg, A. R., Easterbrooks, S., Schick, B., Branum-Martin, L., Connor, C. M., & Webb, M.-Y. (2020). Language and Reading Progress of Young Deaf and Hard-of-Hearing Children. The Journal of Deaf Studies and Deaf Education, 25(3), 334–350. https://doi.org/10.1093/deafed/enz050

Armstrong, D. F., & Wilcox, S. (2003). Origins of sign languages. The Oxford Handbook of Deaf Studies, Language and Education, 305-18.

Arnold, P., & Köpsel, A. (1996). Lipreading, reading and memory of hearing and hearing-impaired children. Scandinavian audiology, 25(1), 13-20.

Bélanger, N. N., Baum, S. R., & Mayberry, R. I. (2012). Reading Difficulties in Adult Deaf Readers of French: Phonological Codes, Not Guilty! Scientific Studies of Reading, 16(3), 263–285. https://doi.org/10.1080/10888438.2011.568555

Bélanger, N. N., Mayberry, R. I., & Rayner, K. (2013). Orthographic and Phonological Preview Benefits: Parafoveal Processing in Skilled and Less-Skilled Deaf Readers. Quarterly Journal of Experimental Psychology, 66(11), 2237–2252. https://doi.org/10.1080/17470218.2013.780085

Bélanger, N. N., & Rayner, K. (2015). What Eye Movements Reveal About Deaf Readers. Current Directions in Psychological Science, 24(3), 220–226. https://doi.org/10.1177/0963721414567527

Berent, I., & Perfetti, C. (1995). A Rose Is a REEZ: The Two-Cycles Model of Phonology Assembly in Reading English. Psychological Review - PSYCHOL REV, 102, 146–184. https://doi.org/10.1037/0033-295X.102.1.146

Brentari, D. (1998). A prosodic model of sign language phonology. Mit Press.

Breznitz, Z., & Share, D. L. (1992). Effects of accelerated reading rate on memory for text. Journal of Educational Psychology, 84(2), 193.

Brown, V. L., Hammill, D. D., & Wiederholt, J. L. (1978). Test of Reading Comprehension. Austin, TX: Pro-ED.

Brown, L., Sherbenou, R. J., & Johnsen, S. K. (1990). Test of Nonverbal Intelligence-Second Edition. Austin, TX: Pro-Ed.

Bishop, D. V. M., & Snowling, M. J. (2004). Developmental Dyslexia and Specific Language Impairment: Same or Different? Psychological Bulletin, 130(6), 858–886. https://doi.org/10.1037/0033-2909.130.6.858

Bodner, G. E., & Masson, M. E. J. (1997). Masked Repetition Priming of Words and Nonwords: Evidence for a Nonlexical Basis for Priming. Journal of Memory and Language, 37(2), 268–293. https://doi.org/10.1006/jmla.1996.2507

Borleffs, E., Maassen, B. A., Lyytinen, H., & Zwarts, F. (2017). Measuring orthographic transparency and morphological-syllabic complexity in alphabetic orthographies: a narrative review. Reading and writing, 30(8), 1617-1638.

Blythe, H. I., Dickins, J. H., Kennedy, C. R., & Liversedge, S. P. (2018). Phonological processing during silent reading in teenagers who are deaf/hard of hearing: An eye movement investigation. Developmental Science, 21(5), e12643. https://doi.org/10.1111/desc.12643

Broom, Y. M., & Doctor, E. A. (1995). Developmental phonological dyslexia: A case study of the efficacy of a remediation programme. Cognitive Neuropsychology, 12(7), 725–766. https://doi.org/10.1080/02643299508251400

Brysbaert, M. (2001). Prelexical phonological coding of visual words in Dutch: Automatic after all. Memory & Cognition, 29(5), 765–773. https://doi.org/10.3758/BF03200479

Campbell, R. (2011). Speechreading and the Bruce–Young model of face recognition: Early findings and recent developments. British Journal of Psychology, 102(4), 704-710.

Campbell, R., & Wright, H. (1988). Deafness, Spelling and Rhyme: How Spelling Supports Written Word and Picture Rhyming Skills in Deaf Subjects. The Quarterly Journal of Experimental Psychology Section A, 40(4), 771–788. https://doi.org/10.1080/14640748808402298

Caramazza, A., Chialant, D., Capasso, R., & Miceli, G. (2000). Separable processing of consonants and vowels. Nature, 403(6768), 428–430. https://doi.org/10.1038/35000206

Carreiras, M., Alvarez, C. J., & Devega, M. (1993). Syllable Frequency and Visual Word Recognition in Spanish. Journal of Memory and Language, 32(6), 766–780. https://doi.org/10.1006/jmla.1993.1038

Carreiras, M., Armstrong, B. C., Perea, M., & Frost, R. (2014). The what, when, where, and how of visual word recognition. Trends in Cognitive Sciences, 18(2), 90–98. https://doi.org/10.1016/j.tics.2013.11.005

Carreiras, M., Ferrand, L., Grainger, J., & Perea, M. (2005). Sequential Effects of Phonological Priming in Visual Word Recognition. Psychological Science, 16(8), 585–589. https://doi.org/10.1111/j.1467-9280.2005.01579.x

Carreiras, M., Perea, M., Vergara, M., & Pollatsek, A. (2009). The time course of orthography and phonology: ERP correlates of masked priming effects in Spanish. Psychophysiology, 46(5), 1113–1122. https://doi.org/10.1111/j.1469-8986.2009.00844.x

Carrillo, M. (1994). Development of phonological awareness and reading acquisition: A study in spanish language. Reading and Writing, 6(3), 279–298. https://doi.org/10.1007/BF01027086

Castles, A., & Coltheart, M. (1993). Varieties of developmental dyslexia. Cognition, 47(2), 149-180.

Castles, A., & Coltheart, M. (2004). Is there a causal link from phonological awareness to success in learning to read? Cognition, 91(1), 77–111. https://doi.org/10.1016/S0010-0277(03)00164-1

Castles, A. & Nation, K. (2006). How does orthographic learning happen? In S. Andrews (Ed.), From inkmarks to ideas: Challenges and controversies about word recognition and reading. London: Psychology Press.

Castles, A., & Nation, K. (2008). Learning to be a good orthographic reader. Journal of Research in Reading, 31(1), 1-7.

Castles, A., & Nation, K. (2010). How does orthographic learning happen?. In From inkmarks to ideas (pp. 181-209). Psychology Press.

Castles, A., Rastle, K., & Nation, K. (2018). Ending the Reading Wars: Reading Acquisition From Novice to Expert. Psychological Science in the Public Interest, 19(1), 5–51. https://doi.org/10.1177/1529100618772271

Castles Max Coltheart Greg Savage A, A. (1996). Morphological Processing and Visual Word Recognition Evidence from Acquired Dyslexia. Cognitive Neuropsychology, 13(7), 1041–1058. https://doi.org/10.1080/026432996381773

Cattell, J. M. (1886). The time it takes to see and name objects. Mind, 11(41), 63-65.

Chamberlain, C. (2002). Reading skills of deaf adults who sign: Good and poor readers compared.

Chamberlain, C., & Mayberry, R. I. (2000). Theorizing about the relation between American Sign Language and reading. Language acquisition by eye, 221-259.

Chamberlain, C., & Mayberry, R. I. (2008). American Sign Language syntactic and narrative comprehension in skilled and less skilled readers: Bilingual and bimodal evidence for the linguistic basis of reading. Applied Psycholinguistics, 29(3), 367–388. https://doi.org/10.1017/S014271640808017X

Chambers, S. M. (1979). Letter and order information in lexical access. Journal of Verbal Learning and Verbal Behavior, 18(2), 225-241

Charlier, B. L., & Leybaert, J. (2000). The Rhyming Skills of Deaf Children Educated with Phonetically Augmented Speechreading. 27.

Chen, H.-C., Yamauchi, T., Tamaoka, K., & Vaid, J. (2007). Homophonic and semantic priming of Japanese kanji words: A time course study. Psychonomic Bulletin & Review, 14(1), 64–69. https://doi.org/10.3758/BF03194029

Chetail, F., & Mathey, S. (2012). Effect of Syllable Congruency in Sixth Graders in the Lexical Decision Task With Masked Priming. Scientific Studies of Reading, 16(6), 537–549. https://doi.org/10.1080/10888438.2011.607480

Coltheart, M. (1996). Phonological dyslexia: Past and future issues. Cognitive Neuropsychology

Coltheart, M. (1998). SEVEN QUESTIONS ABOUT PURE ALEXIA (LETTER-BY-LETTER READING). Cognitive Neuropsychology, 15(1–2), 1–6. https://doi.org/10.1080/026432998381203

Coltheart, M. (2000). Deep Dyslexia Is Right-Hemisphere Reading. Brain and Language, 71(2), 299–309. https://doi.org/10.1006/brln.1999.2183

Coltheart, M., Langdon, R., & Haller, M. (1996). Computational neuropsychology and acquired dyslexia. Models of language: Illurnination from impairment. London: Whurr Publishers.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. Psychological Review, 108(1), 204–256. https://doi.org/10.1037/0033-295X.108.1.204

Comesaña, M., Soares, A. P., Marcet, A., & Perea, M. (2016). On the nature of consonant/vowel differences in letter position coding: Evidence from developing and adult readers. British Journal of Psychology, 107(4), 651–674. https://doi.org/10.1111/bjop.12179

Conrad, R. (1979). The deaf schoolchild: Language and cognitive function. London: Harper & Row

Conrad, N. J., Harris, N., & Williams, J. (2013). Individual differences in children's literacy development: The contribution of orthographic knowledge. Reading and Writing, 26(8), 1223–1239. https://doi.org/10.1007/s11145-012-9415-2

Cortese, M. J., & Balota, D. A. (2012). Visual Word Recognition in Skilled Adult Readers. In M. Spivey, K. McRae, & M. Joanisse (Eds.), The Cambridge Handbook of Psycholinguistics (1st ed., pp. 159–185). Cambridge University Press. https://doi.org/10.1017/CBO9781139029377.009

Costello, B., Caffarra, S., Fariña, N., Duñabeitia, J. A., & Carreiras, M. (2021). Reading without phonology: ERP evidence from skilled deaf readers of

Spanish. Scientific Reports, 11(1), 5202. https://doi.org/10.1038/s41598-021-84490-5

Cripps, J. H., McBride, K. A., & Forster, K. I. (2005). Lexical processing with deaf and hearing: Phonology and orthographic masked priming. Journal of Second Language Acquisition and Teaching, 12, 31-44.

Cuetos, F., Alvarez, B., González-Nosti, M., Méot, A., & Bonin, P. (2006). Determinants of lexical access in speech production: Role of word frequency and age of acquisition. Memory & Cognition, 34(5), 999–1010. https://doi.org/10.3758/BF03193247

Davis, C., Castles, A., & Iakovidis, E. (1998). Masked homophone and pseudohomophone priming in children and adults. Language and Cognitive Processes, 13(6), 625-651.

Davis, C. J., & Lupker, S. J. (2006). Masked inhibitory priming in English: Evidence for lexical inhibition. Journal of Experimental Psychology: Human Perception and Performance, 32(3), 668–687. https://doi.org/10.1037/0096-1523.32.3.668

DeFrancis, J. (1989). Visible speech: The diverse oneness of writing systems. University of Hawaii Press

Dehaene, S., & Cohen, L. (2007). Cultural Recycling of Cortical Maps. Neuron, 56(2), 384–398. https://doi.org/10.1016/j.neuron.2007.10.004

Deterding, D. (2004). How many vowel sounds are there in English. STETS Language & Communication Review, 19(10), 19-21

Dickinson, D. K., McCabe, A., Anastasopoulos, L., Peisner-Feinberg, E. S., & Poe, M. D. (2003). The comprehensive language approach to early literacy: The interrelationships among vocabulary, phonological sensitivity, and print knowledge among preschool-aged children. Journal of Educational Psychology, 95(3), 465–481. https://doi.org/10.1037/0022-0663.95.3.465

DiFrancesca, S. Academic achievement test results of a national testing program for hearing-impaired students: United States, Spring, 1971. Washington, D.C.: Gallaudet.

Doering, P. P. (2020). Can computational models of reading aloud account for how individuals who are d/Deaf and hard of hearing read? (Doctoral dissertation).

Domínguez, A. B., Pérez, I., & Alegría, J. (2012). La lectura en los alumnos sordos: aportación del implante coclear. Infancia y Aprendizaje, 35(3), 327-341.

Drieghe, D., & Brysbaert, M. (2002). Strategic effects in associative priming with words, homophones, and pseudohomophones. Journal of Experimental Psychology: Learning, Memory, and Cognition, 28(5), 951

Durgunoğlu, A. Y., & Öney, B. (1999). A cross-linguistic comparison of phonological awareness and word recognition. Reading and Writing, 11(4), 281-299.

Dye, M. W. G., Hauser, P. C., & Bavelier, D. (2008). Visual Skills and Cross-Modal Plasticity in Deaf Readers. Annals of the New York Academy of Sciences, 1145(1), 71–82. https://doi.org/10.1196/annals.1416.013

Dyer, A. (2003). Predictors of Reading Delay in Deaf Adolescents: The Relative Contributions of Rapid Automatized Naming Speed and Phonological Awareness and Decoding. Journal of Deaf Studies and Deaf Education, 8(3), 215–229. https://doi.org/10.1093/deafed/eng012

Ehri, L. (1999). Phases of development in learning to read words. In J. Oakhill & R. Beard (Eds.), Reading development and the teaching of reading: A psychological perspective (pp. 79–108). Oxford, UK: Blackwell.

Emmorey, K. (2020). The Neurobiology of Reading Differs for Deaf and Hearing Adults. In M. Marschark & H. Knoors (Eds.), The Oxford Handbook of Deaf Studies in Learning and Cognition (pp. 346–359). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190054045.013.25

Emmorey, K. (2001). Language, cognition, and the brain: Insights from sign language research. Psychology Press.

Emmorey, K., & Petrich, J. A. F. (2012). Processing Orthographic Structure: Associations Between Print and Fingerspelling. Journal of Deaf Studies and Deaf Education, 17(2), 194–204. https://doi.org/10.1093/deafed/enr051

Emmorey, K., Weisberg, J., McCullough, S., & Petrich, J. A. F. (2013). Mapping the reading circuitry for skilled deaf readers: An fMRI study of semantic and phonological processing. Brain and Language, 126(2), 169–180. https://doi.org/10.1016/j.bandl.2013.05.001

Fariña, N., Duñabeitia, J. A., & Carreiras, M. (2017). Phonological and orthographic coding in deaf skilled readers. Cognition, 168, 27–33. https://doi.org/10.1016/j.cognition.2017.06.015

Ferrand, L., Brysbaert, M., Keuleers, E., New, B., Bonin, P., Méot, A., ... & Pallier, C. (2011). Comparing word processing times in naming, lexical decision, and progressive demasking: Evidence from Chronolex. Frontiers in psychology, 2, 306

Ferrand, L., & Grainger, J. (1992). Phonology and Orthography in Visual Word Recognition: Evidence from Masked Non-Word Priming. The Quarterly Journal of Experimental Psychology Section A, 45(3), 353–372. https://doi.org/10.1080/02724989208250619

Ferrand, L., & Grainger, J. (1993). The time course of orthographic and phonological code activation in the early phases of visual word recognition. Bulletin of the Psychonomic Society, 31(2), 119–122. https://doi.org/10.3758/BF03334157

Ferrand, L., & Grainger, J. (1994). Effects of Orthography are Independent of Phonology in Masked form Priming. The Quarterly Journal of Experimental Psychology Section A, 47(2), 365–382. https://doi.org/10.1080/14640749408401116

Fiez, J. A., Balota, D. A., Raichle, M. E., & Petersen, S. E. (1999). Effects of Lexicality, Frequency, and Spelling-to-Sound Consistency on the Functional Anatomy of Reading. Neuron, 24(1), 205–218. https://doi.org/10.1016/S0896-6273(00)80833-8

Fleisher, L. S., Jenkins, J. R., & Pany, D. (1979). Effects on Poor Readers' Comprehension of Training in Rapid Decoding. Reading Research Quarterly, 15(1), 30–48. https://doi.org/10.2307/747430

Forbach, G. B., Stanners, R. F., & Hochhaus, L. (1974). Repetition and practice effects in a lexical decision task. Memory & Cognition, 2(2), 337–339. https://doi.org/10.3758/BF03209005

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. Journal of Experimental Psychology: Learning, Memory, and Cognition, 10(4), 680–698. https://doi.org/10.1037/0278-7393.10.4.680

Forster, K. I., Davis, C., Schoknecht, C., & Carter, R. (1987). Masked priming with graphemically related forms: Repetition or partial activation?. The Quarterly Journal of Experimental Psychology, 39(2), 211-251.

Forster, K., & Yoshimura, K. (1994). Phonological processes in visual word recognition: Masked priming experiments in Japanese and Chinese. In Asian-Australian Workshop on Cognitive Processing of Asian Languages, Sydney.

Frith, I. C. (1972). Components of reading disability. University of NSW.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. Patterson, M. Coltheart and J. Marshall (Eds.) Surface Dyslexia. London: Erlbaum.

Frith, U. (1986). A developmental framework for developmental dyslexia. Annals of Dyslexia, 36, 69–81.

Frost, R. (1994). Prelexical and postlexical strategies in reading: evidence from a deep and a shallow orthography. Journal of Experimental Psychology: Learning, Memory, and Cognition, 20(1), 116

Frost, R. (1998). Toward a Strong Phonological Theory of Visual Word Recognition: True Issues and False Trails. 29.

Frost, R., Ahissar, M., Gotesman, R., & Tayeb, S. (2003). Are phonological effects fragile? The effect of luminance and exposure duration on form priming and phonological priming. Journal of Memory and Language, 48(2), 346–378. https://doi.org/10.1016/S0749-596X(02)00510-7

Frost, R., & Katz, L. (Eds.). (1992). Orthography, phonology, morphology and meaning. Elsevier.

Gardner, D. (2013). Exploring vocabulary: Language in action. Routledge.

Glezer, L. S., Jiang, X., Luetje, M. M., Napoliello, E. M., Kim, J., Riesenhuber, M., & Eden, G. F. (2019). An fMRI-adaptation study of phonological and orthographic selectivity to written words in adults with poor reading skills. Brain and Language, 191, 1–8. https://doi.org/10.1016/j.bandl.2019.01.002

Goldin-Meadow, S., & Mylander, C. (1998). Spontaneous sign systems created by deaf children in two cultures. Nature, 391(6664), 279–281. https://doi.org/10.1038/34646

Gomez, P., Ratcliff, R., & Perea, M. (2008). The overlap model: a model of letter position coding. Psychological review, 115(3), 577

Goswami, U. (2002). Phonology, reading development, and dyslexia: A cross-linguistic perspective. Annals of Dyslexia, 52(1), 139–163. https://doi.org/10.1007/s11881-002-0010-0

Goswami, U. B., & Bryant, P. P. 1990, Phonological skills and learning to read.

Goswami, U., Ziegler, J. C., Dalton, L., & Schneider, W. (2001). Pseudohomophone Effects and Phonological Recoding Procedures in Reading Development in English and German. Journal of Memory and Language, 45(4), 648–664. https://doi.org/10.1006/jmla.2001.2790

Gough, P. B., & Tunmer, W. E. (1986). Decoding, Reading, and Reading Disability. Remedial and Special Education, 7(1), 6–10. https://doi.org/10.1177/074193258600700104

Grainger, J., Diependaele, K., Spinelli, E., Ferrand, L., & Farioli, F. (2003). Masked Repetition and Phonological Priming Within and Across Modalities. Journal of Experimental Psychology: Learning, Memory, and Cognition, 29(6), 1256–1269. https://doi.org/10.1037/0278-7393.29.6.1256

Grainger, J., & Ferrand, L. (1996). Masked orthographic and phonological priming in visual word recognition and naming: Cross-task comparisons. Journal of memory and language, 35(5), 623-647.

Grainger, J., & Holcomb, P. J. (2009). Watching the Word Go by: On the Time-course of Component Processes in Visual Word Recognition: Time-course of Word Recognition. Language and Linguistics Compass, 3(1), 128–156. https://doi.org/10.1111/j.1749-818X.2008.00121.x

Grainger, J., Kiyonaga, K., & Holcomb, P. J. (2006). The Time Course of Orthographic and Phonological Code Activation. Psychological Science, 17(12), 1021–1026. https://doi.org/10.1111/j.1467-9280.2006.01821.x

Grainger, J., & Ziegler, J. C. (2011). A Dual-Route Approach to Orthographic Processing. Frontiers in Psychology, 2. https://doi.org/10.3389/fpsyg.2011.00054

Gutierrez-Sigut, E., Vergara-Martínez, M., & Marcet, A. (2018a). Automatic use of phonological codes during word recognition in deaf signers of Spanish Sign Language. FEAST. Formal and Experimental Advances in Sign Language Theory, 1, 1–15. https://doi.org/10.2436/20.8050.03.1

Gutierrez-Sigut, E., Vergara-Martínez, M., & Marcet, A. (2018b). Automatic use of phonological codes during word recognition in deaf signers of Spanish Sign Language. FEAST. Formal and Experimental Advances in Sign Language Theory, 1, 1–15. https://doi.org/10.2436/20.8050.03.1

Gutierrez-Sigut, E., Vergara-Martínez, M., & Perea, M. (2017). Early use of phonological codes in deaf readers: An ERP study. Neuropsychologia, 106, 261–279. https://doi.org/10.1016/j.neuropsychologia.2017.10.006

Gutierrez-Sigut, E., Vergara-Martínez, M., & Perea, M. (2019). Deaf readers benefit from lexical feedback during orthographic processing. Scientific Reports, 9(1), 12321. https://doi.org/10.1038/s41598-019-48702-3

Hammill, D., Larsen, S., Wiederholt, J., & Fountain-Chambers, J. (1982). PLLE: Prueba de Lectura y Lenguaje Escrito.

Hanson, V. L. (1989). Phonology and reading: Evidence from profoundly deaf readers. In Meeting of the International Academy for Research on Learning Disabilities, Oct, 1986, Northwestern U, Evanston, IL, US. The University of Michigan Press.

Hanson, V. L., & Fowler, C. A. (1987). Phonological coding in word reading: Evidence from hearing and deaf readers. Memory & Cognition, 15(3), 199–207. https://doi.org/10.3758/BF03197717

Hanson, V. L., Goodell, E. W., & Perfetti, C. A. (1991). Tongue-twister effects in the silent reading of hearing and deaf college students. Journal of memory and language, 30(3), 319-330.

Hanson, V. L., & McGarr, N. S. (1989). Rhyme Generation by Deaf Adults. Journal of Speech, Language, and Hearing Research, 32(1), 2–11. https://doi.org/10.1044/jshr.3201.02

Hanson, V. L., Shankweiler, D., & Fischer, F. W. (1983). Determinants of spelling ability in deaf and hearing adults: Access to linguistic structure. Cognition, 14(3), 323-344.

Haptonstall-Nykaza, T. S., & Schick, B. (2007a). The Transition From Fingerspelling to English Print: Facilitating English Decoding. Journal of Deaf Studies and Deaf Education, 12(2), 172–183.

Haptonstall-Nykaza, T. S., & Schick, B. (2007b). The Transition From Fingerspelling to English Print: Facilitating English Decoding. Journal of Deaf Studies and Deaf Education, 12(2), 172–183.

Harm, M. W., & Seidenberg, M. S. (1999). Phonology, reading acquisition, and dyslexia: Insights from connectionist models. Psychological Review, 106(3), 491–528. https://doi.org/10.1037/0033-295X.106.3.491

Harm, M. W., & Seidenberg, M. S. (2004). Computing the Meanings of Words in Reading: Cooperative Division of Labor Between Visual and Phonological Processes. Psychological Review, 111(3), 662–720. https://doi.org/10.1037/0033-295X.111.3.662

Hedderly, R. (1996). Vernon-warden reading test, restandardised 1993 and 1994. Dyslexia Review, 7(2).

Hermans, D., Ormel, E., & Knoors, H. (2010). On the relation between the signing and reading skills of deaf bilinguals. International Journal of Bilingual Education and Bilingualism, 13(2), 187–199. https://doi.org/10.1080/13670050903474093

Hirshorn, E. A., Dye, M. W. G., Hauser, P., Supalla, T. R., & Bavelier, D. (2015). The contribution of phonological knowledge, memory, and language background to reading comprehension in deaf populations. Frontiers in Psychology, 6. https://doi.org/10.3389/fpsyg.2015.01153

Hirsh-Pasek, K. (1987). The Metalinguistics of Fingerspelling: An Alternate Way to Increase Reading Vocabulary in Congenitally Deaf Readers. Reading Research Quarterly, 22(4), 455. https://doi.org/10.2307/747702

Holcomb, P. J., & Grainger, J. (2006). On the Time Course of Visual Word Recognition: An Event-related Potential Investigation using Masked Repetition Priming. Journal of Cognitive Neuroscience, 18(10), 1631–1643. https://doi.org/10.1162/jocn.2006.18.10.1631

Holyk, G. G., & Pexman, P. M. (2004). The elusive nature of early phonological priming effects: Are there individual differences? Brain and Language, 90(1–3), 353–367. https://doi.org/10.1016/S0093-934X(03)00447-4

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. Reading and writing, 2(2), 127-160.

Houghton, G., & Zorzi, M. (2003). NORMAL AND IMPAIRED SPELLING IN A CONNECTIONIST DUAL-ROUTE ARCHITECTURE. Cognitive Neuropsychology, 20(2), 115–162. https://doi.org/10.1080/02643290242000871

Humphreys, G. W., Besner, D., & Quinlan, P. T. (1988). Event perception and the word repetition effect. Journal of Experimental Psychology: General, 117(1), 51.

Humphreys, G. W., Evett, L. J., & Taylor, D. E. (1982). Automatic phonological priming in visual word recognition. Memory & Cognition, 10(6), 576–590. https://doi.org/10.3758/BF03202440

Humphries, T., Kushalnagar, P., Mathur, G., Napoli, D. J., Padden, C., & Rathmann, C. (2014). Ensuring language acquisition for deaf children: What linguists can do. Language, 90(2), e31–e52. https://doi.org/10.1353/lan.2014.0036

Huurre, T., Aro, H., Rahkonen, O., & Komulainen, E. (2006). Health, lifestyle, family and school factors in adolescence: Predicting adult educational level. Educational Research, 48(1), 41–53. https://doi.org/10.1080/00131880500498438

Jackson, N. E., & Coltheart, M. (2013). Routes to reading success and failure: Toward an integrated cognitive psychology of atypical reading. Psychology Press.

Keane, J., & Brentari, D. (2016). Fingerspelling: Beyond handshape sequences. The Oxford handbook of deaf studies in language, 146-160.

Kargin, T., Guldenoglu, B., Miller, P., Hauser, P., Rathman, C., Kubus, O., & Spurgeon, E. (2012). Differences in Word Processing Skills of Deaf and Hearing Individuals Reading in Different Orthographies. Journal of Developmental and Physical Disabilities, 24(1), 65–83. https://doi.org/10.1007/s10882-011-9255-z

Kelly, L. P. (2003). Considerations for designing practice for deaf readers. Journal of deaf studies and deaf education, 8(2), 171-186

Kinoshita, S., & Lupker, S. J. (2004). Masked priming: The state of the art. Psychology Press

Kohnen, S., & Castles, A. (2013). Pirates at parties: Letter position processing in developing readers. Journal of Experimental Child Psychology, 115(1), 91–107. https://doi.org/10.1016/j.jecp.2012.08.011

Krouse, H. E., & Braden, J. P. (2011). The reliability and validity of WISC-IV scores with deaf and hard-of-hearing children. Journal of Psychoeducational Assessment, 29(3), 238-248.

Ktori, M., Grainger, J., Dufau, S., & Holcomb, P. J. (2012). The “electrophysiological sandwich”: A method for amplifying ERP priming effects: Electrophysiological sandwich priming. Psychophysiology, n/a-n/a. https://doi.org/10.1111/j.1469-8986.2012.01387.x

Ktori, M., Kingma, B., Hannagan, T., Holcomb, P. J., & Grainger, J. (2014). On the time-course of adjacent and non-adjacent transposed-letter priming. Journal of Cognitive Psychology, 26(5), 491–505. https://doi.org/10.1080/20445911.2014.922092.

Kuntze, M. (1998). Literacy and deaf children: The language question. Topics in language disorders, 18, 1-15.

Kyle, F. E. (2006). Concurrent Correlates and Predictors of Reading and Spelling Achievement in Deaf and Hearing School Children. Journal of Deaf Studies and Deaf Education, 11(3), 273–288. https://doi.org/10.1093/deafed/enj037

Kyle, F. E. (2015). Research Methods in Studying Reading and Literacy Development in Deaf Children Who Sign. In E. Orfanidou, B. Woll, & G. Morgan (Eds.), Research Methods in Sign Language Studies (1st ed., pp. 300–318). Wiley. https://doi.org/10.1002/9781118346013.ch16

Kyle, F. E., Campbell, R., & MacSweeney, M. (2016). The relative contributions of speechreading and vocabulary to deaf and hearing children’s reading ability. Research in Developmental Disabilities, 48, 13–24. https://doi.org/10.1016/j.ridd.2015.10.004

Kyle, F. E., Campbell, R., Mohammed, T., Coleman, M., & MacSweeney, M. (2013). Speechreading Development in Deaf and Hearing Children: Introducing the

Test of Child Speechreading. Journal of Speech, Language, and Hearing Research, 56(2), 416–426. https://doi.org/10.1044/1092-4388(2012/12-0039)

Kyle, F. E., & Harris, M. (2006). Concurrent correlates and predictors of reading and spelling achievement in deaf and hearing school children. The Journal of Deaf Studies and Deaf Education, 11(3), 273-288.

Kyle, F. E., & Harris, M. (2010). Predictors of reading development in deaf children: A 3-year longitudinal study. Journal of Experimental Child Psychology, 107(3), 229–243. https://doi.org/10.1016/j.jecp.2010.04.011

Kyle, F. E., & Harris, M. (2011). Longitudinal Patterns of Emerging Literacy in Beginning Deaf and Hearing Readers. Journal of Deaf Studies and Deaf Education, 16(3), 289–304. https://doi.org/10.1093/deafed/enq069

Lederberg, A. R., Branum-Martin, L., Webb, M., Schick, B., Antia, S., Easterbrooks, S. R., & Connor, C. M. (2019). Modality and Interrelations Among Language, Reading, Spoken Phonological Awareness, and Fingerspelling. The Journal of Deaf Studies and Deaf Education, 24(4), 408–423. https://doi.org/10.1093/deafed/enz011

Lederberg, A. R., Schick, B., & Spencer, P. E. (2013). Language and literacy development of deaf and hard-of-hearing children: Successes and challenges. Developmental Psychology, 49(1), 15–30. https://doi.org/10.1037/a0029558

Lee, J. (2011). Size matters: Early vocabulary as a predictor of language and literacy competence. Applied Psycholinguistics, 32(1), 69–92. https://doi.org/10.1017/S0142716410000299

Lervåg, A., Hulme, C., & Melby-Lervåg, M. (2018). Unpicking the developmental relationship between oral language skills and reading comprehension: It's simple, but complex. *Child development*, *89*(5), 1821-1838.

Liberman, I. Y., Shankweiler, D., Fischer, F. W., & Carter, B. (1974). Explicit syllable and phoneme segmentation in the young child. Journal of Experimental Child Psychology, 18(2), 201–212. https://doi.org/10.1016/0022-0965(74)90101-5

Liu, Y., Georgiou, G. K., Zhang, Y., Li, H., Liu, H., Song, S., Kang, C., Shi, B., Liang, W., Pan, J., & Shu, H. (2017). Contribution of cognitive and linguistic skills to word-reading accuracy and fluency in Chinese. International Journal of Educational Research, 82, 75–90. https://doi.org/10.1016/j.ijer.2016.12.005

Lukatela, G., Frost, S. J., & Turvey, M. T. (1998). Phonological Priming by Masked Nonword Primes in the Lexical Decision Task. Journal of Memory and Language, 39(4), 666–683. https://doi.org/10.1006/jmla.1998.2599

Lukatela, G., & Turvey, M. T. (1994). Visual lexical access is initially phonological: I. Evidence from associative priming by words, homophones, and pseudohomophones. Journal of Experimental Psychology: General, 123(2), 107.

Lupker, S. J., & Davis, C. J. (2009). Sandwich priming: A method for overcoming the limitations of masked priming by reducing lexical competitor effects. Journal of Experimental Psychology: Learning, Memory, and Cognition, 35(3), 618–639. https://doi.org/10.1037/a0015278

Lupker, S. J., Perea, M., & Davis, C. J. (2008). Transposed-letter effects: Consonants, vowels and letter frequency. Language and Cognitive Processes, 23(1), 93–116. https://doi.org/10.1080/01690960701579714

Mackinson, J. A., Leigh, I. W., Blennerhassett, L., & Anthony, S. (1997). Validity of the TONI-2 with Deaf and Hard of Hearing Children. American Annals of the Deaf, 142(4), 294–299. https://doi.org/10.1353/aad.2012.0240

MacSweeney, M., Capek, C. M., Campbell, R., & Woll, B. (2008). The signing brain: The neurobiology of sign language. Trends in Cognitive Sciences, 12(11), 432–440. https://doi.org/10.1016/j.tics.2008.07.010

MacSweeney, M., Goswami, U., & Neville, H. (2013). The Neurobiology of Rhyme Judgment by Deaf and Hearing Adults: An ERP Study. Journal of Cognitive Neuroscience, 25(7), 1037–1048. https://doi.org/10.1162/jocn_a_00373

MacSweeney, M., Waters, D., Brammer, M. J., Woll, B., & Goswami, U. (2008). Phonological processing in deaf signers and the impact of age of first language acquisition. 11.

Marín, J., Carrillo, M. S., Cuadro, A., Costa, D., Trias, D., & Ponce de León, P. (1997). Evaluación del nivel lector. Manual técnico del test de Eficacia Lectora (TECLE).

Mayberry, R. I., del Giudice, A. A., & Lieberman, A. M. (2011). Reading Achievement in Relation to Phonological Coding and Awareness in Deaf Readers: A Meta-analysis. Journal of Deaf Studies and Deaf Education, 16(2), 164–188. https://doi.org/10.1093/deafed/enq049

Mayberry, R. I., & Eichen, E. B. (1991). The long-lasting advantage of learning sign language in childhood: Another look at the critical period for language acquisition. Journal of Memory and Language, 30(4), 486–512. https://doi.org/10.1016/0749-596X(91)90018-F

McArthur, G., & Castles, A. (2017). Helping children with reading difficulties: Some things we have learned so far. Npj Science of Learning, 2(1), 7. https://doi.org/10.1038/s41539-017-0008-3

McCandliss, B., Beck, I. L., Sandak, R., & Perfetti, C. (2003). Focusing Attention on Decoding for Children With Poor Reading Skills: Design and Preliminary Tests of the Word Building Intervention. Scientific Studies of Reading, 7(1), 75–104. https://doi.org/10.1207/S1532799XSSR0701_05

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. Psychological review, 88(5), 375

McGurk, H., & MacDonald, J. (1976). Hearing lips and seeing voices. Nature, 264(5588), 746-748.

McKee, M. M., Paasche-Orlow, M. K., Winters, P. C., Fiscella, K., Zazove, P., Sen, A., & Pearson, T. (2015). Assessing Health Literacy in Deaf American Sign Language Users. Journal of Health Communication, 20(sup2), 92–100. https://doi.org/10.1080/10810730.2015.1066468

Meade, G., Grainger, J., Midgley, K. J., Holcomb, P. J., & Emmorey, K. (2019). ERP Effects of masked orthographic neighbour priming in deaf readers. Language, Cognition and Neuroscience, 34(8), 1016–1026. https://doi.org/10.1080/23273798.2019.1614201

Meade, G., Grainger, J., Midgley, K. J., Holcomb, P. J., & Emmorey, K. (2020a). An ERP investigation of orthographic precision in deaf and hearing readers. 9.

Meade, G., Grainger, J., Midgley, K. J., Holcomb, P. J., & Emmorey, K. (2020b). An ERP investigation of orthographic precision in deaf and hearing readers. Neuropsychologia, 146, 107542. https://doi.org/10.1016/j.neuropsychologia.2020.107542

Meier, R. P., & Newport, E. L. (1990). Out of the hands of babes: On a possible sign advantage in language acquisition. Language, 1-23

Melby-Lervåg, M., Lyster, S.-A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. Psychological Bulletin, 138(2), 322–352. https://doi.org/10.1037/a0026744

Merrills, J. D., Underwood, G., & Wood, D. J. (1994). The word recognition skills of profoundly, prelingually deaf children. British Journal of Developmental Psychology, 12(3), 365–384. https://doi.org/10.1111/j.2044-835X.1994.tb00640.x

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. Journal of Experimental Psychology, 90(2), 227–234. https://doi.org/10.1037/h0031564

Milledge, S. V., & Blythe, H. I. (2019). The Changing Role of Phonology in Reading Development. Vision, 3(2), 23. https://doi.org/10.3390/vision3020023

Miller, P., Banado-Aviran, E., & Hetzroni, O. E. (2021). Developing Reading Skills in Prelingually Deaf Preschool Children: Fingerspelling as a Strategy to Promote Orthographic Learning. The Journal of Deaf Studies and Deaf Education, 26(3), 363–380. https://doi.org/10.1093/deafed/enab004

Miller, P., & Clark, M. D. (2011). Phonemic Awareness is Not Necessary to Become a Skilled Deaf Reader. Journal of Developmental and Physical Disabilities, 23(5), 459–476. https://doi.org/10.1007/s10882-011-9246-0

Miller, R. T. (2019). English Orthography and Reading. In J. I. Liontas, T. International Association, & M. DelliCarpini (Eds.), The TESOL Encyclopedia of English Language Teaching (pp. 1–7). John Wiley & Sons, Inc. https://doi.org/10.1002/9781118784235.eelt0461

Mitchell, R. E., & Karchmer, M. A. (2004). Chasing the Mythical Ten Percent: Parental Hearing Status of Deaf and Hard of Hearing Students in the United States. Sign Language Studies, 4(2), 138–163. https://doi.org/10.1353/sls.2004.0005

Mohammed, T., Campbell, R., MacSweeney, M., Milne, E., Hansen, P., & Coleman, M. (2005). Speechreading Skill and Visual Movement Sensitivity are Related in Deaf Speechreaders. Perception, 34(2), 205–216. https://doi.org/10.1068/p5211

Moreno-Pérez, F. J., Saldaña, D., & Rodríguez-Ortiz, I. R. (2015). Reading Efficiency of Deaf and Hearing People in Spanish. Journal of Deaf Studies and Deaf Education, 20(4), 374–384. https://doi.org/10.1093/deafed/env030

Morgan, G., & Woll, B. (2002). Directions in sign language acquisition. J. Benjamins.

Musselman, C. (2000). How Do Children Who Can't Hear Learn to Read an Alphabetic Script? A Review of the Literature on Reading and Deafness. Journal of Deaf Studies and Deaf Education, 5(1), 9–31. https://doi.org/10.1093/deafed/5.1.9

Muter, V., Hulme, C., Snowling, M. J., & Stevenson, J. (2004). Phonemes, Rimes, Vocabulary, and Grammatical Skills as Foundations of Early Reading Development: Evidence From a Longitudinal Study. Developmental Psychology, 40(5), 665–681. https://doi.org/10.1037/0012-1649.40.5.665

Nation, K. (2009). Form–meaning links in the development of visual word recognition. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1536), 3665–3674. https://doi.org/10.1098/rstb.2009.0119

Nation, K., & Norbury, C. F. (2005). Why Reading Comprehension Fails: Insights From Developmental Disorders. Topics in Language Disorders, 25(1), 21–32. https://doi.org/10.1097/00011363-200501000-00004

Nation, K., & Snowling, M. J. (1998a). Semantic Processing and the Development of Word-Recognition Skills: Evidence from Children with Reading Comprehension Difficulties. Journal of Memory and Language, 39(1), 85–101. https://doi.org/10.1006/jmla.1998.2564

Nation, K., & Snowling, M. J. (1998b). Semantic Processing and the Development of Word-Recognition Skills: Evidence from Children with Reading Comprehension Difficulties. Journal of Memory and Language, 39(1), 85–101. https://doi.org/10.1006/jmla.1998.2564

Nation, K., & Snowling, M. J. (2004). Beyond phonological skills: Broader language skills contribute to the development of reading. Journal of Research in Reading, 27(4), 342–356. https://doi.org/10.1111/j.1467-9817.2004.00238.x

Newport, E. L., & Meier, R. P. (1986). The acquisition of American sign language. Erlbaum.

Nickels, L., Biedermann, B., Coltheart, M., Saunders, S., & Tree, J. J. (2008). Computational modelling of phonological dyslexia: How does the DRC model fare? Cognitive Neuropsychology, 25(2), 165–193. https://doi.org/10.1080/02643290701514479

O'Connor, R. E., & Forster, K. I. (1981). Criterion bias and search sequence bias in word recognition. Memory & Cognition, 9(1), 78-92.

Ormel, E., Giezen, M. R., Knoors, H., Verhoeven, L., & Gutierrez-Sigut, E. (2022). Predictors of Word and Text Reading Fluency of Deaf Children in Bilingual Deaf Education Programmes. Languages, 7(1), 51. https://doi.org/10.3390/languages7010051

Ouellette, G. P. (2006). What's meaning got to do with it: The role of vocabulary in word reading and reading comprehension. Journal of Educational Psychology, 98(3), 554–566. https://doi.org/10.1037/0022-0663.98.3.554

Paap, K. R., McDonald, J. E., Schvaneveldt, R. W., & Noel, R. W. (1987). Frequency and pronounceability in visually presented naming and lexical decision tasks.

Paap, K. R., Newsome, S. L., McDonald, J. E., & Schvaneveldt, R. W. (1982). An activation–verification model for letter and word recognition: The word-superiority effect. Psychological Review, 89(5), 573–594. https://doi.org/10.1037/0033-295X.89.5.573

Paap, K. R., & Noel, R. W. (1991). Dual-route models of print to sound: Still a good horse race. Psychological Research, 53(1), 13–24. https://doi.org/10.1007/BF00867328

Padden, C. (2006). Learning to fingerspell twice: Young signing children's acquisition of fingerspelling. Advances in the sign language development of deaf children, 189-201.

Padden, C., & Ramsey, C. (2000). American Sign Language and reading ability in deaf children. Language acquisition by eye, 1, 65-89.

Padden, C., Ramsey, C., Chamberlain, C., Morford, J. P., & Mayberry, R. I. (2000). Language acquisition by eye. Mahwah, NJ: Eribaum.

Paulesu, E., Perani, D., Blasi, V., Silani, G., Borghese, N. A., De Giovanni, U., ... & Fazio, F. (2003). A functional-anatomical model for lipreading. Journal of neurophysiology, 90(3), 2005-2013.

Paulesu, E., Paganelle, F., & Brunswick, N. (2010). Cross-cultural differences in normal and dyslexic reading: behavioural and functional anatomical observations in readers of regular and irregular orthographies.

Patterson, K., Marshall, J. C., & Coltheart, M. (Eds.). (2017). Surface dyslexia: Neuropsychological and cognitive studies of phonological reading (Vol. 8). Routledge.

Perea, M., & Acha, J. (2009). Does letter position coding depend on consonant/vowel status? Evidence with the masked priming technique. Acta Psychologica, 130(2), 127–137. https://doi.org/10.1016/j.actpsy.2008.11.001

Perea, M., & Carreiras, M. (2006). Do transposed-letter effects occur across lexeme boundaries? Psychonomic Bulletin & Review, 13(3), 418–422. https://doi.org/10.3758/BF03193863

Perea, M., & Carreiras, M. (2008). Do orthotactics and phonology constrain the transposed-letter effect? Language and Cognitive Processes, 23(1), 69–92. https://doi.org/10.1080/01690960701578146

Perea, M., Dunabeitia, J. A., & Carreiras, M. (2008). Masked associative/semantic priming effects across languages with highly proficient bilinguals. Journal of memory and language, 58(4), 916-930.

Perea, M., Jiménez, M., & Gómez, P. (2014). A challenging dissociation in masked identity priming with the lexical decision task. Acta Psychologica, 148, 130–135. https://doi.org/10.1016/j.actpsy.2014.01.014

Perea, M., & Lupker, S. J. (2004). Can CANISO activate CASINO? Transposed-letter similarity effects with nonadjacent letter positions. Journal of Memory and Language, 51(2), 231–246. https://doi.org/10.1016/j.jml.2004.05.005

Perfetti, Charles A. "Reading skills." Psychiatry 50 (1985): 1125-1129.

Perfetti, C. A. (1992). The representation problem in reading acquisition. In P. Gough, L. Ehri, & R. Treiman (Eds.), Reading acquisition (pp. 145–174). Hillsdale, NJ: Erlbaum.

Perfetti, C. (2007). Reading Ability: Lexical Quality to Comprehension. Scientific Studies of Reading, 11(4), 357–383. https://doi.org/10.1080/10888430701530730

Perfetti, C. A. (2017). Lexical quality revisited. Developmental perspectives in written language and literacy: In honor of Ludo Verhoeven, 51-67.

Perfetti, C. A., Bell, L. C., & Delaney, S. M. (1988). Automatic (prelexical) phonetic activation in silent word reading: Evidence from backward masking. Journal of Memory and Language, 27(1), 59-70.

Perfetti, C. A., & Bell, L. (1991). Phonemic activation during the first 40 ms of word identification: Evidence from backward masking and priming. Journal of Memory and language, 30(4), 473-485.

Perfetti, C. A., & Hart, L. (2002). The lexical quality hypothesis. Precursors of functional literacy, 11, 67-86.

Perfetti, C. A., & Sandak, R. (2000). Reading optimally builds on spoken language: Implications for deaf readers. Journal of deaf studies and deaf education, 5(1), 32-50.

Perfetti, C. A., & Tan, L. H. (1998). The time course of graphic, phonological, and semantic activation in Chinese character identification. Journal of Experimental Psychology: Learning, Memory, and Cognition, 24(1), 101.

Perfetti, C. A., & Tan, L. H. (1999). The constituency model of Chinese word identification. In Reading chinese script (pp. 127-146). Psychology Press.

Perry, C., Ziegler, J. C., & Zorzi, M. (2007). Nested incremental modeling in the development of computational theories: The CDP+ model of reading aloud. Psychological Review, 114(2), 273–315. https://doi.org/10.1037/0033-295X.114.2.273

Perry, C., Ziegler, J. C., & Zorzi, M. (2010). Beyond single syllables: Large-scale modeling of reading aloud with the Connectionist Dual Process (CDP++) model. Cognitive Psychology, 61(2), 106–151. https://doi.org/10.1016/j.cogpsych.2010.04.001

Pfau, R., Steinbach, M., & Woll, B. (Eds.). (2012). Sign language. De Gruyter Mouton.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (2020). Understanding Normal and Impaired Word Reading: Computational Principles in Quasi-Regular Domains. 60.

Pollatsek, A., Perea, M., & Carreiras, M. (2005). Doesconal prime canal more thancinal? Masked phonological priming effects in Spanish with the lexical decision task. Memory & Cognition, 33(3), 557–565. https://doi.org/10.3758/BF03193071

Protopapas, A., Mouzaki, A., Sideridis, G. D., Kotsolakou, A., & Simos, P. G. (2013). The Role of Vocabulary in the Context of the Simple View of Reading. Reading & Writing Quarterly, 29(2), 168–202. https://doi.org/10.1080/10573569.2013.758569

Puente, A., Alvarado, J. M., & Herrera, V. (2006). Fingerspelling and Sign Language as Alternative Codes for Reading and Writing Words for Chilean Deaf Signers. American Annals of the Deaf, 151(3), 299–310. https://doi.org/10.1353/aad.2006.0039

Qi, S., & Mitchell, R. E. (2012). Large-Scale Academic Achievement Testing of Deaf and Hard-of-Hearing Students: Past, Present, and Future. Journal of Deaf Studies and Deaf Education, 17(1), 1–18. https://doi.org/10.1093/deafed/enr028

Rastle, K. (2016). Visual word recognition. In Neurobiology of language (pp. 255-264). Academic Press.

Rastle, K., & Brysbaert, M. (2006). Masked phonological priming effects in English: Are they real? Do they matter? Cognitive Psychology, 53(2), 97–145. https://doi.org/10.1016/j.cogpsych.2006.01.002

Rayner, K. (Ed.). (2012). Psychology of reading (2nd ed). Psychology Press.

Rayner, K., Foorman, B. R., Perfetti, C. A., Pesetsky, D., & Seidenberg, M. S. (2001). How Psychological Science Informs the Teaching of Reading. Psychological Science in the Public Interest, 2(2), 31–74. https://doi.org/10.1111/1529-1006.00004

Rayner, K., Pollatsek, A., Ashby, J., & Clifton Jr, C. (2012). Psychology of reading. Psychology Press.

Reicher, G. M. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. Journal of Experimental Psychology, 81(2), 275–280. https://doi.org/10.1037/h0027768

Reichle, E. D., & Perfetti, C. A. (2003). Morphology in word identification: A word-experience model that accounts for morpheme frequency effects. Scientific Studies of Reading, 7(3), 219-237

Rice, G. A., & Robinson, D. O. (1975). The role of bigram frequency in the perception of words and nonwords. Memory & Cognition, 3(5), 513–518. https://doi.org/10.3758/BF03197523

Rodríguez-Ortiz, I. R., Saldaña, D., & Moreno-Perez, F. J. (2017). How speechreading contributes to reading in a transparent ortography: The case of Spanish deaf people: How Speechreading Contributes to Reading. Journal of Research in Reading, 40(1), 75–90. https://doi.org/10.1111/1467-9817.12062

Rubenstein, H., Lewis, S. S., & Rubenstein, M. A. (1971). Evidence for phonemic recording in visual word recognition. Journal of verbal learning and verbal behavior, 10(6), 645-657.

Sehyr, Z. S., Petrich, J., & Emmorey, K. (2017). Fingerspelled and Printed Words Are Recoded into a Speech-based Code in Short-term Memory. Journal of Deaf Studies and Deaf Education, 22(1), 72–87. https://doi.org/10.1093/deafed/enw068

Seidenberg, M. S. (2005). Connectionist Models of Word Reading. Current Directions in Psychological Science, 14(5), 238–242. https://doi.org/10.1111/j.0963-7214.2005.00372.x

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. Psychological review, 96(4), 523.

Seidenberg, M. S., Waters, G. S., Barnes, M. A., & Tanenhaus, M. K. (1984). When does irregular spelling or pronunciation influence word recognition?. Journal of Verbal Learning and Verbal Behavior, 23(3), 383-404.

Senghas, A., & Coppola, M. (2001). Children Creating Language: How Nicaraguan Sign Language Acquired a Spatial Grammar. Psychological Science, 12(4), 323–328. https://doi.org/10.1111/1467-9280.00359

Seymour, P. H. K., Aro, M., Erskine, J. M., & collaboration with COST Action A8 network. (2003). Foundation literacy acquisition in European orthographies. British Journal of Psychology, 94(2), 143–174. https://doi.org/10.1348/000712603321661859

Shen, D., & Forster, K. I. (1999). Masked Phonological Priming in Reading Chinese Words Depends on the Task. Language and Cognitive Processes, 14(5–6), 429–459. https://doi.org/10.1080/016909699386149

Snowling, M., & Hulme, C. (1989). A longitudinal case study of developmental phonological dyslexia. Cognitive Neuropsychology, 6(4), 379–401. https://doi.org/10.1080/02643298908253289

Snowling, M. J. (2013). Early identification and interventions for dyslexia: A contemporary view: Early identification and interventions for dyslexia: a contemporary view. Journal of Research in Special Educational Needs, 13(1), 7–14. https://doi.org/10.1111/j.1471-3802.2012.01262.x

Snowling, M. J., & Hulme, C. (2012). Interventions for children's language and literacy difficulties. International Journal of Language & Communication Disorders, 47(1), 27–34. https://doi.org/10.1111/j.1460-6984.2011.00081.x

Stanovich, K. E., & West, R. F. (1989). Exposure to Print and Orthographic Processing. Reading Research Quarterly, 24(4), 402. https://doi.org/10.2307/747605

Stone, A., Kartheiser, G., Hauser, P. C., Petitto, L.-A., & Allen, T. E. (2015). Fingerspelling as a Novel Gateway into Reading Fluency in Deaf Bilinguals. PLOS ONE, 10(10), e0139610. https://doi.org/10.1371/journal.pone.0139610

Storch, S. A., & Whitehurst, G. J. (2002). Oral language and code-related precursors to reading: Evidence from a longitudinal structural model. Developmental Psychology, 38(6), 934–947. https://doi.org/10.1037/0012-1649.38.6.934

Sutton-Spence, R. (1994). The role of the manual alphabet and fingerspelling in British Sign Language (Doctoral dissertation, University of Bristol).

Sutton-Spence, R., Woll, B., & Allsop, L. (1990). Variation and recent change in fingerspelling in British Sign Language. Language Variation and Change, 2(3), 313–330. https://doi.org/10.1017/S0954394500000399

Sutton-Spence, R., & Woll, B. (1999). The linguistics of British Sign Language: an introduction. Cambridge University Press.

Taylor, J. S. H., Rastle, K., & Davis, M. H. (2013). Can cognitive models explain brain activation during word and pseudoword reading? A meta-analysis of 36 neuroimaging studies. Psychological Bulletin, 139(4), 766–791. https://doi.org/10.1037/a0030266

Transler, C., & Reitsma, P. (2005). Phonological coding in reading of deaf children: Pseudohomophone effects in lexical decision. British Journal of Developmental Psychology, 23(4), 525–542. https://doi.org/10.1348/026151005X26796

Treiman, R., & Kessler, B. (2007). Learning to read. Oxford handbook of psycholinguistics, 657-666.

van Orden, G. C. (1987). A ROWS is a ROSE: Spelling, sound, and reading. Memory & Cognition, 15(3), 181–198. https://doi.org/10.3758/BF03197716

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? 39.

Verhoeven, L., van Leeuwe, J., & Vermeer, A. (2011). Vocabulary Growth and Reading Development across the Elementary School Years. Scientific Studies of Reading, 15(1), 8–25. https://doi.org/10.1080/10888438.2011.536125

Verstaen, A., Humphreys, G. W., & Olson, A. (1995). Are phonemic effects in backward masking evidence for automatic prelexical phonemic activation in visual word recognition?. Journal of Memory and Language, 34(3), 335-356.

Wauters, L. N., Van Bon, W. H. J., & Tellings, A. E. J. M. (2006). Reading Comprehension of Dutch Deaf Children. Reading and Writing, 19(1), 49–76. https://doi.org/10.1007/s11145-004-5894-0

Woll, B., & Macsweeney, M. (2016). Let's not forget the role of deafness in sign/speech bilingualism. Bilingualism: Language and Cognition, 19(2), 253–255. https://doi.org/10.1017/S1366728915000371

Yan, G., Lan, Z., Meng, Z., Wang, Y., & Benson, V. (2021). Phonological Coding during Sentence Reading in Chinese Deaf Readers: An Eye-Tracking Study. Scientific Studies of Reading, 25(4), 287–303. https://doi.org/10.1080/10888438.2020.1778000

Yan, M., Pan, J., Bélanger, N. N., & Shu, H. (2015). Chinese deaf readers have early access to parafoveal semantics. Journal of Experimental Psychology: Learning, Memory, and Cognition, 41(1), 254–261. https://doi.org/10.1037/xlm0000035

Ye Wang, Beverly J. Trezek, John L. Luckner, & Peter V. Paul. (2008). The Role of Phonology and Phonologically Related Skills in Reading Instruction for Students Who Are Deaf or Hard of Hearing. American Annals of the Deaf, 153(4), 396–407. https://doi.org/10.1353/aad.0.0061

Yovanoff, P., Duesbery, L., Alonzo, J., & Tindal, G. (2005). Grade-Level Invariance of a Theoretical Causal Structure Predicting Reading Comprehension With Vocabulary and Oral Reading Fluency. Educational Measurement: Issues and Practice, 24(3), 4–12. https://doi.org/10.1111/j.1745-3992.2005.00014.x

Wechsler, D. 2004. Wechsler Intelligence Scale for Children — Fourth UK Edition: administrative and scoring manual; London, The Psychological Corporation.

Wechsler, D. (2011). Wechsler Abbreviated Scale of Intelligence–Second Edition (WASI-II). San Antonio, TX: NCS Pearson.

Xu, B., & Perfetti, C. A. (1999). Nonstrategic subjective threshold effects in phonemic masking. Memory & Cognition, 27(1), 26-36.

Zhao, Y., & Wu, X. (2021). Impact of visual processing skills on reading ability in Chinese deaf children. Research in Developmental Disabilities, 113, 103953. https://doi.org/10.1016/j.ridd.2021.103953

Ziegler, J. C., Bertrand, D., Lété, B., & Grainger, J. (2014). Orthographic and phonological contributions to reading development: Tracking developmental trajectories using masked priming. Developmental Psychology, 50(4), 1026–1036. https://doi.org/10.1037/a0035187

Ziegler, J. C., & Goswami, U. (2005). Reading Acquisition, Developmental Dyslexia, and Skilled Reading Across Languages: A Psycholinguistic Grain Size Theory. Psychological Bulletin, 131(1), 3–29. https://doi.org/10.1037/0033-2909.131.1.3

Zoccolotti, P., De Luca, M., Di Filippo, G., Judica, A., & Martelli, M. (2009). Reading development in an orthographically regular language: Effects of length, frequency, lexicality and global processing ability. Reading and Writing, 22(9), 1053–1079. https://doi.org/10.1007/s11145-008-9144-8

Zoccolotti, P., De Luca, M., Judica, A., & Spinelli, D. (2008). Isolating global and specific factors in developmental dyslexia: A study based on the rate and amount model (RAM). Experimental Brain Research, 186(4), 551–560. https://doi.org/10.1007/s00221-007-1257-9

Zorzi, M. (2010). The connectionist dual process (CDP) approach to modelling reading aloud. European Journal of Cognitive Psychology, 22(5), 836–860. https://doi.org/10.1080/09541440903435621

Zorzi, M., Houghton, G., & Butterworth, B. (1998). Two routes or one in reading aloud? A connectionist dual-process model. Journal of Experimental Psychology: Human Perception and Performance, 24(4), 1131.

Ziegler, J. C., Stone, G. O., & Jacobs, A. M. (1997). What is the pronunciation for-ough and the spelling for/u/? A database for computing feedforward and feedback consistency in English. Behavior Research Methods, Instruments, & Computers, 29(4), 600-618.