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Effects between reading skills and form-related word priming in bilingual sentence reading: Evidence from Eye movements

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Abstract

This study aims to investigate the effects of inhibitory neighbourhood priming on sentence reading and its relationship with the reading skills of Norwegian-English bilinguals reading in their second language. We aimed to investigate if the findings from previous studies (Frisson et al., 2014b; Pélissier et al., 2022) can be replicable when individual differences are considered. Previous research found that inhibitory priming effects disappear as the distance between the prime and target increases, skilled monolingual readers do not get inhibitory priming when a full stop separates the prime and target, and that proficient readers exhibit inhibition priming longer than less skilled readers.

In the experiment, we recorded the eye movements of bilingual participants as they read a single sentence on a screen, and gathered data on participants' individual differences by performing additional tasks measuring their inhibition, working memory and proficiency skills. We investigated the effects of distance (short vs. long) between the prime and target (e.g. *train-trail*) and sentence structure, where the prime and target were either within the same sentence or in two different sentences, and related this to individual differences.

The results showed that individuals with high proficiency and inhibitory skills exhibit less inhibition in short-distance conditions. We also observed interesting effects on working memory that were conditioned by a sentence break in short-distance conditions. Higher working memory skills facilitated the recognition of the target word when prime and target were in different sentences. Additionally, those with low inhibition skills exhibited inhibition priming on the spillover region when there was an interaction between inhibition skills and a full stop. We observed some effects with sentence breaks regardless of the individual differences.

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Table of contents

1. Introduction

This thesis will investigate second language reading and the relationship between reading skills and inhibitory neighbourhood priming. There is evidence suggesting that the speed at which we recognise words in the mental lexicon is influenced by their neighbours, which are words that differ by one letter (Coltheart et al., 1977; Davis & Lupker, 2006; Andrews & Lo, 2012; Perry, Lupker & Davis, 2008). Studies have found that words with larger neighbourhoods are recognised more quickly and accurately than words with smaller neighbourhoods, and that orthographic neighbourhoods with many substitution neighbours can slow down word recognition. Moreover, there is evidence that individuals who have better reading skills are better at suppressing competitors; words that are form-related but are not the one the reader is trying to recognise (Borella et al., 2010; Frisson et al., 2014b; Gernsbacher, 1993). Less skilled readers may struggle with suppressing irrelevant information, leading to slower reading and impeded comprehension.

It can be argued that competitive processes hold even greater significance for this group of bilinguals than monolinguals because of the non-selective language activation that occurs (Dijkstra & Van Heuven, 2010; Sunderman & Kroll, 2006; Van Heuven et al., 1998). Theories on bilingual language processing suggest that when individuals who speak two languages receive input in one language, activation occurs in both languages, leading to lexical competition between the languages, which can impact various aspects of language processing, including word recognition. However, it is unclear what aspects of reading skill underlie the relationship between reading skill and inhibitory neighbour priming.

This thesis aims to investigate the replicability of previous findings regarding reading skills in bilingual individuals. Specifically, it examines the impact of factors such as working memory, inhibitory control, and language proficiency on reading abilities. By focusing on these factors, it seeks to shed light on the complex processes involved in bilingual language processing and their implications for reading.

This introduction first reviews relevant studies that have investigated the effect of neighbouring words when recognising single words in a first language (e.g. Davis & Lupker, 2006; Andrews & Lo, 2012; Perry, Lupker & Davis, 2008), and form priming between words in sentences (Frisson et al., 2014b). Then, we will review various factors that have an impact on an individual's reading skills, including their working memory skills (e.g. Tenpenny, 1995;

Daneman & Carpenter, 1980; Daneman & Merikle, 1996) and inhibitory control (e.g. Gernsbacher et al. 1990; De Beni et al., 1998), and a summary of studies that have explored the influence of syntactic boundaries while reading (e.g. Fodor et al., 1974; Carroll & Slowiaczek, 1986; Frisson et al., 2014b). We will then discuss bilingual cognitive processing on reading, giving a description of non-selective language activation models (Dijkstra & Van Heuven, 2010; Sunderman & Kroll, 2006), the Bilingual Interaction Activation model (Van Heuven et al., 1998), the Revised Hierarchical Model (Sunderman & Kroll, 2006), and the Inhibitory Control Model (Green, 1998). Finally, before moving on to the aims, predictions, methods and results of our study, a study is reported that investigated second language proficiency and inhibitory form-related word priming in second language (English) reading (Pélissier et al., 2022).

2. Single word reading in L1

Many studies have shown that the speed at which a single word is processed can be affected by its similarity in spelling or pronunciation to its neighbourhood word, i.e., a word that differs from another word by a single letter (e.g. *bamp* and *camp*) (e.g. Andrews & Lo, 2012; Coltheart et al., 1977; Davis & Lupker, 2006). Masked priming is a widely used technique for studying written word processing. In this method, a prime word is presented to the subject briefly on a screen, usually 40-60 milliseconds. This is too short for the subject to perceive the word consciously, yet, the brain can process the information during this short period. The prime is typically displayed in lowercase letters, followed by a symbol mask such as "####". The target is usually shown in uppercase letters, to rule out effects of visual similarity - for example, tank-BANK, bank-BARK, and kwqm-FISH (Forster et al., 1987). When a target word is primed by a masked word that is an orthographic neighbour, the processing of the target word tends to slow down. When the frequency of the prime word is higher than that of the target word (e.g., *royal* is a higher frequency word than *loyal*) this effect tends to become more pronounced (Davis & Lupker, 2006).

Several studies have investigated the influence of orthographic neighbourhoods on the speed and accuracy of word recognition (e.g. Coltheart et al., 1977; Davis & Lupker, 2006; Andrews & Lo, 2012; Perry, Lupker & Davis, 2008). These studies have shown that words with larger orthographic neighbourhoods (e.g., *crown*) are recognised more quickly and accurately than words with smaller neighbourhoods (e.g., *crowd*). Other studies investigated the influence of phonological neighbourhoods, i.e., a set of words that differ by one phoneme, and semantic neighbourhoods, i.e., a set of words that are related in meaning, on word recognition, again finding similar facilitative effects for larger neighbourhoods (e.g. Davis & Lupker, 2006; Perry, Lupker & Davis, 2008). These studies suggest that orthographic, phonological, and semantic neighbourhoods play important roles in the process of recognising written words. Coltheart et al. (1977) examined the effect of orthographic neighbourhoods on lexical decision tasks and found that words with many substitution neighbours are recognised slower than words with smaller neighbourhoods; since words with larger neighbourhoods have more potential candidates for substitution errors, which increases the amount of time required to process and recognise the correct word.

Andrew and Hersch (2010) examined the effect of reading and spelling skills on word recognition. They found that individuals who were better at spelling exhibited inhibitory priming effects for high-frequency neighbouring words. In contrast, poorer spellers experienced facilitatory priming for high- and low-frequency neighbouring word targets. They found that better spelling skills were associated with stronger inhibitory priming for neighbour primes. Furthermore, better spellers showed greater inhibition for neighbour primes (e.g., pitch) as compared to unambiguous partial primes (e.g., pa#ch). Their study sheds light on how spelling proficiency influences word recognition, which could be explained by competitive network models.

2.1 Competitive network models

The inhibitory effects of neighbouring words have been explained using competitive network models of word recognition such as the Dual Route Cascaded Model (Coltheart et al., 2001), the Spatial Coding Model (Davis, 2010) and the Interactive Activation Model (IAM) (McClelland & Rumelhart, 1981). According to these models, multiple representations are activated simultaneously and compete for recognition, and the most strongly activated representation ultimately wins. According to all these models, word recognition depends on competition among words with similar forms. The IAM model (McClelland & Rumelhart, 1981, see Figure 1), is the most influential connectionist cognitive model of visual word recognition. This model was inspired by Hubel and Wiesel (1965), who discovered that there are neurons in the visual cortex which only respond to certain kinds of stimuli. The IAM is based on three fundamental assumptions. First, it assumes that perceptual processing occurs in a system with different levels of processing, each level responsible for creating a representation of the input at a unique level of abstraction. In the case of visual word perception, three levels of processing are assumed: a visual feature level, a letter level, and a word level. Furthermore, higher levels of processing provide "top-down" input to the word level. Secondly, it assumes that visual perception involves parallel processing, where information covering a region in space is processed simultaneously. This model is spatially parallel, allowing it to simultaneously process at least four letters and operate at several levels. Therefore, processing at the letter level co-occurs with processing at the word level and with processing at the feature level. Thirdly, the IAM proposes that perception is an interactive process involving top-down and bottom-up processing that works simultaneously. This process creates multiple constraints that determine what is perceived. According to IAM, lexicality and relative frequency effects are a result of form priming. In this type of priming, there is assistance provided by sublexical overlap and inhibition caused by the competition between lexical items.

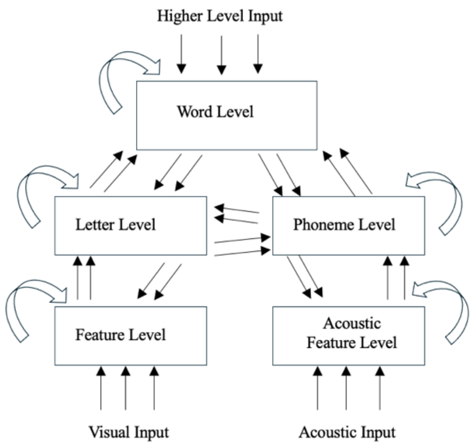

Figure 1. The processing levels involved in visual and auditory word perception with interconnections (Based on McClelland and Rumelhart, 1981, p. 378)

3. Sentence reading in L1

As previously mentioned, studies have shown that the speed of recognising a word can be influenced by previous exposure to an orthographically similar word, and research has focused on the influence of neighbouring words in inhibiting subsequent target-word recognition. In general, inhibitory effects are observed when the prime is of higher frequency, which can interfere with target-word recognition. This effect is attributed to the higher-frequency neighbour prime giving a lexical competitor a “head start” in processing, thereby interfering with target-word recognition (Andrews, 1996; Coltheart et al., 1977; Davis & Lupker, 2006; Davis, 2010; McClelland & Rumelhart, 1981). This offers insight into how the spelling of words impacts their recognition and when this impact occurs. Understanding this information is essential to create effective models that can accurately identify words. A few studies have suggested that the surroundings of a word can influence its identification while reading an entire text (Perea & Pollatsek, 1998; Slattery, 2009). For example, Perea and Pollatsek (1998) found that words with a higher-frequency substitution neighbour (SN), i.e., a word that differs from another by one letter and has the same length and letter order (e.g.

queen-queer), received longer total reading times than control words, revealing that neighbourhood effects occur naturally during reading.

Further, research has found a correlation between reading skills and the effect of inhibition priming, where skilled readers tended to slow down when encountering neighbouring words (Frisson et al., 2014b). Studies (Frisson et al., 2014a; Paterson et al., 2009) have shown that encountering a word's orthographic neighbour a few words earlier in the sentence can influence fixation times on the target. Paterson et al. (2009) found that when participants were exposed to a substitution neighbour of a word (e.g. *blue*) before encountering the target word (e.g. *blur*) in a sentence (e.g. "In the photograph, the *blue* lights were a blur against the cold night sky"), their fixations on the target word were longer. This effect was observed during the first fixation on the target word and was not influenced by the frequency of occurrence of the prime and target words, suggesting that inhibition priming is a natural occurrence during reading. Frisson et al. (2014a) found that the level of fixation is higher when the neighbouring word overlaps orthographically and phonologically with the target word. Moreover, a study found a similar effect where exposure to a Mandarin character that is phonologically and visually similar but differs by one- or two-character strokes can hinder the processing of the target character for native speakers of Mandarin (Wang, Tian, Han, Liversedge & Paterson, 2014). Additionally, Pagán et al. (2016) investigated the effect of prior exposure to a word's transposed letter neighbour (TLN), (e.g. *scared-sacred*) instead of SN. They found that TLNs have a more inhibitory effect on eye movements during reading than SNs; readers tend to skip over TNs more often than SNs, which slows down their reading speed. This suggests that the similarity between TLNs and the target word creates a processing difficulty that inhibits the readers' ability to process the target word efficiently.

Frisson, Bélanger, and Rayner (2014a) explored how orthographic and phonological information is processed while reading. The study compared three types of overlap between prime and target words: high orthographic and high phonological overlap (e.g. *flash-clash*), high orthographic and low phonological overlap (e.g. *pint-tint*) or low orthographic and high phonological overlap (e.g. *boot-lute*). In addition, they explored whether onset overlap (e.g. *slung-slunk*) had the same priming pattern as rhyme overlap (e.g. *define-refine*). They used a fast priming task to study how words are read in context and a masked priming task to test single-word recognition of the same words out of context. The fast priming task presents a target word in a text as a random string of letters. When the reader's eyes land on the target word, the random letters are quickly replaced by a prime word and then by the target word, and eye-fixation data are recorded. The masked priming task briefly presents a prime word so quickly that it is below the level of conscious awareness before replacing it with a target word to study how the information from the first word affects the processing of the second word. The words are presented in isolation on a computer screen, and the participants are required to provide a response (such as naming or judging the lexicality, i.e., is this a real word or not) after reading the second word.

The fast priming results indicate significant facilitatory priming when the prime and target shared both phonological and orthographic features. The priming effect was stronger and the reading times for the target word were faster when the overlap was orthographically and phonologically related compared to when only one was related. In the masked priming task, inhibitory priming was observed in two out of three orthographically overlapping prime-target pairs that showed facilitatory priming in the fast priming task; the onset overlap item pairs (e.g. *strain-strait*) did not provide faster reaction times than when a non-word with no overlapping letters with the target word preceded the word, and there was a trend towards inhibition in the phonological-only overlap condition, in contrast to the numerical advantage found in the fast priming results for this overlap condition. The study suggests that low-level visual overlap did not determine the observed facilitation in the fast priming experiments. Instead, the study identified a second mechanism that could facilitate target processing: the larger context in which the word appears. The study observed that when a prime word is read, some of its orthographic neighbours will receive priming from the context (e.g., in contexts where only a noun could be used, neighbouring words that are nouns will receive additional activation).

Frisson, Koole, Hughs, Olson and Wheeldon (2014b) investigated the effects of competition between different words in a sentence during silent reading, particularly in terms of different types of orthographic and phonological overlap. As Frisson et al. (2014a), the researchers found that the inhibitory priming effect is restricted to word pairs that overlap both at the orthographic and phonological levels, which means that the target word took longer to process when it was preceded by an overlapping prime word than when it was preceded by a non-overlapping control word. In addition, Frisson et al. (2014b) aimed to investigate the effects that adding a full stop between the prime and the target words would cause on inhibition priming, Frisson et al. (2014b) further investigated the inhibitory priming effects of orthographic and/or phonological neighbouring words while reading. Specifically, they tested the prediction of interactive-activation accounts that activation levels of lexical candidates decay over time (priming at short and long distances with 3 and 9 intervening words) (e.g. McClelland & Rumelhart, 1981; Paterson et al., 2009). The study also examined whether syntactic structure (priming within or across sentences) plays a role in the degree of activation of the prime word and tested an alternative explanation for the inhibition effect related to episodic memory effects. An additional aim of the study was to find out whether there was a relationship between inhibitory priming and individual differences in reading skill. They found that the inhibition effect disappears when the distance between the prime and target increases from about 3 to 9 intervening words. However, they concluded that reading skills may influence the inhibition effect since better comprehenders still showed inhibition effects when the target word was delayed in a sentence, whereas less skilled comprehenders did not. According to Frisson et al. (2014b), individuals with better comprehension tend to retain surface-level information for longer, enabling them to keep the prime active for a longer duration and leading them to superior memory compared to less skilled readers. However, they suggest that skilled comprehension may involve the ability to combine lexical information across larger portions of text since the presence of a sentence boundary resulted in readers discarding low-level information, such as the spelling of specific words and forgetting or suppressing their memory of specific details, which indicates that syntactic structure did have an impact on inhibition priming. Finally, they suggest that good comprehension may be related to memory and precision in lexical representation, explaining that if good comprehenders are also good spellers, then the results will fit with the lexical precision theory (Andrews & Hersch, 2010).

4. Underlying processes that contribute to reading skills

4.1 Studies on working memory

An explanation for the effect of inhibitory priming of orthographic neighbours could be found in an episodic account of lexical priming (as proposed by Tenpenny in 1995). According to this account, when a person reads a prime and a target word separately, and if these words have a similar spelling, then the processing of the target word creates a memory trace that gets encoded during the processing of the prime word. In repetition priming, the memory of a prime word processed earlier could help identify subsequent target words. However, this memory could also interfere with target word identification when the prime is a neighbour of the target (e.g., *cars*-*card*) (Tenpenny, 1995).

In 1995, Tenpenny explored the long-term priming effect and its relationship with memory. Long-term priming is when exposure to a stimulus in the past can affect the process of the same or similar stimulus in the future, even after a significant period has passed (e.g. weeks, months and even a year later). His article discusses two theories that aim to explain how we process and utilise information from the original stimulus to facilitate processing in the future: the abstractionist (e.g., Becker, 1980; Coltheart, 1980) and the episodic theories (Jacoby, 1983; McClelland & Rumelhart, 1985). Abstractionist theories suggest that priming occurs because information from the original exposure is abstracted or generalised, allowing for a more efficient processing of the stimulus in the future (e.g., Johnson & Pugh, 1994; Carr & Pollatsek, 1985). In other words, a summary of the information received is created and stored in the memory for easy retrieval in the future. Supporting this view, studies have found that priming effects can occur even when the stimuli are not identical but share a common morpheme: studying "*cars*" facilitates the identification of the word "*car*" but studying "*card*" does not (Murrell & Morton, 1974; Napps & Fowler, 1987). On the other hand, episodic theories propose that priming occurs when the specific details of the original exposure are stored and later utilised to facilitate processing of the stimulus (e.g., Logan, 1988, 1990) This means that a memory of the stimulus, including its context and surrounding events, is stored. When the stimulus is reencountered, this stored memory is used to enhance its processing.

Tenpenny (1995) suggests that both theories have some merit, but they also have limitations. For instance, abstractionist theories (e.g., Becker, 1980; Coltheart, 1980) cannot explain why priming effects can occur even when the stimuli do not share a base morpheme. In contrast, the episodic theory (Jacoby, 1983; McClelland & Rumelhart, 1985) cannot account for why priming effects can last for days or even weeks.

Working memory (WM) capacity is one of the factors that contribute to the differences in reading ability among individuals. When we read and comprehend, we perform multiple tasks simultaneously that involve processing and storing information. To comprehend a text, readers start by recognizing words visually, constructing semantic representations in long-term memory, and then combining all these representations with the text to ultimately grasp its essence (see the cognitive model of reading by Khalifa & Weir, 2009). WM plays a crucial role in the reading comprehension process by retaining relevant information in short-term memory, retrieving information from long-term memory, and integrating all sources of information to form an accurate representation of the situation described by the text (Van den Broek, Mouw, & Kraal, 2016).

Working memory theory suggests that the ability to comprehend information is closely linked to the capacity of our working memory (Daneman & Carpenter, 1980; Daneman & Merikle, 1996). Individuals with limited space to process and store information in their working memory have a harder time integrating successively encountered ideas in a text. This is because they struggle to keep earlier relevant information active in their working memory, whereas individuals with larger short-term memory capacities are better at retaining earlier relevant information, enabling them to comprehend and integrate successive ideas more effectively.

Daneman and Carpenter (1980) developed a measure to assess working memory span, the Reading Span Task. Participants were given sets of sentences to read or listen to, and then asked to recall the final word of each sentence. Participants' working memory span was determined by measuring their ability to recall the final words of a set of sentences after reading or listening to them. The test also included the additional component of processing the relations among the words. The study found that individuals with poor comprehension skills allocate more cognitive capacity to comprehend the sentences, which limits their ability to store and recall the final words. Their study found that people with limited working memory capacity struggled with language comprehension tests. Burton and Daneman (2007) found that low-span readers with mature epistemic beliefs (awareness about knowledge and learning) engaged in more strategic backtracking than low-span readers with naive epistemic beliefs. This selective backtracking suggests that readers with mature epistemic knowledge have an increased metacognitive awareness of when they have an insufficient understanding of relevant information. Additionally, Walcyk and Taylor (1996) found that compensatory mechanisms, such as slowing down the reading rate or looking back at the text, are used to overcome obstacles that might normally impair comprehension in readers with lower working memory capacities. However, the study found no support for the idea that readers with lower working memory capacities would look back more often in text, although they argue that their sentence-by-sentence presentation of the text might have interfered with this (Walcyk & Taylor, 1996). This finding would suggest that less skilled readers, in terms of their recall performance (working memory), who are aware of their struggles in decoding words and comprehending a text, tend to have more lookbacks at a text than perhaps skilled readers or less skilled readers with low epistemic knowledge. Hamilton, Freed, and Long (2016) found that the connection between word decoding and working memory capacity was noticeable only under high demands on word decoding. This discovery is consistent with Bell and Perfetti's (1994) argument that word decoding's impact on comprehension in proficient adult readers is primarily visible when texts include many low-frequency words.

4.2 Studies on inhibition

To read fluently, one must continuously activate and suppress potential word options. The level of success in this task may be linked to an individual's reading proficiency (e.g. Andrews & Hersch, 2010; Andrews & Lo, 2012; Gernsbacher, 1993). Gernsbacher et al. (1990) suggest that some of the mechanisms that influence adult reading skills might be cognitive mechanisms that are involved in the comprehension of non-linguistic media, and not specific to language. One of these mechanisms is suppression, which involves actively reducing the activation of mental representations to prevent irrelevant or inappropriate information from affecting ongoing processes. Less skilled readers may be less efficient at suppressing the automatic activation of irrelevant or inappropriate information, which can jeopardise their success in comprehension (Gernsbacher, 1993). In addition, they activate information as efficiently as skilled readers, but struggle to suppress irrelevant or inappropriate information. According to Gernsbacher and Faust (1991), individuals with lower reading skills may experience a stronger inhibition effect than those with higher reading skills when the prime and the target are further apart from each other because of their poor suppression skills. However, since individuals with lower reading skills tend to lose access to surface features, such as the spelling of a word, more quickly than those with higher reading skills, they are likely to have less inhibition when the prime and target are further apart (e.g. Gernsbacher, Varner, & Faust, 1990).

Research has indicated that children who experience difficulties with comprehension skills tend to exhibit poor performance on tasks that measure working memory and inhibitory control (Borella, Carretti & Pelegrina, 2010). These tasks were designed to assess an individual's ability to resist interference. De Beni, Palladino, Pazzaglia, and Cornoldi (1998) analysed the efficiency of inhibition mechanisms in young adult good and poor comprehenders using a new WM task called Categorization Working Memory Span. In this task, young adults aged 18 to 20, listened to increasing series of lists of words and indicate as soon as they detected the name of an animal by tapping on the table with their hand. At the end of each series, they had to recall the last word of each list. The researchers found that intrusion errors (i.e., the recall of words not in the current final position) could be an indicator of difficulty in suppressing activated information. Non-final animal names were more prone to intrusion errors in poor comprehenders, indicating weaker inhibition mechanisms in their working memory. Borella et al. (2010) found that children aged 10 to 11 who are poor comprehenders have problems with inhibitory processes, particularly in their ability to resist proactive interference (PI), suppressing the activation of no longer relevant items, during WM tasks. Poor comprehenders also showed poorer performance in working memory tasks, regardless of whether the tasks required semantic processing or not. In contrast, for tasks less demanding in attentional control, such as their PI task, poor and good comprehenders performed equally well regarding correct recall. However, poor comprehenders encountered challenges in managing irrelevant information during retrieval and suppressing activated items, as they tended to recall information presented in past trials during the PI task (Borella et al., 2010).

Further, De Rom and Van Revbroeck (2023) conducted a study, with children aged 7 to 8, on a sentence reading task and found a significant inhibitory effect during different stages of reading. The study revealed that when children read a sentence and an expected word was replaced by an orthographic neighbour, they made more mistakes, exhibited greater latency times, and read slower compared to control sentences. The results indicate that the expected word is preactivated while reading the preceding context and is harder to inhibit, leading to more reading errors and slower response times. Children with better word and text reading abilities are less impacted by inhibitory demands, while children with poor inhibition skills tend to be poorer readers.

The studies conducted on children have demonstrated a correlation between working memory, inhibitory control, and comprehension skills. These findings could hold relevance for adults too, indicating that poor performance in tasks measuring working memory and inhibitory control may result in difficulties in comprehension, reading, and other cognitive tasks.

There are two views on inhibition that have been suggested by researchers. The first view posits that inhibition occurs due to competition between orthographic neighbours, while the second view suggests that the inhibition effect is related to episodic memory effects. The episodic memory account predicts longer-lasting inhibition, whereas the competition account predicts that the inhibition effect should disappear quite quickly. According to Paterson et al. (2009), exposure to a word's orthographic neighbour earlier in a sentence interferes with word identification during normal sentence comprehension. This inhibitory priming effect can be explained by an episodic account of lexical priming, while the effect on total reading times is due to readers making a regressive saccade, a small rapid movement of both eyes between two or more points of fixation, from the target word or post-target region to reinspect and reprocess the prime word. Regressive eye movements were most likely the result of readers having increased difficulty in processing the target word, and possibly even misidentifying it when it followed a neighbour word (e.g. Davis & Lupker, 2006). In addition, if we consider both the episodic and competition accounts (e.g. Jacoby, 1983; Grainger & Jacobs, 1996), they would both suggest that the degree of priming should remain unchanged regardless of the syntactic structure, as long as the time between the prime and target is approximately the same.

4.3 Studies with Syntactic Boundaries

The implications of the influence of syntactic boundaries on priming are significant for developing sentence processing models, as various theories on language processing propose different extents to which prior context can impact the processing of new information. Interactive processing models propose that all types of information can be accessed immediately to influence processing at any level, including syntax (e.g., Just & Carpenter, 1980; McClelland & Rumelhart, 1981). These models suggest that previous sentences, phrases, and words through various levels and stages of processing can significantly affect the comprehension of new words and phrases. As per these models, each word is integrated into the mental representation of discourse as soon as it is encountered. Therefore, interactive models suggest that all information, including syntax and previous context, should be used to facilitate understanding (e.g., McClelland & Rumelhart, 1981; Perry et al., 2008). On the other hand, modular processing models propose that lexical, syntactic, and semantic processing take place in separate subsystems, with the syntactic module organizing words into clauses that serve as the units for semantic analysis (e.g., Forster, 1979; Freeman & Forster, 1985). The models suggest that information is passed from one module to the next as it is completed. However, modular processing models also have limitations, as they constrain the extent to which context can impact processing and the point at which information can be integrated into a text representation (e.g., Forster, 1979; Freeman & Forster, 1985).

Approaches that propose that the structure of sentences guides and limits the processing flow are of particular interest (e.g., Bever & Hurtig, 1975; Fodor, Bever & Garrett, 1974). According to some models (e.g. Fodor, Bever & Garrett, 1974; Frazier & Fodor, 1978), sentence comprehension and concept integration occur in stages determined by the clausal units of the input sentence. Words are integrated within the same clausal constituent before any higher-level discourse integration occurs. If clausal constituents work as the domain for integrating individual words, then the integration process would be made easier only by words with associations within the same clause.

Carroll and Slowiaczek (1986) found that semantic priming occurred when semantically associated words (e.g., *king-queen*) were within the same clause but not when they were separated by a clause boundary, suggesting that the immediate syntactic constituent appears to be the reason for such facilitation. This finding is significant to this thesis as they indicated that there was a cancellation effect when the prime and target words were separated by a clause boundary, as there was no priming effect observed. This suggests that syntax plays a crucial role in the processing of words and sentences in L1 regarding inhibition and facilitation. The relevant discovery of sentence boundary effect establishes that the structural constraint identified provided support for a modular model of sentence comprehension, supporting the idea that the syntactic module organises words into clauses that serve as the units of processing for semantic analysis. Carroll and Slowiaczek (1986) conducted an analysis of semantically associated words, and a comma separated the two clauses. In our study, we aimed to investigate whether a full stop instead of a comma between sentences has a similar effect with neighbouring words with bilingual participants.

Further, the results from Frisson et al.'s (2014b) study indicated that an activated representation decreases quickly, supporting the interactive activation theory (e.g. McClelland & Rumelhart, 1981; Paterson et al., 2009; Perry et al., 2008). The study showed that the inhibition effect disappeared as the distance (and time) between the prime and target words increased. This was true whether the prime and target appeared in the same sentence or two consecutive sentences, supporting the competition model's assumption that the activation levels of words decay rapidly (Paterson et al., 2009). Skilled readers display an inhibition effect in long distance, whereas those with poor reading comprehension skills do not show any inhibition effect. The study suggests that sentence boundaries cause readers to discard low-level information and suppress their memory trace (Frisson et al., 2014b). This inhibition effect can be due to superior memory, holding onto superficial information for a longer time, relying more on phonological codes, and combining lexical information across larger chunks of text.

The effects of orthographic neighbourhoods on word recognition have been extensively studied in reading in L1. However, reading in a second language can pose additional difficulties due to non-selective language activation and inhibition. In the following section, we will move to the topic of bilingual cognitive processing in reading and explore models of non-selective language activation and inhibition.

5. Understanding Bilingual Cognitive Processing in Reading

5.1 Models of non-selective language activation and inhibition

As previously discussed, research suggests that when reading in a first language, there is a competition between words that share similarities in sound and spelling. For bilinguals, the process of reading might be even more complex. Theories of bilingual language processing propose that language activation is non-selective, meaning that any input, whether spoken or written, activates all the languages known to the individual (e.g. Dijkstra & Van Heuven, 2010; Sunderman & Kroll, 2006). These models, therefore, propose that it is impossible to entirely suppress the vocabulary of any language, as the lexicon of all known languages is automatically activated upon receiving input. Simply put, bilinguals experience lexical competition from all the languages they know.

To investigate language non-selectivity, researchers have employed three methods to measure reaction time. These methods help us understand how language non-selectivity works. *Word naming* will be the first method to discuss. In this method, the subjects are shown an object or image and asked to state its name in the target language verbally. Schwarts, Kroll and Diaz (2007) used this method in their study of English-Spanish bilinguals, where they aimed to understand the influence of orthographic overlap on phonological activation in bilinguals. The researchers used a complementary approach with participants fluent in both English and Spanish, varying the language used. They tested cognates (words that are similar phonologically, orthographically, and semantically in both languages, e.g. *piano* or *base*). The English-Spanish bilinguals were presented with 240

Spanish words with their English translations, where half were cognates, and the other half were non-cognates, in the study. Additionally, a control condition was included, where monolingual participants named all cognates and non-cognates in a single English naming block. For each word to appear, the participants were required to press a button on a keyboard, and the time taken to react was recorded in milliseconds from the moment the stimulus was presented to the point of articulation. After the completion of the tasks, the individuals were asked to fill out a survey regarding their language history. According to the study, when there was a discrepancy between the orthography, phonology and semantics of a word, it caused a delay in the ability to name the word. For instance, when the word "base" was pronounced as English [beɪs] instead of Spanish ['baː.sə], it created a mismatch and caused a delay. The researchers proposed that the level of activation increased when the phonetic patterns were similar, leading to activation of the spelling from the other language, which ultimately inhibited performance.

In the second method, *lexical decision tasks*, a subject is presented with a written word or a pseudo-word (a word without meaning that follows the language's orthographic rules), and they are asked to identify whether it is a real word or not. In a generalised lexical decision task, the subject is asked to identify if the word is valid in any language. Lemhöfer and Dijkstra (2004) conducted a study where they carried out four experiments to examine the impact of cross-linguistic overlap in phonology, orthography, and semantics on bilingual word recognition in various versions of the lexical decision task. They aimed to examine how words that have similar spellings and/or pronunciations but different meanings (false friends) are represented in our mental vocabulary. They tested lexical decision in language-specific (English) and language general (English and Dutch) tasks. Some of these tasks involved interlingual homophones and/or homographs, while others involved cognates. They used an English lexical decision task, where twenty Dutch-English bilinguals (Dutch as their native language) were tested in tasks that involved words that overlapped in orthography, phonology or both. Before the experiment, participants completed a 30-item practice round with the same ratios of false friends (words that are spelt the same but have different meanings than the words in one's native language, i.e. *spot* means "mockery" in Dutch), English words, and nonwords as the experimental stimulus list. The experimental items comprised 180 trials, presented in blocks of 90, which included 15 items from each category (P, O, and OP). In addition, 34 participants were analysed using a Generalised Lexical Decision, where participants had to decide whether a given letter sequence is a correct word in either Dutch or

English, or if it is a non-word in both languages, including either cognates or interlingual homographs.

Lemhöfer and Dijkstra (2004) found that both L1 and L2 word candidates are activated when presented with a stimulus, but L2 lexical codes are activated more slowly than L1 codes. This leads to cross-linguistic facilitation and inhibition effects, which occur when enough time is given for the lexical effects to take place (e.g. when the target language is L2) or when the activation pattern arising at the orthographic level is amplified by semantic feedback (e.g., when the item is a cognate). When making generalised lexical decisions, there seems to be no impact from other languages on interlingual homographs. This implies that the response is based on the quickest available code (L1), which happens to be Dutch orthography in this case. Thus, these items seem to be represented by two codes rather than just one. Rejecting nonwords takes longer in L2 than in L1, suggesting that the criteria for rejecting nonwords depend on the language being used.

The third method is *masked priming*, used in Dijkstra and Van Heuven's (2010) study, where participants are first shown a prime word, which can be either related or unrelated to the target word they will see next. The prime word is intended to either facilitate or inhibit the participant's response time to the target word. This method has been explained before in section 2 (e.g. Davis & Lupker, 2006; Forster et al., 1987; Frisson et al., 2014a). Their study builds on the article's findings by Lemhöfer and Dijkstra (2004) as it replicates the finding that bilingual speakers experience cross-language interference during language processing. In addition, their goal was to assess the degree to which form-related and repetition masked priming (Grainger and Jacobs, 1996) can be extended to the bilingual context. The study examined the effects of word and nonword-masked primes on repeated word and nonword targets from the same language (L1 to L1 effects) or another language (L2 to L1 effects).

The results indicate both within- and between-language priming effects are observed in bilinguals. Word primes from both L1 and L2 resulted in non-significant inhibitory effects on L1 target word processing, while nonword primes derived from L1 and L2 words led to facilitation effects. When the L1 target word was repeated, generally facilitatory effects of related primes were found. The between-language priming effects were smaller in magnitude than the within-language priming effects. Dijkstra and Van Heuven (2010) interpret the findings in terms of the generalised masked priming account, which suggests that lexical competition between orthographically overlapping word candidates from different languages leads to slower reaction times in bilinguals.

Three main models are relevant to understanding how bilingual individuals recognise and process words in multiple languages. These models are the Bilingual Interactive Activation model (Van Heuven, Dijkstra, and Grainger, 1998), the Revised Hierarchical Model (Sunderman and Kroll, 2006), and the Inhibitory Control Model (Green, 1998).

5.2 The Bilingual Interactive Activation Model

Van Heuven, Dijkstra, and Grainger (1998) explained that although many bilingual individuals can impressively avoid interference from their non-target language, it is still a fact that interference can occur, affecting both language structure and processing. Their study investigated how neighbouring words from other languages influence word recognition. To investigate this, they conducted four experiments to examine how changes in tasks and instructions would impact response time patterns.

In the first experiment, 42 students from the Netherlands were selected and divided into two groups: High-Proficiency (HP) and Low-Proficiency (LP). The experiment utilised the progressive demasking (PDM) word identification paradigm, where participants were required to complete two blocks of 80 items each in their respective languages. The recognition of target words was heavily impacted by the number of orthographic neighbours in the non-target language, with English (L2) speakers experiencing a significant inhibitory effect of neighbours of Dutch in both the participant and item analysis, while Dutch (L1) speakers only experienced the inhibitory effect of neighbours of English in the participant analysis. The second experiment used the same materials and tasks as Experiment 1 but had only one block of items with both English and Dutch words presented randomly. The language of instruction and feedback was counterbalanced, with one group receiving them in Dutch and the second group in English. Increasing the number of non-target language neighbours had a significant inhibitory effect on both English and Dutch target items, confirming that non-target language neighbours influence the identification of targets in the PDM task. The pattern of within-language neighbourhood effects was the same as in Experiment 1, with a facilitatory effect observed for English target words and Dutch words continuing to show a significant inhibition effect.

The third experiment involved generalised lexical decision tasks with forty-eight bilinguals in Dutch and English. They were asked to determine whether the presented string of letters was an English or Dutch word or a non-word. The experiment results indicated that Dutch neighbours inhibited English target items, while within-language neighbours facilitated it. Moreover, the results indicated that L1 significantly impacted the participants' performance in identifying non-word stimuli. To investigate these results further, the last experiment tested the exact English words with a different Dutch-English bilingual group and an English monolingual control group, and researchers found that the responses of English monolinguals were unaffected by the number of Dutch neighbours. In contrast, the responses of Dutch-English bilinguals were significantly influenced, even though there were no Dutch stimuli. This finding supports the idea that knowledge in the non-target language can impact language processing.

Van Heuven et al. (1998) found that bilingual individuals process both of their languages simultaneously, with inhibitory effects occurring between words from different languages. They proposed the Bilingual Interactive Activation (BIA) model to explain this phenomenon. The BIA is a bilingual written word recognition algorithmic model that shares the monolingual Interactive Activation model's basic architecture and parameter settings (McClelland & Rumelhart, 1981). It uses non-selective bottom-up processing where letters activate words from both languages in an integrated lexicon. Additionally, it implements language-specific top-down processing where language nodes selectively inhibit activity in words of the other language.

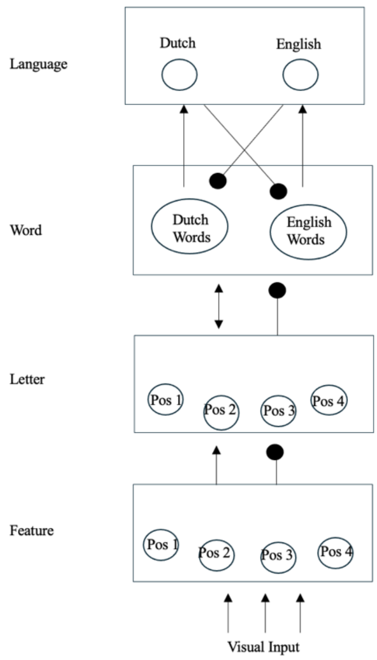

Figure 2. An illustration of the mechanism of the BIA model (Based on Van Heuven et al., 1998, p. 475)

This model assumes that when a string of letters is presented, visual input affects particular features (visual characteristics of a letter) at each letter position, exciting letters containing these features while inhibiting letters lacking them. Activated letters then excite words in both languages, and all words inhibit each other at the word level. Language nodes collect activation from words in their respective languages and inhibit active words of the other language. In this model, letters are identified based on their features. For instance, the feature

"I" might represent letters like "H", "P", and "B". When two features are combined, it causes a higher activation for certain letters. For example, when the feature "I" is combined with the feature "Ɔ", it causes a higher activation for the letters "P" and "B", and a lower activation for "H". When the feature "Ɔ" is added, "P" is excluded, which leaves "B" as the candidate with the higher level of activation. At the letter level, the position of a letter in a word also influences activation. For instance, if the letter "B" is the first letter of a word, it activates all the words that start with that letter that the subject knows. When "B" is followed by "R", this causes activation for all the words that the subject knows that begin with "BR". Finally, when "A" is added, the unit "BRA" can be formed. If this sequence is a word that the individual is familiar with, it is automatically recognised and activated as a word in their mind. Nevertheless, if the word exists in both languages the subject knows, such as "BRA" (Norwegian for "good" and an article of underwear in English), the subject must decide which concept the word refers to. If the target language is English, the concept of "brassiere" will be activated more than the Norwegian "good".

It is worth noting that the BIA model does not offer any insight into how language proficiency affects inhibitory processes in bilingual individuals.

5.3 The Revised Hierarchical Model

The Revised Hierarchical Model (Sunderman & Kroll, 2006) suggests that in mapping words to their respective concepts, L1 words have a direct link to their meanings, while the early stages of L2 acquisition involve relying on L1 translation to access meaning. This means that only proficient L2 users can directly access the conceptual meaning without needing L1 translation, and that less proficient L2 users might have more difficulties rejecting a word if the L1 translation is similar in form producing an inhibitory effect, which indicates that proficiency in L2 does affect word recognition and consequently reading.

Sunderman and Kroll's (2006) study tested the predictions of the BIA model and the revised hierarchical model (RHM) (Talamas, Kroll and Dufour, 1999), to explore various aspects related to the processing of words in a second language. Specifically, the researchers aimed to investigate whether the lexical information in the first language gets activated when processing words in the second language. Additionally, they wanted to determine if the activation of lexical information in L1 differs for L2 learners based on their proficiency level. The study also examined if access to the meaning of L2 words increases with increasing proficiency and, whether grammatical class serves as a cue to lexical status, and if it is differentially effective for more and less proficient second language learners. This study is relevant to our understanding as it can address difficulties that L2 readers encounter while reading in their second language and provide evidence that proficiency in L2 plays a role in how a word is procced.

The study involved 107 bilinguals of English and Spanish who filled out a language history questionnaire where they rated their reading, writing, speaking, and oral comprehension skills in both their L1 and L2 on a scale of 1 to 10. The researchers used a Reading Span Task to evaluate the participants' cognitive abilities. This task was explained in section 4.1 (Daneman & Carpenter, 1980). After the Reading Span Task, the participants were asked to complete a Picture-Naming Task. They were shown 40 pictures of dictionary-like drawings and asked to name each picture aloud in Spanish as quickly as possible, following 10 practice trials.

In their experiment, Sunderman and Kroll (2006) created a set of 48 correct translation pairs (e.g., *cara-face*), each with 6 distractors - 2 for each of 3 different conditions (same and different grammatical class). The first condition consisted of words related in orthographic form to the first item in the pair (e.g. *card-care*). The second condition included words spelt similarly to the second unit of the pair (e.g., *fact-fast*). The third condition included words related in meaning (e.g. *head-pretty*). The participants' task was to identify quickly whether two words were translation equivalents. The L2 (Spanish) word was presented first, followed by the L1 (English) word. Each trial started with a button press, and the L2 word was displayed for 400ms, followed by a blank screen for 100ms before the second word appeared in the same position and remained there until the participant responded. In the experiment, the Bilingual Interactive Activation model and the Revised Hierarchical Model were tested for their predictions in word recognition. The BIA model posited that form similar words like "*gato*" and "*gate*" would compete, leading to longer response times. In contrast, the RHM model predicted that lexical activation would happen at the level of translation equivalents, such as "*gato*" and "*cat*". The RHM model also predicted that response time would decrease as L2 proficiency increased, with skilled users responding faster than less skilled users. The experiment's findings showed that both models were correct in their predictions. Both highly skilled and less skilled L2 users exhibited activation of lexical form neighbours. However, only less skilled learners activated the L1 translation equivalent, supporting the RHM model's predictions. Moreover, the experiment revealed that interference decreased or vanished when the two words belonged to different grammatical classes. The BIA and RHM models did not consider the possibility that interference could vanish when the word pair belonged to different grammatical classes, but it has been incorporated into the revised edition of the BIA (BIA+). Interestingly, the experiment's results showed that both more and less proficient learners experienced inhibitory effects for meaning-related distracters, which contradicts the predictions of the RHM model. Moreover, the less-skilled group showed sensitivity to conceptual information in processing L2 and that grammatical class knowledge could override the effect of similar lexical forms, which was an unexpected finding (Sunderman & Kroll, 2006).

Sunderman and Kroll (2006) found that lexical form relatives and translation equivalents influence the performance of less-proficient learners in their native language (L1). Inhibition occurred in form-related lexical neighbours regardless of proficiency. Additionally, they discovered that conceptual meaning can be accessed through the second language (L2) without always needing to access L1 first.

5.4 The Inhibitory Control Model

Inspired by the Revised Hierarchical Model (Sunderman & Kroll, 2006), which states that bilinguals have extra language inhibition requirements than monolinguals, Green (1998) developed the Inhibitory Control Model (IC model or ICM), which explains the various levels of control that come into play during bilingual word processing. This model highlights the importance of inhibition, which refers to suppressing irrelevant words in a non-target language to facilitate language selection. The activation level of non-target language words determines the degree of inhibition. Therefore, the ICM offers insights into how the semantic system functions when navigating between languages, selectively activating relevant lexical nodes while concurrently inhibiting irrelevant ones. The IC model suggests that language tasks are accomplished by activating language task schemas and coordinating functional circuits that regulate output by activating and inhibiting tags at the lemma level. The activation of specific lemmas depends on the input from external sources or the conceptual system.

The IC model is based on three key assumptions. Firstly, it proposes that inhibition is reactive, meaning that inhibition only comes into play after the lexical nodes are activated. Additionally, the activation level is directly proportional to the degree of inhibition, meaning nodes with higher activation will result in more inhibition. Secondly, the model suggests that the lexical nodes of the non-target language can interfere with the process of lexical selection in the target language. Finally, according to the model, the processing between the lexical and sublexical levels is discrete, which means that phonological activation is limited to the selected lexical node only.

The level of suppression needed is connected to the activation of lexical nodes, as per the IC model. Therefore, proficient bilinguals will require more suppression, leading to greater inhibition. Conversely, less skilled bilinguals in their non-target language will require less inhibition. Based on this, Green (1998) suggested that lexical concepts are distinct for each language. For example, a bilingual who speaks Norwegian and English would have two distinct lexical concepts for any object. When you attempt to express a thought, the lexicalization process activates a lexical node corresponding to the appropriate lexical concept. The selection process incorporates a checking mechanism that ensures that the lexical node corresponds to the intended lexical concept of the specific language. As a result of this checking mechanism, inhibiting incorrect lexical nodes is unnecessary because the process guarantees that the chosen lexical node matches the intended language-specific lexical concept. It is worth noting that while the Inhibitory Control Model assumes the existence of language inhibition, the model can account for bilingual language selection without requiring inhibition due to the checking mechanism (Kroll & De Groot, 2005).

In brief, we have examined some key models related to the processing and suppression of words in bilingual contexts, including language activation and suppression. The evidence strongly indicates that language activation is non-selective, and that orthographic neighbours impact the processing of individual words during reading tasks. However, our study focuses on how language and lexical neighbourhoods are processed when reading sentences. As few studies have investigated this issue, we will consider the study by Pélissier et al. (2022), which provides valuable insights into the topic and serves as a basis for this paper.

6. L2 sentence reading and eye-tracking

Pélissier et al. (2022) looked at how proficient Norwegian-English bilinguals process sentences when reading in their second language (L2) and the influence of neighbouring words while doing so. They investigated the impact of the distance between the prime and target words (short vs. long) and the overlap between the two words. The neighbouring words had either onset overlap (e.g., *green-greet*) or rhyme overlap (e.g., *game-fame*). Furthermore, the researchers examined how individual differences in cognitive skills contribute to these effects. In their experiment, the data of 48 Norwegian-English proficient bilinguals was analysed. The study used 128 pairs of sentences consisting of Related and Unrelated versions, with the prime being an orthographic neighbour of the target word in the Related version, see Table 1. Four conditions were created by combining different levels of the factors Overlap and Distance. The Related version had prime and target words that overlapped in both orthography and phonology, and differed by no more than one letter. The target word was always less frequent than the prime or the control word. The stimuli were divided into two lists, and sentences were pseudo-randomised to ensure that participants never saw more than two related sentences in a row.

Short – End	The scary house was **brown** [**blue**] with a golden CROWN painted over the door.
Short – Begin	He counted up to **seven** [**eight**] knights that could SEVER the dragon's head.
Long – End	The alarm had a red **patch** [**stamp**] that I noticed far too late after opening the HATCH to the cellar of the house.
Long – Begin	Drinking the old **paint** [**juice**] caused Leif to experience lasting and severe stomach PAINS and he was rushed to the hospital.

Table 1. Example of stimuli (Pélissier et al., 2022, p. 387)

The study comprised three parts: a language history data collection, additional tasks, and the eye-tracking experiment with sentence reading. The language history data was collected using a modified version of the LEAP-Q questionnaire (Marian, Blumenfeld & Kaushanskaya, 2007). The study included additional tasks to collect measures of proficiency, which included the York Assessment of Reading Comprehension (Snowling et al., 2009), spelling test, British Picture Vocabulary Scale 3 (Dunn et al., 1982), elision, non-word repetition, sentence acceptability judgment, and Gray Silent reading (Wiederholt & Blalock, 2000). The participants were required to complete the tasks, and the results were analysed to determine proficiency.

According to their results, bilingual individuals encounter the influence of word neighbours while reading, just like monolingual individuals. However, the effect is somewhat slower for bilinguals, which suggests a slower processing speed. Individual differences modulated the effects found, and the key factor is phonological. During reading, better phonological decoders are more sensitive to the visual similarity between words and the position where the overlapping letters occur. On the contrary, poor phonological decoders are less influenced by these factors. The effect of inhibition at close distance is related to the activation and preservation of L2 phonological codes rather than the individual's proficiency in L2 reading. The results of their study reveal that in a second language, individual words in a sentence affect each other. However, this interference mainly depends on the reader's proficiency in phonological decoding and reading skills. The key findings of the research suggest that form-related priming in sentence reading is a substantial and resilient effect in language reading, as it replicates in second-language reading what has been previously established in monolinguals.

7. Examining Bilingual Profile and Proficiency in L2

This thesis aims to investigate the impact of reading neighbouring words in the same sentence and different sentences on the bilingual reading process. Additionally, we aim to explore how these effects can be related to the bilingual profile and L2 proficiency. While we did use a revised version of the Language Experience and Proficiency Questionnaire (LEAP-Q) to assess the bilingual profile of our participants so that they would fit into our required profile, it is not a major focus of our analysis. According to Marian et al. (2007) and Delgado et al. (1999), self-assessment is reliable for gathering data about an individual's bilingual profile.

In the following section, we will briefly explain our study, and then provide a section detailing the methodology and the procedures.

8. The present study

As previously mentioned, the purpose of this study is to enhance the existing knowledge on bilingualism and cognitive processes, building on the seminal studies conducted by Pélissier, Haugland, Handeland, Urland, Wetterlin, Wheeldon and Frisson (2022), and Frisson, Koole, Hughes, Olson and Wheeldon (2014b). The former study successfully replicated the outcomes of monolingual research with bilingual subjects, examining the interference caused by L2 reading skills, particularly phonological decoding, by manipulating the distance between primer and target words. The latter study investigated crucial aspects of the effect of relatedness, including orthographic and phonological factors, as well as rhyme and alliteration in L1 sentence reading. Moreover, it examined inhibitory effects under different conditions, such as short and long-distance conditions and the strategic use of full stops.

Our study investigated second language reading and the relationship between reading skill and inhibitory neighbourhood priming. Our study aimed to investigate whether individual differences can affect the speed at which a reader recognises a word after reading a neighbouring word (e.g., scars-scarfs) at a short (3-4 words in between) and long distance (8-9 words in between). We also wanted to determine whether the presence of a full stop between neighbouring words, in each distance condition, can reduce inhibitory effects. Lastly, we aimed to explore whether highly proficient bilingual readers experience stronger and longer-lasting inhibitory effects than less proficient ones.

Based on the research discussed so far in this paper (Frisson et al., 2014; Pélissier et al., 2022), we can make several predictions. For instance, it is likely that skilled readers may inhibit the prime's neighbours more, making it harder to recover later in the sentence. However, inhibitory priming effects should disappear when the distance between the prime and target increases. Additionally, skilled readers would show inhibition priming, while less skilled readers may show facilitation in the long condition. Furthermore, a sentence boundary can cause skilled readers to discard low-level details and suppress their memory of specific details. Finally, individual differences can affect the extent of inhibitory priming effects when reading in a second language. According to the Bilingual Interactive Activation model (Van Heuven et al., 1998), bilinguals with an extensive vocabulary are more likely to experience a greater inhibition effect when encountering a neighbouring word due to increased lexical competition. On the other hand, the Revised Hierarchical Model (Sunderman & Kroll, 2006) predicts that less skilled readers may experience greater inhibition as they rely on translation to access conceptual meaning. Finally, the Inhibitory Control Model (Green, 1998) suggests that highly proficient bilinguals may exhibit stronger and longer-lasting inhibitory effects.

Our first task will test whether bilinguals are affected by a full stop and/or the distance between the prime and target word while reading, as monolinguals were in Frisson et al.'s (2014b) study. As we aimed to investigate if their findings (Frisson et al., 2014b; Pélissier et al., 2022) are replicable when inhibition, working memory and proficiency skills are taken into consideration, we measured participants' inhibition skills, working memory and L2 proficiency. To measure participants' inhibition skills, we conducted the *Flanker Task* and *Word Naming Task* (adapted from Friedman & Miyake, 2004). The former task assessed the effectiveness of cognitive processing and the ability to inhibit irrelevant information. The later task was a cognitive assessment that measured verbal processing and attention, that aimed to assess the impact of distractor words on a participant's ability to selectively attend to and process relevant information. We utilised two tasks to evaluate the participants' working memory and cognitive processing abilities. The first task was the *Reading Span Task*, which can be found on cognitivetools.uk and has been modified based on Stone & Towse (2015) and von Bastian et al. (2012). This task required participants to recall a number while simultaneously evaluating the semantic acceptability of a sentence to assess their capacity to store and process information simultaneously. The second task was the *Digit Span Memory Task* (Walters & Caplan, 2003), where participants were presented with a series of numbers and asked to repeat them back in reverse order to evaluate their cognitive abilities. Lastly, to evaluate the participant's L2 proficiency three tasks will be used: *Word Attack* (Snowling et al., 2009), a reading comprehension task that evaluates an individual's ability to read and pronounce words accurately, where participants were required to read aloud the words as they appear on the screen to assess an individual's reading and pronunciation ability; *LexTALE* (Lemhöfer & Broersma, 2012), a lexical decision task that assesses the lexical proficiency of individuals in English, where participants had to decide if the presented letter strings is a word or a pseudoword in order to measure their lexical proficiency in English; and the *Author Recognition Test,* a tool developed by Stanovich and West in 1989, later adapted for a British audience at the University of Birmingham, where participants were required to identify whether the presented name belonged to an actual author or not to evaluate their cognitive abilities related to author recognition.

To conduct a precise correlation analysis between tasks, it was necessary to convert all scores to Z-scores. This conversion facilitated a more comprehensive analysis of the scores. The Z-score is a measure of how many standard deviations a given measurement is above or below the population mean of a specific size where χ is the observed measurement, μ is the expected measurement (population mean), and σ is the population standard deviation (Curtis et al., 2016). Essentially, the Z-score describes how far a measurement is from the average in terms of standard deviation units.

The main manipulations of the experiment were sentence structure (1 or 2 sentences), relatedness (Related/unrelated) and distance (short/long). All conditions occurred within each subject. There were four versions of the experiment, with eight lists for each version. Since each participant only saw one version of each sentence, 64 participants were tested to run each of the 32 lists twice. Also, the neighbouring words in this study were controlled so that there were the same amount of neighbouring words that had an onset overlap (e.g., *speak-spear*) and a rhyme overlap (e.g., *game-fame*) within each block of the related condition.

9. Methods

Table 2. Study components.

Sentence reading experiment	What is measured	Duration
Eye-tracking	Eye movements	45-60 minutes
Additional Tasks	Skill measured	Duration
LEAP-Q	Linguistic profile and self-rating of proficiency	20 minutes
Flanker Task	Non-verbal - Competition resolution	10 minutes
Word Naming Task	Verbal - Competition resolution	15 minutes
Reading Span Task	Verbal - Working memory	10 minutes
Digit Span Memory Task	Non-verbal - Working memory	5 minutes
Word Attack	Decoding - Second language (English) proficiency	5 minutes
LexTALE	Vocabulary - Second language (English) proficiency	4 minutes
Author Recognition Test	Authors recognition - Second language (English) proficiency	5 minutes

9.1 Participants

A total of 64 individuals, who were native speakers of Norwegian and had English as their second language, participated in the experiment. However, two of them were not tested during the results analysis, so the data in this thesis is based on sixty-two participants. The participants were aged between 18 and 35 and had no other languages spoken at home during their upbringing. They had no language impairments, such as dyslexia or stuttering, and had normal or corrected-to-normal vision (with glasses or contact lenses). Most participants were undergraduate students at the University of Agder. After completing the experiment, participants were compensated with a gift card worth 200 NOK for the UiA bookstore. All of them provided written informed consent.

This research has received ethical approval from the Norsk senter for forskningsdata (NSD ref. 616216).

9.2 Sentence reading experiment

9.2.1 Materials

9.2.1.1 Experimental words

The prime and target words were both orthographically and phonologically similar, differing by only one phoneme or grapheme in the same position. There were two positions in which the words could differ; they could differ on the onset position (e.g., tale-kale), and on the rhyme position (e.g., scarf-scars). None of the prime/target/control words were cognates or bilingual homographs/homophones in English or Norwegian; each of these had a maximum of two syllables. Avoiding words that were cognates or bilingual homographs/homophones in both languages ensured that the words used in the experiment did not have any potential confounding effects on the results. This allowed the experiment to measure the specific effect more accurately being studied without interference from other factors that may influence language processing. Our main interest was to study the lexical representations in the L2 without any influence from L1. Further, the target word was less frequent than the prime or control words as shown in Table 3, with frequency information taken from CELEX (The CELEX database, Baayen et al. 2001).

Table 3. Frequency per million words in short and long-distance conditions.

	Short	Long
Control	67.83 (73.65)	75.29 (100.45)
Prime	69.34 (77.56)	71.02 (80.91)
Target	14.85 (17.37)	16.03 (22.43)

9.2.1.2 Experimental sentences

The sentences in the experiment were intentionally created to be clear, unambiguous, grammatically correct, plausible, and with a low degree of constraint. The sentences were carefully selected to be similar in length and equivalent in syntactic and semantic complexity.

There were 192 quadruplets with 4 versions of each sentence. 96 short-distance prime-target sentences and 96 long-distance prime-target sentences were included. The short-distance groups had between 3 and 4 words separating the prime/control from the target, while the long-distance groups contained 8 to 9 words between them.

Each sentence had four versions with variations in relatedness (form-related prime or unrelated control) and structure (1 sentence: prime and target in the same sentence; 2 sentences: prime and target in different sentences). Table 5 provides examples of experimental sentences with primes in bold and targets in italics. Table 4 provides information on the distance between the prime and the target.

There were two sentence structures for both short and long-distance sentences: one sentence and two sentences. Punctuation was controlled in the two-sentence versions, with half of the short sentences (48 out of 96) and half of the long sentences (48 out of 96) having punctuation right after the prime. See Appendix A to view the complete list of stimuli.

Table 4. Distance between prime and target in each condition.

	Short	Long
Length of sentence (NB of characters)		
1 sentence	77.74 (11.17)	104.17 (11.67)
2 sentences	80.25 (11.55)	103.88 (11.53)
Number of intervening words		
1 sentence	3.08 (0.70)	8.75 (1.32)
2 sentences	3.14 (0.90)	8.77 (2.10)
Length of intervening section (NB of characters)		
1 sentence	13.39 (3.61)	42.85 (6.51)
2 sentences	14.34 (4.18)	44.10 (10.45)

9.2.1.3 Fillers

To prevent any potential biases or patterns in experimental materials, filler sentences were included. These filler sentences are strategically placed at the beginning of each block to disrupt any anticipated patterns or expectations that participants may have. By doing so, the experiment can maintain a fair and unbiased approach, allowing for accurate data collection and analysis. These sentences are not constructed with any manipulation, they do not have any correlationship in them.

The reading experiment included 13 filler sentences. Five filler sentences were presented before the first reading block to acclimate the participants to what they were expected to do throughout the experiment. Each of the 8 blocks had a filler at its start (Appendix A provides the filler sentences).

9.2.2 Design

The experiment consisted of four different versions, each with eight lists, resulting in 32 different lists. The four versions were designed so that each version of each group of four items was in a different version of the experiment. The aim was to present an equal number of sentences from each category in each version of the experiment, while also accounting for any potential order effects. Each version of the experiment contained an equal number of sentences from each category, which were divided into eight blocks. Each block contained the same number of sentences from each category.

The eight lists of each version corresponded to eight rotations of the block, so each block appeared in all different positions. The sentences in each block were presented in a fixed pseudo-random order to avoid any potential biases. There were eight pseudo-random blocks containing the stimuli, and each subject was exposed to all eight. All participants were presented with an equal number of related and unrelated sentences, with a maximum of two related sentences in a row.

Each block consisted of 25 sentences from each category, and the blocks were rotated to ensure fair distribution of data and to prevent repetition of questions for each participant. After each sentence, participants were required to answer a comprehension question. These questions were randomly presented and applied to only 25% of the sentences.

This design ensured that each category was presented an equal number of times in each version of the experiment, while also accounting for any potential order effects. The randomised presentation of sentences and questions aimed to minimise potential biases, and the rotation of blocks aimed to ensure that the data was evenly distributed across all participants.

Table 5. Example of experimental sentences for the different conditions (**primes** in bold, targets in *italics*)

Distance	Structure	Relatedness	Example
Short	1 sentence	Related	I had to pay the **bill** before I got the *pill* the doctor prescribed.
		Unrelated	They went to the **fair** and brought a *cake* to give to the family.
	2 sentences	Related	Then it was his turn to **speak**. A metal *spear* was thrown at him.
		Unrelated	They looked at the **wave** quietly. Their *mood* changed a lot.
Long	1 sentence	Related	He knew it would **lift** his mood to sit down for the day and *sift* through the evidence they had collected.
		Unrelated	Sarah searched the **shop** just up the street from me and found a new *marker* to use for her notes.
	2 sentences	Related	Louise decided to **call** the guy she met yesterday. He was *tall* and quite good-looking.
		Unrelated	Clarence noticed a **flag** on the ground. He was about to *leap* over the edge of the cliff.

9.2.3 Apparatus

The SR Research Eyelink 1000 Plus Camera was used to obtain eye movement data. The sample settings were set at 500Hz. Although both eyes were used for viewing, only data from the right eye was recorded. To improve the stability of the recording, a headrest, which was 70 cm away from the screen and 55 cm away from the tracker, and a target sticker were used for the subject. The PC used in the booth was a Lenovo ThinkVision T2454p monitor with a resolution of 1900x10801 and refresh rate of 60hz. The keyboard was a 24-inch Logitech K120 USB wired keyboard, and the mouse was a Logitech M510 wireless mouse. The speakers used were Logitech Z150 which played the output from the experimenter's microphone, and Creative Labs N10225 which played the output from the PC. The microphone used was Røde VideoMic NTG. Participants who sat close to the booth desk without leaning forward were approximately 75-80 cm away from the screen.

9.2.4 Procedure

During the experiment, all communication between the experimenter and the participants was conducted in English. The participants were guided into an isolated booth located in the Experimental Linguistics Lab, where the task was to take place. The participants were asked to remove any make-up they were wearing, if any. Once inside the booth, participants were requested to place a sticker between their eyebrows. This sticker is important since it enables the tracker to locate the left eye pupil of the participants, which in turn allows us to monitor the eye movements of the participants while reading.

The participants were instructed to sit in front of a computer screen and to utilise a Norwegian QWERTY keyboard. An eye-tracking camera was positioned under the screen to monitor their eye movements. They were asked to place their chin on the chin rest and adjust their chair for a comfortable seating position, with their eyes aligned with the top half of the screen. The participants received instructions on how to operate the computer during the experiment, which included the location of the sentence and which keys to use. They were informed that the experimenter could hear them at any time if there were any problems, and the experimenter could also communicate with them through a speaker.

Before starting the experiment, the experimenter had to set up the eye-tracking equipment correctly. This involved selecting the pupil of the participants' eye on the global image, transferring the eye image to the display monitor, adjusting the camera focus, and fine-tuning the pupil threshold. The participants were then asked to look at the four corners of the computer screen to ensure there would be no additional reflection of the eye when recording the eye movements. After the setup, the experimenter carried out a calibration process and validated the eye-tracking system to ensure that the error values were below the required threshold of 0.5. To do this, the participants were instructed to look at a series of fixation points that appeared on the screen until they disappeared, without anticipating where the next point would be. This was done to ensure that the participants' pupil was detected accurately.

The sentence reading experiment began with five practice sentences to familiarise the subjects with the controls for the experiment. The experiment consisted of eight blocks of 25 sentences, with a control sentence at the beginning of each block. A "PAUSE" screen separated each block and allowed the subject to take a short break. For each trial to start, the participants had to look at the fixation point in the middle of the screen (the experimenter pressed SPACE when the participants' pupil was aligned with the fixation point), and the look at a cross that appeared on the left of the screen. Participants were presented with one or two sentences at a time on the screen during the experiment. They were instructed to read them normally and at a regular pace, in silence, and for comprehension. While reading the sentence, participants were asked to try not to blink, but they could do so if necessary. Once they finished reading, they needed to focus on the grey circle located at the bottom right of the screen and press the spacebar. This would trigger a question (25% of the time) or a statement "NO QUESTION" (75% of the time). If it was a question, the subjects had to answer it, pressing 1 on the numerical pad for "YES" and 3 for "NO", and if it was a statement, they had to respond with "YES". After the question was answered, the fixation point appeared, which the participants were asked to look at, to help the experimenter determine whether there was any need for recalibration, if not the experimenter would continue with the next sentence.

This part of the experiment took, in general, between 45 to 60 minutes to complete.

9.3 Additional tasks

9.3.1 Materials

It should be noted that the materials employed for tasks that involve the integration of textual elements, such as quotations or words/names, are readily accessible in Appendix H.

9.3.2 Design and procedure

The additional tasks are to measure each subject's working memory, ability to elicit relevant information, and their English proficiency. All the additional tasks run in Psychopy 2023.2.5.

9.3.2.1 Cognitive tasks

9.3.2.1.1 The Flanker Task

The *Flanker Task* is a cognitive test that evaluates attention and response inhibition. The task involved presenting a fixation cross for 800 milliseconds, followed by a set of five arrows located either above or below the cross. The main goal of the test was to press the corresponding key on the keyboard (left or right arrow) quickly and accurately based on the direction of the central arrow within 5000 milliseconds. The task was divided into a practice phase consisting of 24 trials and a main phase consisting of 192 trials, further divided into two blocks. Half of the trials were incongruent, and the other half were congruent. The primary outcome measure was the difference in reaction time between the two types of trials.

Participants were shown a fixation cross, followed by a set of arrows above or below the cross. They had to quickly and accurately press the corresponding key (left or right arrow on the keyboard) based on the direction of the central arrow. To ensure better concentration, the participants were left alone in the booth during the task, and the duration was approximately 10 minutes. After completing the task, participants could either knock on the door or open it to signal their completion. This allowed the experimenter to provide instructions for the next task.

9.3.2.1.2 The Reading Span Task

The *Reading Span Task,* available from cognitivetools.uk, described in Stone & Towse 2015, with Tatool (von Bastian et al. 2012), is a complex span task designed to assess working memory and cognitive processing. The task was similar to an operation task and comprised three trials for each level of span, which ranged from 2 to 6. It is important to note that the trials were not randomised, meaning that participants completed all span 2 trials before advancing to span 3, and so on. The task assessed working memory capacity by measuring outcomes like response times, accuracy in semantic judgment, and correct sequence recall.

Participants were presented with a number to remember and a sentence to evaluate for semantic acceptability. They were instructed to remember a number between 1 and 99 while judging the semantic acceptability of a sentence (e.g. “Ducks wear tennis shoes”). "). After making the semantic judgment, participants were tasked with restituting the previously remembered numbers in the correct order. To complete the task, participants were instructed to indicate when they were finished after being left alone in the booth for concentration purposes. The task’s duration was approximately 10 minutes.

9.3.2.1.3 The Digit Span Memory Task

The *Digit Span Memory Task* (Walters & Caplan, 2003) is designed to assess an individual’s working memory capacity. It focuses on the person’s ability to store and manipulate data in their memory. The task involved presenting verbally a series of numbers, which the participants had to repeat in reverse order as accurately and quickly as possible. There were five trials for each span level, ranging from span 2 to 8. The maximum span length at which participants scored three or more correct responses out of the five trials was used to determine their "Overall digit span." If participants scored two correct responses on the next span block, an additional 0.5 was added to the overall digit span score. The scoring method considered both the accuracy and flexibility of the participants' backward digit span performance across different span lengths.

During the experiment, participants sat in front of the examiner. The examiner verbally presented a series of numbers, one number per second, in a consistent rhythm. The participants were then required to repeat the numbers in reverse order, immediately after the examiner had finished presenting them. Any errors were noted on a Scoring Sheet, see Appendix C. The participants were not given the opportunity to hear the series of numbers again or write them down. It took about 5 minutes to complete the task.

9.3.2.2 Language tasks

9.3.2.2.1 The Word Naming Task

The *Word Naming Task* (adapted from Friedman & Miyake 2004 but without the priming trials), involved presenting two words on the screen differentiated by colour (green and blue, designed to be colour-blind-friendly). The task involved a practice phase with three trials and a main phase with 168 trials, including 112 distractor trials and 56 no distractor trials. All stimuli were three-letter nouns —CAT, POT, TIE, CUP, TIN, PAN, PET, COW— starting with an unvoiced plosive to facilitate voice key detection during analysis. The task began with a fixation cross displayed for 500 milliseconds on a black screen. This was followed by the presentation of the green target word (along with the blue word in distractor trials) at either the top or bottom of the screen for 225 milliseconds. A grey mask was then presented for 100 milliseconds, leading to a black screen that persisted until the end of the recording, with a maximum duration of 3 seconds. The practice phase consisted of three trials to help participants become familiar with the task requirements.

Participants were seated in front of a computer screen and provided with headphones so that the utterances could be recorded. One or two words were shown on the screen, and they were told to quickly say the green target word out loud while disregarding the blue word as quickly as possible. The experimenter noted any errors in an Excel file, which is provided in Appendix B. The task lasted for about 15 minutes.

9.3.2.2.2 The Word Attack

The *Word Attack* (Snowling et al., 2009) comprised seven lists, each containing ten words. The words were systematically organised in increasing levels of difficulty for reading and pronunciation. The primary measure of performance for this task was the "Error rate," which was calculated based on the number of words pronounced incorrectly. The task emphasised the participants' oral reading proficiency and pronunciation accuracy.

During the task, participants were presented with a list of ten words on a computer screen. The entire list was shown at once, and participants were instructed to read the words aloud one at a time as they appeared on the screen. After each list was completed, the next was shown when the participant was ready to continue. The participants' utterances were recorded with headphones, allowing for later analysis. Simultaneously, as the participants read the words out loud, the experimenter noted down any mispronounced words in a Scoring Sheet, see Appendix D. The task lasted for approximately 5 minutes.

9.3.2.2.3 The LexTALE

The *LexTALE* task was developed by Lemhöfer and Broersma in 2012 and consisted of 63 trials. Each trial displayed a string of letters on the screen that could be a real word or a pseudoword. The main aim of the task was to measure the accuracy score, which was derived from the number of correct responses given by the participants across the 63 trials.

Participants were instructed to respond with a YES or NO key when presented with a string of letters on the screen (pressing "J" for YES or "K" for NO on the keyboard). The participants were told only to respond YES when they were confident that the word presented truly exists in the English language. Unlike some lexical decision tasks, there was no imposed time limit for responses, allowing participants to consider their answers carefully. The participants were left alone in the booth to complete the task and asked to signal when finished. The task took approximately 4 minutes to complete, and a comprehensive list of the words used in the *LexTALE* task is available in Appendix H.

9.3.2.2.4 The Authors Recognition Test

The *Author Recognition Test* (based on Stanovich & West, 1989) involved presenting a list of 100 names, half of which were real authors, and the participants had to determine whether the presented name corresponded to a real author. The scoring system was based on a three-tier system, where the participants received 1 point for correctly identifying a real author, 0 points for incorrectly identifying a name, and -1 point for falsely stating a name. The ART was a useful way to assess participants' knowledge of authors and their ability to distinguish real authors from fictional or non-author names.

Participants were presented with names that could be an author's name or a combination of different names. When a name was presented, they had to respond YES (pressing "J" on the keyboard) if they were confident that the given name was associated with a real author, if not, they had to respond with a NO (pressing "K" on the keyboard). In this task, participants were encouraged to respond as quickly as possible, but there was no time limit for their responses. After the instructions were given, the participants were left alone in the booth to complete the task independently. They were instructed to signal once they had finished the task. The task lasted for approximately 5 minutes. The names used are available in Appendix H.

9.3.2.2.5 The language profile questionnaire

The adapted version of the LEAP-Q (Marian, Blumenfeld & Kaushanskaya, 2007) consisted of 30 questions and covered various aspects of language use such as reading, writing, speaking, and listening. The questionnaire was divided in three parts. The first part contained a screening questionnaire with 14 questions that asked for personal information about the participant, including their age, place of birth, language impairments, and years of education. The second part consisted of 9 questions about the participants' language background, including the different languages they know, the order in which they acquired them, the percentage of time they spend speaking/reading/exposed to each language, and their language preference. The third part included 7 questions about Norwegian and English proficiency. This part asked about the factors that contributed to their language learning, the time spent in each language environment, or their level of proficiency in several aspects (e.g., reading, grammar, spelling) in each language. A complete list of all the questions can be found in Appendix G.

The procedure involves self-reporting and rating language proficiency and usage on a scale of 1 to 5, where 1 indicates no proficiency, and 5 indicates native-like proficiency. The participants were sent the questionnaire by e-mail and asked to fill it out before they came to the Experimental Linguistics Laboratory. Completing the questionnaire took about 20 minutes.

9.4 General procedure

Throughout the entire process, starting from the moment the participants were greeted until after they were presented with the gift card, all communication was carried out in English. This approach was taken to help familiarise the subjects with the language and prepare them for its usage. The participants were guided to the Experimental Linguistics Lab and were provided with written instructions. If they agreed to the criteria, they were required to sign a consent form. The experimenter, together with the participants, looked over the adapted version of the LEAP-Q questionnaire (Marian, Blumenfeld & Kaushanskaya, 2007) that they had filled out at home to ensure that all the questions were answered. The consent form can be found in Appendix E and the LEAP-Q questionnaire in Appendix G.

The experiment was conducted in two parts. The first part involved a sentence-reading experiment, while the second part consisted of 7 additional tasks. The participants were asked to complete the sentence reading experiment as the first part of the study. Earlier on, a detailed outline of the procedure for this task was given. In essence, participants were directed to an isolated booth where they received all the necessary information and instructions to successfully complete the task.

After completing the sentence reading experiment, participants took a brief break while the experimenter set up the computer with Psychopy 2023.2.5 for the second part. During this break, the participants were offered water, coffee, or tea.

During the second phase of the experiment, participants completed seven tasks in a specific order, as outlined in Table 6. The first two tasks, the Flanker Task and the Word Naming Task, were administered to assess the participants' competition resolution. Subsequently, the Reading Span Task and the Digit Span Memory Task were administered to test their working memory. The remaining three tasks, Word Attack, LexTALE, and Authors Recognition Test, were designed to evaluate their second language proficiency. It is worth noting that the second phase of the experiment was conducted on a different computer in the isolated booth.

After finishing the additional tasks, the participants received a gift card worth 200 NOK for the UiA bookstore. They were required to sign a register to confirm that they had received it. Additionally, they were given the chance to sign up for future experiments in the Experimental Linguistics Laboratory.

In the following sections, we will describe the process we used to calculate the scores for the additional tasks, the correlation between each measure, and the analysis of the data collected from the eye-tracking experiment, including measures of inhibition, working memory, and proficiency. Following this, we will present the outcomes of the eye-tracking experiment.

10. Analysis

10.1 Measures for Additional tasks

10.1.1 Inhibition measure

The experimenters identified and recorded the errors for all the Inhibition Tasks (Flanker Task & Word Naming Task), which were then converted into a percentage of correct responses (see Table 6 for the results).

10.1.2 Working memory measure

In the case of working memory tasks, the average scores were measured differently. For the Reading Span Task, the average score represents the last span the participants repeated/finished correctly, as the task stopped with the first incorrect span. For the Digit Span Memory Task, the score represents the last span in which participants got a correct trial. Participants had to get through all the spans in this task, so the score indicates the last correct trial (see Table 6 for the results).

10.1.3 Proficiency measure

In measuring the proficiency tasks, the scores for Word Attack and LexTALE were calculated similarly to the Inhibition Tasks, by converting the number of correct answers into a percentage. However, the Authors Recognition Test score was determined differently. Here, the score was calculated by subtracting the number of incorrect answers (with each incorrect answer getting a -1) from the number of correct answers and then converting the result into a percentage (see Table 6 for the results).

Table 6. The average score for each additional task.

Component	Measure	Average (SD)
Inhibition	Flanker score /100	98.34 (1.56)
	Word naming score /100	98.96 (1.71)
Working memory	Reading span max span	3.61 (1.08)
	Digit span max span	4.58 (1.07)
Proficiency	Word attack score /100	86.10 (10.06)
	LexTALE score /100	84.89 (11.44)
	Authors score /100	32.06 15.79)

10.2 Correlations between individual difference measures

To assess the correlations between tasks, all scores were converted to Z-scores to put them on the same scale. The correlation matrix is shown in Table 7. The most significant finding is that the measures of proficiency skills correlate with each other, but not between the inhibition and working memory tasks; the closer the z-score is to 1.00, the higher the correlation. Word Attack has a high correlation with LexTALE (z = 0.90, p = 0.0061), and LexTALE has also a strong correlation with the Author Recognition Test (z = 0.83, p = 0.0204).

Table 7. Correlations between z scores of the additional tasks, where WN = Word Naming, WA = Word Attack, DS = Digit Span, RS = Reading Span (significant results in **bold**).

	zFlanker	zWN	zRS	zDS	zWA	zLexTALE	zAuthors
zFlanker	1.00	-0.61	-0.17	-0.64	-0.26	-0.33	-0.28
zWN	-0.61	1.00	-0.10	0.09	-0.21	-0.16	-0.22
zRS	-0.17	-0.10	1.00	0.29	-0.21	-0.25	-0.45
zDS	-0.64	0.09	0.29	1.00	0.11	-0.01	-0.01
zWA	-0.26	-0.21	-0.21	0.11	1.00	**0.90***	0.65
zLexTALE	-0.33	-0.16	-0.25	-0.01	**0.90***	1.00	**0.83***
zAuthors	-0.28	-0.22	-0.45	-0.01	0.65	**0.83***	1.00

N = 7

10.3 Eye-tracking data

Two regions of interest were reported: the target region and a spillover region, defined as the next word if it is at least four characters long or the following two words otherwise. (e.g. Whenever she sat down to **spin** wool she *spit* her tobacco into a bowl). The following three duration measures were reported: First pass dwell time (the total duration of fixations at a region before leaving the region for the first time), regression path duration (the total duration of fixations in all regions, after entering a region of interest, and before going past it), and total dwell time (the total duration of all fixations at a region). Two conditions were analysed in each region of interest and for each time measure: Distance (short, long), crossed with Sentence break (with break, without break).

10.4 Eye-Tracking Data Analysis with Inhibition, Working Memory and Proficiency Measures

Linear regression models were run separately for each distance to simplify the interpretation and make it easier to compare the results to those from Frisson et al. (2014) and Pélissier et al. (2022) since they used this approach in their study. For all models the difference in reading time between the related-unrelated conditions was the dependent variable and several factors were included as independent variables: SentenceBreak (2 levels; break/no break); proficiency (composite score); inhibition (composite score); working memory (composite score); and the interaction between sentence break and each measure of individual difference. These models were run for each region of interest. To account for the fact that the measures were repeated within participants, a random intercept per participant was added. For example, the effect of sentence break could be stronger for one participant than another.

11. Results

11.1 Reading Time Difference in Related and Unrelated Conditions – Target and Spillover area

The results reveal (see Table 8) that when reading in the short-distance condition without a sentence break, there was a facilitation effect on the regression path duration if the target was in the related condition. This means that reading time was reduced. However, when the target area was in the related condition, it took longer on the first-pass dwell time and total dwell time. In the short-distance condition with a sentence break, a facilitation effect was observed on the target area in the related condition on the first-pass dwell time but not on regression path duration and total dwell time.

Moreover, in the long-distance condition without a sentence break, the target area in the related condition had a facilitation effect on the first-pass dwell time. In the long-distance sentence break condition, the target word in the related condition had a facilitation effect on the first-pass dwell time and regression path duration but not on total dwell time.

Table 8. The difference in reading time between unrelated and related conditions on the target area in milliseconds (mean, SD between parentheses)

	Short distance		Long distance	
	No break	Sentence break	No break	Sentence break
First-pass dwell time	3.80 (60.81)	-7.14 (47.97)	-3.10 (45.76)	-4.99 (45.44)
Regression path duration	-1.98 (75.63)	18.40 (73.90)	5.30 (73.43)	-15.14 (73.49)
Total dwell time	29.81 (113.76)	27.08 (85.30)	1.13 (66.34)	9.70 (61.17)

The results (in Table 9) reveal that there was a facilitation effect observed when reading the related condition on the spillover area in the first-time pass dwell, regression path duration, and total dwell time for the long-distance with no-break condition. Furthermore, there was also a facilitation effect in the first pass dwell time for the long-distance with a sentence break condition. However, it took longer to read in the related condition on the spillover area in all areas for the short-distance conditions, and on the regression path duration and total dwell time for the long-distance with a sentence break condition.

Table 9. The difference in reading time between unrelated and related conditions (related-unrelated) on the spillover area in milliseconds (mean, SD between parentheses).

	Short distance		Long distance	
	No break	Sentence break	No break	Sentence break
First pass dwell time	8.81 (46.94)	6.93 (57.18)	-8.32 (54.35)	-1.39 (60.99)
Regression path duration	46.40 (75.00)	22.52 (102.00)	-17.15 (79.01)	10.83 (91.49)
Total dwell time	24.85 (99.37)	7.46 (71.51)	-13.67 (73.00)	7.23 (75.24)

In sum, reading time varies depending on the distance between the target word and the presence or absence of a full stop. It is important to keep in mind that the data collected is based on the recollection of all participants, which means there may be variation in reading time based on individual differences in inhibition, working memory, and proficiency skills. Therefore, the results provided should be considered as an estimate on average.

11.2 Eye-tracking data and individual difference measures

11.2.1 Short distance

11.2.1.1 Target region

11.2.1.1.1 First-pass dwell time

No significant priming effect was observed on first-pass dwell time. However, follow-up tests revealed a significant effect of proficiency (β = -12.2071, $t(98)$ = -2.161, p = .0331), showing that higher proficiency is associated with decreased reading time on the target area during the first fixation (see Figure 3a). Additionally, there was a significant interaction between proficiency and sentence break (β = -24.1717, $t(98)$ = -2.139, p = .0348). The results indicate that lower proficiency skills result in a higher inhibition priming when there is no full stop, while higher proficiency skills lead to less inhibition priming. Interestingly, proficiency skills did not have an effect when there was a sentence break (see Figure 3a).

There was also a significant interaction of working memory and sentence break (β = 21.3907, $t(98)$ = 2045, p = .0434). The results indicate that when there is no sentence break, low working memory skills result in no inhibition priming, while higher working memory skills lead to increased inhibition priming. The opposite was observed when there was a sentence break, as higher working memory skills was associated with a facilitation effect (see Figure 3b).

Finally, a significant effect of inhibitory skills was also observed (β = -12.1950, $t(98)$ = -2.345, p = .0210). Poorer inhibition skills are associated with greater inhibitory priming (see Figure 3c)

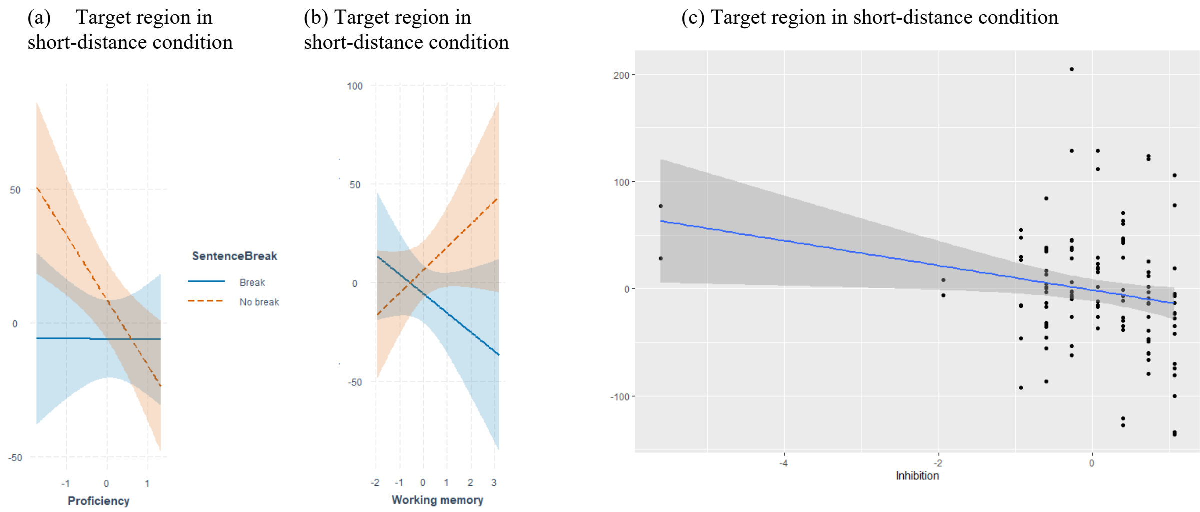

Figure 3. Individual differences effects on relatedness for first-pass dwell time: a. the interaction with proficiency, b. the interaction with working memory, c. the effect of inhibition.

11.2.1.1.2 Regression path duration

No priming effect was observed on regression path duration. Significant effects were found for proficiency (β = -16.743, t(98) = -2.083, p = .0398), with a reduction in inhibition priming when proficiency skills increase (see Figure 4a). In addition, there were marginally significant effects of inhibitory skills (β = -13.111, t(98) = -1.805, p = .0741), which indicates that the worse the inhibition skills, the higher the inhibition priming (see Figure 4b).

In sum, participants with low proficiency and inhibition skills looked back for longer than those with good proficiency and inhibition skills.

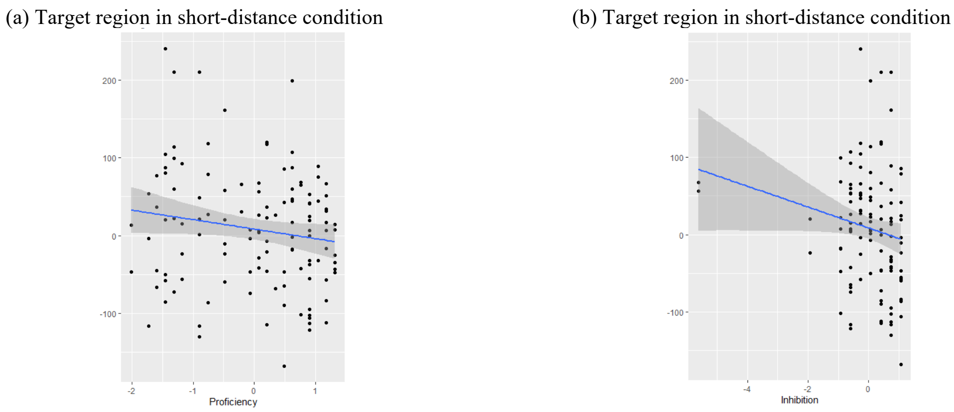

Figure 4. Individual differences effects on relatedness for regression path duration: a. the effect of proficiency, b. the effect of inhibition.

11.2.1.1.3 Total dwell time

There was a significant priming effect on dwell time (*β* = 33.287, *t*(50.000) = 3.066, *p* = .00350). Further follow-up tests indicate a significant effect of proficiency, which indicates that participants with lower proficiency skills spend more time looking at the target area (see Figure 5b).

There was also a marginally significant interaction between working memory and sentence break (β = 28.763, $t(50.000)$ = 1.811, p = .07622). Participants with better working memory spent more time looking at the target area in the absence of a sentence break, indicating an inhibition priming effect. When there is a sentence break, no effect of working memory skills is observed (see Figure 5a).

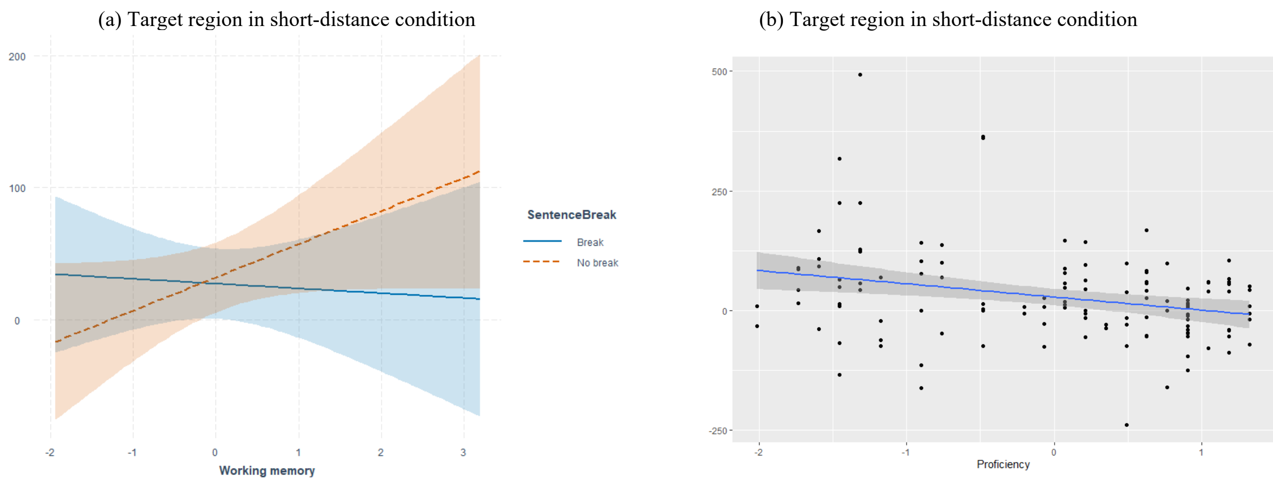

Figure 5. Individual differences effects on relatedness for total dwell time: a. the interaction with working memory, b. the effect of proficiency.

11.2.1.2 Spillover region

11.2.1.2.1 First-pass dwell time

No effects were obtained for this time measure in any of the variables.

11.2.1.2.2 Regression path duration

A significant effect of relatedness was observed on regression path duration (β = 37.514, $t(50.000)$ = 3.996, p = .000212). There was a significant effect of proficiency (β = -23.262, $t(50.000)$ = -2.275, p = .027230), with greater inhibition priming associated with participants with lower proficiency skills (see Figure 6b). There was also a significant interaction of inhibitory skills and sentence break (β = 32.423, $t(50.000)$ = 1.931, p = .059220), with greater inhibition priming associated with participants with low inhibition skills, when there was a sentence break. Participants with high inhibition skills experienced an inhibition priming effect when there was no sentence break (see Figure 6a).

(a) Spillover region in short-distance condition (b) Spillover region in short-distance condition

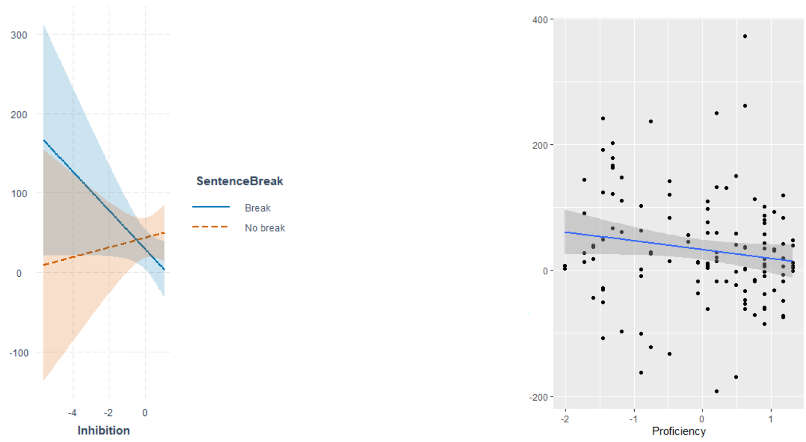

Figure 6. Individual differences effects on relatedness for regression path duration: a. the interaction with inhibition, b. the effect of proficiency.

11.2.1.2.3 Total dwell time

No effects were obtained for this time measure in any of the variables.

11.2.2 Long distance

11.2.2.1 Target region

11.2.2.1.1 First-pass dwell time

A marginally significant effect of proficiency (β = 9.860, t(49.000) = 1.844, p = .0713) on first-pass dwell time was found. The results indicate that with low proficiency skills, a facilitation effect occurred, and the opposite happened for those with good proficiency skills since they experienced a slight inhibition priming effect (see Figure 7a).

(a) Target region in long-distance condition

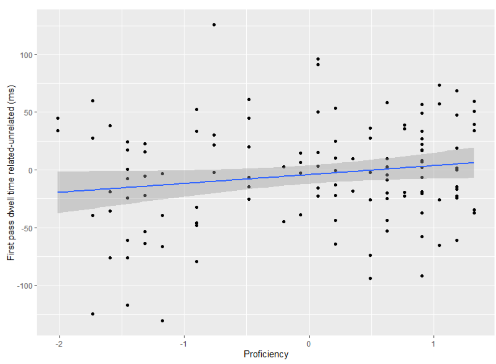

Figure 7. Individual differences effects on relatedness for first-pass dwell time: a. the effect of proficiency.

11.2.2.1.2 Regression path duration

A significant effect of SentenceBreak (β = 32.101, t(49.000) = 2.727, p = .00884), was observed for regression path duration. The results indicated that a sentence break removes the inhibition priming effect, as a slight facilitation effect was observed. Further, no inhibition priming effect was observed when there was no sentence break (see Figure 8a).

(a) Target region in long-distance condition

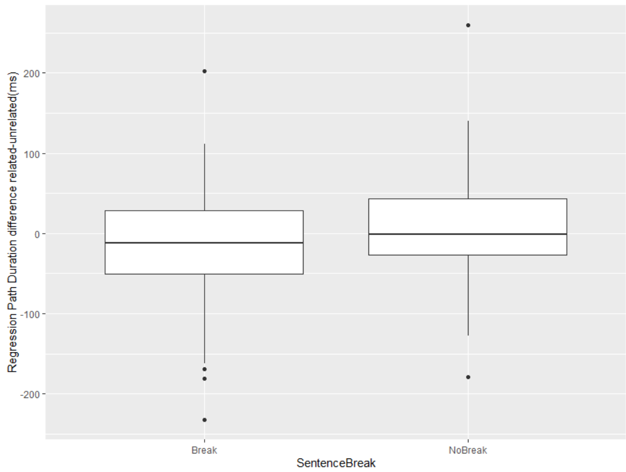

Figure 8. Sentence break effect for regression path duration: a. the effect of sentence break.

11.2.2.1.3 Total dwell time

No effects were obtained for this time measure in any of the variables.

11.2.2.2 Spillover region

11.2.2.2.1 First-pass dwell time

No effects were obtained for this time measure in any of the variables.

11.2.2.2.2 Regression path duration

There was again a significant of SentenceBreak (β = -31.2552, t(49.000) = -2382, p = .0212), but in the opposite direction compared to the regression path results on the Target region. The results revealed a higher inhibition priming effect when there was a sentence break. A slight facilitation effect occurred when there was no sentence break (see Figure 9a).

(a) Spillover region in long-distance condition

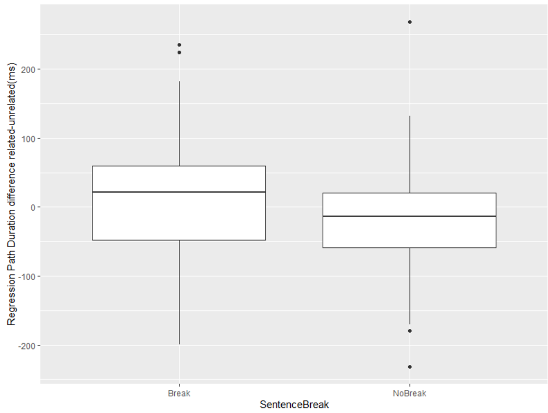

Figure 9. Sentence break effect for regression path duration: a. the effect of sentence break.

11.2.2.2.3 Total dwell time

No effects were obtained for this time measure in any of the variables.

12. Discussion

This research investigated the effects of inhibition, working memory, and proficiency skills on neighbourhood priming among proficient Norwegian-English bilinguals when reading in their L2. According to Pélissier et al. (2022), bilinguals experience similar interference from reading neighbouring words in a sentence as monolinguals, but the interference tends to occur with a delay, indicating slower processing among bilinguals. In our study, we intend to extend the findings from Pélissier et al.'s study (2022) by analysing how individual differences can affect reading form-related words within or in different sentences when these were at a short and long distance from each other.

The three issues we intended to address were whether individual differences can affect the speed at which a word is recognised while reading neighbouring words when these are at a short and long distance. We also wanted to investigate whether having a full stop between neighbouring words can lessen inhibitory effects and whether the same applies to both monolinguals and bilinguals. According to Frisson et al. (2014b), there is no inhibition effect when a full stop separates the prime and target words for monolinguals. Lastly, we want to explore whether highly proficient bilinguals experience stronger and longer-lasting inhibitory effects than less skilled readers.

The key findings were that, in a short-distance condition, we got effects associated with proficiency skills, showing that high proficiency skills are related to less inhibition. The same was true for inhibitory skills. Also, we found interesting effects on working memory that are conditioned by sentence break in the short-distance condition. Working memory skills was the only skill that, when prime and target were within the same sentence, as it increased so did the inhibitory priming effect. However, higher working memory skills facilitated the recognition of the target word when prime and target were in different sentences. Further, an interaction was observed between inhibition skills and a full stop, as those with low inhibition skills exhibited inhibition priming on the spillover region. Lastly, we found no interaction between any individual differences and the presence of a sentence break in the long-distance condition. Nevertheless, we got some effects regarding sentence break.

12.1 What did we find regarding the relationship between inhibitory and proficiency skills and word recognition when form-related words were within the same sentence?

Our findings indicate that in the short-distance condition where the form-related words were within the same sentence, high inhibitory and proficiency skills were associated with decreased reading time in the target area, meaning that those with good inhibitory and proficiency skills did not get affected by the encounter of a neighbour word while reading in this sentence condition. The opposite was observed for those with poor inhibition and proficiency skills, as their fixation time on the target region increased while reading, as they took longer to recognise the target word. We will discuss the two sets of findings, first regarding inhibition skills and then proficiency skills.

Fluent reading requires activating and suppressing possible words, which is linked to reading proficiency (Andrew & Hersch, 2010). One of the multiple mechanisms influencing reading skills (Gernsbacher, 1990) is effective suppression mechanisms, which are important for reducing mental representation activation and preventing irrelevant information from interfering with ongoing processes. Gernsbacher (1993) suggests that individuals who struggle with reading tend to automatically activate irrelevant or inappropriate information while trying to comprehend a text. As they face difficulties in suppressing such information, poor suppressing mechanisms could be why poor inhibitors took longer to process the target word when preceded by a form-related prime (with 3 to 4 words in between) in our study.

This thought is in line with De Rom and Van Revbroeck's (2023) finding that children with poorer inhibition skills had more difficulties when encountering a neighbouring word while reading. As they were more impacted by inhibitory demands, they were also found to be poorer readers. Although that does not explain why poor inhibitors did not experience inhibition priming during the long-distance condition, if they are bad at suppressing irrelevant information, they would be expected to exhibit inhibition priming to some extent. Nevertheless, a possibility could be found related to working memory, as individuals with lower reading skills tend to lose access to surface features more quickly, they are more likely to have less inhibition effect when the prime and target are further apart (e.g. Gernsbacher, Varner & Faust, 1090). We will discuss how working memory affects recognizing words while reading in more detail later, in section 12.2.

The finding that an increase in fixation time occurred on the target word during reading when proficiency skills were poor was interesting. This conflicts with the results of Pélissier et al.'s (2022) study, in which good phonological decoders exhibited inhibition effects on the target area, if we consider that highly proficient participants are good phonological decoders as one of the proficiency tasks, Word Attack, evaluates participant's oral reading proficiency and pronunciation. Further, the results could contradict the Bilingual Interactive Activation model (Van Heuven et al., 1998). Because language activation is non-selective (e.g. Dijkstra & Van Heuven, 2010; Sunderman & Kroll, 2006), bilinguals in our study experienced lexical competition from English and Norwegian. Participants with higher proficiency skills would have more lexical candidates to suppress than those with lower proficiency skills, as they could have a bigger range of L2 vocabulary since they might have gotten high scores in LexTALE. According to the Bilingual Interactive Activation model (Van Heuven et al., 1998), bilinguals with high proficiency skills are expected to exhibit greater inhibition, and those with less proficiency skills to less inhibition since they do not have as many nodes activated that need suppression. There are two possible explanations for this finding.

Firstly, as bad inhibitors exhibited inhibition priming since they might be bad at suppressing activated nodes in the non-target language and irrelevant information while reading, the same could be happening to those with poor proficiency skills. However, in our study, inhibition and proficiency measures did not correlate with each other, indicating that those with poor inhibition skills do not necessarily have to have poor proficiency skills.

Secondly, an explanation could be given by the RHM model since it suggests that proficient L2 users can understand the meaning of words without relying on translation from their L1. However, less proficient L2 users may struggle to reject a word if the translation in their L1 is similar in form, causing an inhibitory effect. Therefore, the RHM model predicts that as L2 proficiency decreases fixation time would increase. From this view, there could be a possibility that poor proficient L2 participants in our study translated words while reading for better comprehension, leading to higher inhibition priming, as participants in Sunderman and Kroll's (2006) study.

An alternative explanation is that proficient bilinguals require more time to process the priming word, causing inhibition to occur when the target word is later in the sentence, which could explain the trend in the data that in the long-distance condition, individuals with high proficiency skills had a higher fixation time in the target region than those with less proficiency skills. Again, if we consider that bilinguals with high proficiency skills are also good readers and spellers, the results are consistent with those by Pélissier et al. (2022) that supported that only good readers, in the long-distance condition, exhibited inhibition effects on the target area, which was also the case for monolinguals (Frisson et al., 2014b). And, would support the notion that there is a positive correlation between good spelling skills and stronger inhibitory priming for neighbour primes (Andrew & Hersh, 2010). Even though it is strange that when the distance between the prime and target increases (from 3 to 9), the effects of proficiency are opposing, as in the short-distance condition, those with high proficiency skills experienced facilitation effects while, in the long-distance condition, they experienced inhibition priming effects. Although, since the results from the long-distance condition related to proficiency skills were a trend and a marginal replication from previous studies, we will further analyse the effects of working memory skills while reading to see if it could explain the effects found.

12.2 What did we find regarding the relationship between working memory skills and word recognition when form-related words were within the same sentence?

Interestingly, when related words were within the same sentence in the short-distance condition, higher working memory skills resulted in increased fixation time, and lower working memory skills led to a slight facilitation effect. Working memory skills was the only skill, in the short-distance condition with the related-form words within the same sentence, that when it increased, so did the inhibition priming effect, meaning that better storing and recalling information abilities, the more time was needed to recognise a word preceded by a neighbouring word. Interactive competition models suggest that the recognition of a word may be slowed down when a neighbou's word in the same sentence is read. These models explain how word candidates compete for recognition, where presented letters activate competing word candidates.

The Bilingual Interactive Activation model (Dijkstra & van Heuven, 1998) involves activating and inhibiting language nodes to the word level and from the word to the letter level. Additionally, to inhibition at the word level. When a word candidate reaches a certain activation level, it is recognised as the best-matching solution. The Inhibitory Control Model (Green,1998) suggests that word lemmas are first activated and then inhibited, with the level of activation determining the degree of inhibition. These models predict that proficient readers would exhibit greater inhibitory priming as they have to suppress more activated lexical codes, which supports the notion that proficient readers tend to have good storing and recalling abilities of words; as they found that individuals with poor comprehension skills focused more on comprehending the sentences, limiting their ability to store and recall the final words (Daneman & Carpenter, 1980). These models would support the finding that participants with better working memory skills were more affected by encountering a form-related word at a short distance within the same sentence. Therefore, working memory skills could be the key to Pélissier et al.'s (2022) finding that good phonological decoders fixated longer on the target word in the short-distance condition, as they might have superior working memory skills. Additionally, based on the Inhibitory Control Model (Green, 1998), it was also expected that skilled readers would demonstrate stronger and more persistent inhibition priming effects. However, our data did not support this hypothesis. We did not observe any evidence that individuals with good working memory displayed inhibition priming in the long-distance condition, which is what the episodic account of lexical priming (Tenpenny, 1995) would predict. This finding contrasts with previous research by Frisson et al. (2014b), which found that even skilled readers were influenced by the presence of the prime when encountering the target after nine words. Still, it is unclear why delaying the target word by nine words would eliminate the inhibition effect, as the episodic account of lexical priming (Tenpenny, 1995) suggests that the memory trace from a word can last for a long period (days, months and even a year).

12.3 What did we find regarding the relationship between inhibition and proficiency skills and word recognition when form-related words were separated by a full stop?

One purpose of this study was to extend Pélissier et al.'s (2022) research by investigating the effects of having the prime and target words in different sentences for word recognition when reading in a second language, like Frisson et al. (2014b) investigated with monolinguals. In addition, we analysed if the effect of having a full stop is dependent on individual differences; inhibition, working memory and proficiency skills. Can a full stop between neighbouring words reduce inhibitory effects? Do readers use syntactic information when they are reading? And if they do, is it related to any reading skill in particular? These are some issues that we are going to discuss while using our study's results.

According to Frisson et al. (2014b), sentence boundaries can cause readers to suppress their memory traces and discard low-level information. Making inhibition priming effects disappear when the prime and target words appear in two subsequent sentences. Carroll and Slowiaczek (1986) suggest that syntax plays a role in processing words and sentences in L1 regarding inhibition and facilitation. They found evidence of a cancellation effect when the prime and target were separated by a comma. While their study used semantically associated words instead of form-related words, it still suggests that syntax plays a role in processing words during reading. What previous studies have found for monolinguals, correlates with our findings for bilinguals, that a full stop does cause an influence when reading. However, some interesting results were found regarding sentence boundaries for inhibitory and working memory skills in the short-distance condition. The results regarding working memory skills and sentence boundaries will be discussed in section 12.4.

It was found that the effects of inhibitory skills and their interaction with a sentence break were only present in the spillover region for the short-distance condition. When related words were read within the same sentence, those with good inhibition skills spent more time looking at the spillover region, and when the related words were in different sentences, those with low inhibition skills were more affected. For instance, the effect occurred in the spillover region as a result of the complex process of reading for bilinguals, with slower lexical access than monolinguals as they have to suppress activated candidates from the languages they know (e.g. Dijkstra & Van Heuven, 2010), and they look at the next word/words (spillover region) while still processing the target word. A similar occurrence was found in Pélissier et al.'s (2022) study. Interestingly, those with lower inhibitory skills showed sensitivity when the prime and target words were separated by a full stop as their fixation time on the spillover region increased. This effect only occurred in the short-distance condition. One possible reason for this outcome is that individuals with weaker inhibitory abilities might be more influenced by the distance/time between form-related words rather than whether there is a full stop between them. This effect is supported by competition models, which suggest that inhibition effects only appear in the short-distance condition because word activation levels decrease rapidly (Paterson et al., 2009). Nonetheless, poor inhibitors did not experience any inhibition priming when the form-related words were within the same sentence on the spillover region. An alternative explanation could be that since poor inhibitors struggle to suppress irrelevant information (Gernsbacher, 1993), they show inhibition priming when the prime and target are in different sentences, as they lack the ability to comprehend that a full stop separating sentences has a function. Poor comprehension could be correlated to poor performance on inhibitory and working memory tasks (Borella et al., 2010). According to Borella et al. (2010), individuals in their study with poor comprehension skills and weak inhibitory abilities often tend to remember irrelevant information from prior tasks. This is similar to what the participants in our study did, where they recalled and activated nodes related to the prime word from the preceding sentence, even though it was not necessary, leading to inhibition prime. It is uncertain whether an episodic memory account would predict the same outcome, as the purpose of this type of account has been to explain long-term priming effects that can last for a long period of time (Tenpenny, 1995). Nevertheless, in the long-distance, inhibition skills did not have any interactions with a full stop, which could indicate that good inhibitors use the information provided by a full stop, eliminating unnecessary information, and for less good inhibitors increased time results in decreased activation levels (Paterson et al., 2009).

When reading the prime and target words in different sentences at a short distance (3-4 words), no inhibition effects were found regardless of proficiency skills, which correlates with the findings for monolinguals that no inhibition effects were observed on the target region after a full stop (Frisson et al., 2014b). Therefore, this finding is consistent with the claim that readers are sensitive to the encounter of a full stop, and that is the natural place for them to erase their memory trace, dumping low-level information, like the spelling of words.

12.4 What did we find regarding the relationship between working memory skills and word recognition when form-related words were separated by a full stop?

Our findings revealed that there was a noticeable impact of a full stop between form-related words for word recognition. However, the findings suggest that individuals are utilising this information, and only in the short-distance condition, their utilisation is affected by their working memory capacity. When reading the form-related words in different sentences but at a close distance (3 to 4 words), high working memory skills facilitated the reading of the target word, while less good working memory skills delayed its recognition. This result is opposite of what we discussed earlier that as working memory skills increased, the time to recognise the target word also increased when there was no sentence break. These findings suggest that individuals with high working memory skills are sensitive to the information provided by a full stop and, that working memory skills interact with whether there is or not a full stop. It is interesting that if we only consider competition accounts and the episodic account of lexical priming (Paterson et al., 2009; Tenpenny, 1995) having a full stop between the prime and target word would not matter. What would matter is the distance/time between the form-related words. However, we can speculate why people with high working memory skills may spend less time recognising the target word when it was preceded by a full stop and why those with lower working memory skills increased their recognition time. It could be that better comprehenders tend to ignore low-level information like the spelling of specific words and may erase or suppress their memory trace after encountering a full stop when reading (e.g. Carroll & Slowiaczek, 1986; Frisson et al., 2014b). This is supported by research showing that good comprehenders typically have good working memory skills to better understand the text they are reading (Van den Broek, Mouw & Kraal, 2016). Individuals with poor comprehension skills tend to use more cognitive capacity to understand sentences, which can limit their ability to store and recall information (Daneman & Carpenter, 1980).

Additionally, readers with lower working memory capacities may use compensatory mechanisms, such as slowing down their reading rate or looking back at the text, to overcome obstacles that may hinder comprehension (Walcyk & Taylor, 1996). A suggestion could be that individuals with poor working memory skills may find encountering a full stop while reading to be an extra cognitive load, leading to increased interference. This can make it more difficult for them to suppress activated lexical representations and, in turn, they may spend more time recognising the target word when a sentence break separates it from the prime word. Further, perhaps individuals with poor working memory took less time to recognise a target word when it was preceded by a prime word within the same sentence, as words that were related in form are processed in a continuous flow, allowing for shared lexical activation, and facilitating the process of word recognition, instead of inhibition effects as predicted by the BIA model (Van Heuven et al., 1998).

12.5 What did we find on the effects of sentence break in the long-distance condition?

Some interesting results related to the effects of full stops on inhibition priming in the long-distance condition were found. According to the results, a sentence break removes the inhibition effect, and a slight facilitation effect occurs. In other words, independently of individual differences, we found that when there was a sentence break, the prime word helped the participants to anticipate and recognise the target word, which is consistent with Frisson et al.'s (2014b) finding that a full stop causes readers to forget low-level information, regardless of their skills. Furthermore, we got effects in the spillover region, showing that participants looked longer at this area when a sentence break was introduced. A compensation effect may be occurring, suggesting that when readers put more effort into processing information at an earlier stage (such as the target region), it requires less effort in the later stage (such as the spillover region).

13. Limitations

In our study, there may be a weakness in the selection of the inhibitory and working memory tasks. This is because all groups of additional tasks were aimed to measure the same thing. It was expected that the tasks within each skill, e.g. inhibition skills, working memory skills and proficiency skills, would correlate with each other. Nevertheless, the only tasks that correlated with each other were proficiency tasks. It is possible that the lack of correlation between the inhibition and working memory tasks could be attributed to the fact that we intentionally designed the pairs to have both a lexical and non-lexical component. As we combined the scores of each additional task group to gather a combined score for easier analysis of the results, that might have diluted the results. It is possible that we would have gotten different outcomes if there was a correlation between the tasks in each pair, as people may have different abilities with more language-based working memory and inhibition, and less language-based working memory and inhibition.

Further, even though proficiency tasks correlated with each other, that does not mean that they were the most accurate tasks. As we included LexTALE, where they had to recall if a word exists, and the Author Recognition Test, where they had to recognise an author's name, we might have lost participants who were strong readers. Therefore, if the proficiency score was based on the participant's ability to read correctly, maybe we would have gotten different results. Perhaps, that could be the reason why highly proficient participants only showed a trend of inhibition in the long-distance condition where prime and target were within the same sentence, when it was expected that they would be as affected as monolinguals in Frisson et al.'s (2014b) study.

14. Future research

One approach in future research could be to use a wider range of inhibitory and working memory tasks that either have a lexical or non-lexical component to measure the comprehension of linguistic and non-linguistic media separately. This would allow for a more comprehensive understanding of participants' abilities in these areas and to better isolate the effects of each. This could lead to a more accurate and insightful analysis of the results. For instance, using the Categorization Working Memory Span (De Beni et al, 1998) would help us identify the strengths and weaknesses of participants' working memory abilities, particularly in terms of their ability to suppress activated information and inhibit irrelevant information.

Further, future research could explore different ways of measuring reading proficiency to ensure that all participants are accurately represented, rather than potentially excluding strong readers due to the limitations of the current study's measures.

In addition, as we have in our study relatively highly proficient bilinguals. Therefore, it is difficult to determine the specific proficiency range where the observed effects related to this skill actually occurred. It would be interesting to conduct further research to investigate this in more detail.

15. Conclusion

In conclusion, this study provides further evidence that form-related primes have an impact on bilinguals' inhibition priming effect during regular sentence reading in their second language. And that inhibition, working memory and proficiency skills do affect the degree of inhibitory neighbourhood priming. The distance between the prime and the target was found to be a significant factor, with shorter distances leading to increased reading time in the target region for those with poor inhibition and proficiency skills. On the other hand, those with high inhibitory and proficiency skills were able to overcome the effect of the form-related prime and process the target word more efficiently. The study highlights the importance of effective suppression mechanisms in reading skills. Additionally, an interesting interaction was found between working memory skills and sentence boundaries in the short-distance condition, with higher working memory skills leading to increased reading time when the prime and target were in the same sentence, and decreased reading time when they were separated by a full stop. This finding emphasises the important role of working memory skills in reading sentences in a second language.

Lastly, to address the intended issues, we found that individual differences do affect the recognition speed of words while reading neighbouring words. The present experiment provides further evidence that a full stop placed between a prime and target word does have an impact while reading, indicating that readers do use this syntactic information. Further, our experiment also suggests that highly proficient bilinguals may not necessarily experience stronger and longer-lasting inhibitory effects, as we did not find enough evidence to support this prediction.

16. Sources

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

Baayen, R. H., Piepenbrock, R., & Gulikers, L. (1996). The CELEX Lexical Database (CD-ROM). *Linguistic Data Consortium.*

Becker, C. A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory & Cognition, 8*, 493-512. https://doi.org/10.3758/BF03213769

Bell, L. C., & Perfetti, C. A. (1994). Reading skill: Some adult comparisons. *Journal of Educational Psychology, 86*(2), 244–255. https://doi.org/10.1037/0022-0663.86.2.244

Bever, T. G., & Hurtig, R. R. (1975). Detection of a nonlinguistic stimulus is poorest at the end of a clause. *Journal of Psycholinguistic Research, 4*(1), 1–7. https://doi.org/10.1007/BF01066985

Borella, E., Carretti, B., & Pelegrina, S. (2010). The Specific role of inhibition in reading comprehension in good and poor comprehenders. *Journal of Learning Disabilities 43*(6), 541–552. https://doi.org/10.1177/0022219410371676

Burton, C., & Daneman, M. (2007). Compensating for a Limited Working Memory Capacity During Reading: Evidence from Eye Movements. *Reading Psychology*, *28*(2), 163–186. https://doi.org/10.1080/02702710601186407

Carr, T. H., & Pollatsek, A. (1985). Recognizing printed words: A look at current models. In D. Besner, K. G. Waller, & E. M. MacKinnon (Eds.), *Reading research: Advances in theory and practice* (Vol. 5, pp, 1-81). Toronto: Academic Press.

Carroll, P., & Slowiaczek, M. (1986). Constraints on semantic priming in reading: A reading time study. *Memory & Cognition*, *14*, 509-522. https://doi.org/10.3758/BF03202522

Coltheart, M. (1980). Reading, phonological recoding, and deep dyslexia. In M. Coltheart, K. Patterson, & 1. Marshall (Eds.), *Deep dyslexia* (pp. 197-226). London: Routledge & Kegan Paul.

Coltheart, M., Davelaar, E., Jonasson, J.T., & Besner, D. (1977). Access to the internal lexicon. In Dornick S (ed), *Attention and performance VI*: Vol.VI. Erlbaum, pp. 535–556. DOI: 10.4324/9781003309734-29

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

Curtis, A. E., Smith, T. A., Ziganshin, B. A., & Elefteriades, J. A. (2016). The Mystery of the Z-Score. *Aorta (Stamford, Conn.), 4*(4), 124–130. https://doi.org/10.12945/j.aorta.2016.16.014

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, *19*(4), 450–466. https://doi.org/10.1016/S0022-5371(80)90312-6

Daneman, M., & Merikle, P. M. (1996). Working memory and language comprehension: A meta analysis. *Psychonomic Bulletin and Review 3*, 422–433. https://doi.org/10.3758/BF03214546

Davis C. J. (2010). The spatial coding model of visual word identification. *Psychological Review, 117*(3), 713–758. https://doi.org/10.1037/a0019738

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

De Beni, R., Palladino, P., Pazzaglia, F., & Cornoldi, C. (1998). Increases in intrusion errors and working memory deficit of poor comprehenders. *The Quarterly Journal of Experimental Psychology Section A 51*(2), 305–320. https://doi.org/10.1080/713755761

De Rom, M., Szmalec, A., & Van Reybroeck, M. (2023). The involvement of inhibition in word and sentence reading. *Reading and writing*, *36*(5), 1283–1318. https://doi.org/10.1007/s11145-022-10337-8

Delgado, P., Guerrero, G., Goggin, J., & Ellis, B. (1999). Self-Assessment of Linguistic Skills by Bilingual Hispanics. *Hispanic Journal of Behavioral Sciences, 21*(1), 31-46. https://doi.org/10.1177/073998639921100

Dijkstra, T., & Van Heuven, WJB. (2010) Repetition and masked form priming within and between languages using word and nonword neighbors. *Bilingualism: Language and Cognition 13*(3), 341–357. doi: 10.1017/ S1366728909990575

Dunn, L.M., Dunn, L.M., & Whetton, C. (1982) *The British Picture Vocabulary Scale.* NFER-Nelson.

Fodor, J. A., Bever, T. G., & Garrett, M. F. (1974). *The psychology of language*. New York: McGraw-Hill.

Forster, K. (1979). Levels of processing and the structure of the language processor. In W. E. Cooper & E. C. T. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett* (pp. 27–85). Hillsdale, NJ: Erlbaum.

Forster, K. I., Davis, C., Schoknecht, C., and Carter, R. (1987). Masked priming with graphemically related forms: Repetition or partial activation? *The Quarterly Journal of Experimental Psychology Section A, 39*(2), 211–251. https://doi.org/10.1080/14640748708401785

Frazier, L., & Fodor, J. D. (1978). The sausage machine: A new two-stage parsing model. *Cognition, 6*(4), 291–325. https://doi.org/10.1016/0010-0277(78)90002-1

Freeman, S. E., & Forster, K. I. (1985). The psychological status of overgenerated sentences. *Cognition, 19*(2), 101-131. https://doi.org/10.1016/0010-0277(85)90015-0

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: a latent-variable analysis. *Journal of experimental psychology. General, 133*(1), 101–135. https://doi.org/10.1037/0096-3445.133.1.101

Frisson, S., Bélanger, N.N., & Rayner, K. (2014a) Phonological and orthographic overlap effects in fast and masked priming. *Quarterly Journal of Experimental Psychology 67*(9), 1742–1767. https://doi.org/10.1080/17470218.2013.869614

Frisson, S., Koole, H., Hughes, L., Olson, A., & Wheeldon, L. (2014b) Competition between orthographically and phonologically similar words during sentence reading: Evidence from eye movements. *Journal of Memory and Language 73*, 148–173. https://doi.org/10.1016/j.jml.2014.03.004

Gernsbacher, M. A. (1993). Less skilled readers have less efficient suppression mechanism. *Psychological Science, 4*(5), 294–298. https://doi.org/10.1111/j.1467-9280.1993.tb00567.

Gernsbacher, M. A., & Faust, M. E. (1991). The mechanism of suppression: A component of general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*(2), 245–262. https://doi.org/10.1037/0278-7393.17.2.245

Gernsbacher, M. A., Varner, K. R., & Faust, M. (1990). Investigating differences in general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*(3), 430–445. https://doi.org/10.1037/0278-7393.16.3.430

Grainger, J., & Jacobs, A. (1996). Orthographic processing in visual word recognition: A multiple read-out model. *Psychological review*, *103*(3), 518-565. https://doi.org/10.1037/0033-295X.103.3.518

Green D. W. (1998) Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition 1*(2)*,* 67–81. https://doi.org/10.1017/S1366728998000133

Hamilton, S., Freed, E., & Long, D. L. (2016). Word-Decoding Skill Interacts With Working Memory Capacity to Influence Inference Generation During Reading. *Reading Research Quarterly*, *51*(4), 391–402. https://doi.org/10.1002/rrq.148

Hubel, D.H., & Wiesel, T.N. (1965). Binocular interaction in striate cortex of kittens reared with artificial squint. *Journal of neurophysiology, 28*(6), 1041-59. https://doi.org/10.1152/jn.1965.28.6.1041

Jacoby, L. L. (1983). Perceptual enhancement: Persistent effects of an experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9*, 21–38. https://doi.org/10.1037/0278-7393.9.1.21

Johnson, N. E, & Pugh, K. R. (1994). A cohort model of visual word recognition. *Cognitive Psychology, 26*, 240-346. https://doi.org/10.1006/cogp.1994.1008

Just, M. A., & Carpenter, P. (1980). A theory of reading: From eye fixations to comprehension. *Psychological Review, 87*(4), 329–354. https://doi.org/10.1037/0033-295X.87.4.329

Khalifa, H., & Weir, C. J. (2009). *Examining Reading: Research and Practice in Assessing Second Language Reading*. Cambridge University Press.

Kroll, J., & De Groot, A. (2005). *Handbook of Bilingualism.* Oxford: Oxford University Press.

Lemhöfer, K., & Broersma, M. (2012). Introducing LexTALE: a quick and valid Lexical Test for Advanced Learners of English. *Behavior research methods, 44*(2), 325–343. Doi: https://doi.org/10.3758/s13428-011-0146-0

Lemhöfer, K., & Dijkstra, T. (2004). Recognizing cognates and interlingual homographs: Effects of code similarity in language-specific and generalized lexical decision. *Memory & Cognition, 32*(4), 533–550. https://doi.org/10.3758/BF03195845

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review,* 95, 492-527. https://doi.org/10.1037/0033-295X.95.4.492

Logan, G. D. (1990). Repetition priming and automaticity: Common underlying mechanisms? *Cognitive Psychology, 22*, 1-35. https://doi.org/10.1016/0010-0285(90)90002-L

Marian, V., Blumenfeld, H.K., & Kaushanskaya, M. (2007) The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech, Language, and Hearing Research* 50, 940–967. https://doi.org/10.1044/1092-4388(2007/067)

McClelland, J. L., & Rumelhart, D. E. (1985). Distributed memory and the representation of general and specific information. *Journal of Experimental Psychology: General,* 114, 159-188. https://doi.org/10.1037/0096-3445.114.2.159

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, 375–407. https://doi.org/10.1037/0033-295X.88.5.375

Murrell, G. A., & Morton, J. (1974). Word recognition and morphemic structure. *Journal of Experimental Psychology, 102*, 963- 968. https://doi.org/10.1037/h0036551

Napps, S. E., & Fowler, C. A. (1987). Formal relationships among words and the organization of the mental lexicon. *Journal of Psycholinguistic Research,* 16, 257-272. https://doi.org/10.1007/BF01067546

Pagán, A., Paterson, K.B., Blythe, H.I. & Liversedge S. P. (2016) An inhibitory influence of transposed-letter neighbors on eye movements during reading. *Psychonomic Bulletin and Review 23*, 278–284. doi: 10.3758/s13423-015-0869-5

Paterson, K.B., Liversedge, S. P. & Davis, C. J. (2009) Inhibitory neighbor priming effects in eye movements during reading. *Psychonomic Bulletin and Review 16*, 43–50. 10.3758/PBR.16.1.43

Pélissier, M., Haugland, D., Handeland, B., Urland, B. Z., Wetterlin, A., Wheeldon, L., & Frisson, S. (2022). Competition between form-related words in bilingual sentence reading: Effects of language proficiency. *Bilingualism (Cambridge, England)*, *26*(2), 384–401. https://doi.org/10.1017/S1366728922000529

Perea, M., & Pollatsek, A. (1998). The effects of neighborhood frequency in reading and lexical decision. *Journal of Experimental Psychology: Human Perception & Performance*, 24, 767-779. https://doi.org/10.1037/0096-1523.24.3.767

Perry, J. R., Lupker, S.J. & Davis, C. J. (2008) An evaluation of the interactive-activation model using masked partial-word priming. *Language and Cognitive Processes 23*, 36–68. https://doi.org/10.1080/01690960701578112

Schwartz, A., Kroll, J. F., & Diaz, M. (2007, March). Reading words in Spanish and English: Mapping orthography to phonology in two languages. *Language and Cognitive processes*, pp. 106-129.

Slattery, T. J. (2009). Word misperception, the neighbor frequency effect, and the role of sentence context: Evidence from eye movements. *Journal of Experimental Psychology: Human Perception and Performance, 35*(6), 1969–1975. https://doi.org/10.1037/a0016894

Snowling, M.J., Stothard, S., Clarke, P., Bowyer-Crane, C., Harrington, A., Truelove, E., Nation, K., & Hulme, C. (2009) *YARC York Assessment of Reading for Comprehension*. GL Publishers. https://www.worldcat.org/title/york-assessment-of-reading-forcomprehension-complete-set/oclc/ 873011477

Stanovich, K. E., & West, R. F. (1989). Exposure to Print and Orthographic Processing. *Reading Research Quarterly, 24*(4), 402–433. https://doi.org/10.2307/747605

Stone, J. M., & Towse, J. N. (2015). A Working Memory Test Battery: Java-Based Collection of Seven Working Memory Tasks. *Journal of Open Research Software, 3*(1), e5. https://doi.org/10.5334/jors.br

Sunderman, G., & Kroll. J.F. (2006). First Language Activation During Second Language Lexical Processing. An Investigation of Lexical Form, Meaning, and Grammatical Class. *Studies in Second Language Acquisition, 28*(3), 387–422. https://doi.org/10.1017/S0272263106060177

Talamas, A., Kroll, J.F., & Dufour. R. (1999). Form related errors in second language learning: A preliminary stage in the acquisition of L2 vocabulary. *Bilingualism: Language and Cognition*, pp. 45–58. doi:10.1017/S1366728999000140

Tenpenny, P. L. (1995) Abstractionist versus episodic theories of repetition priming and word identification. *Psychonomic Bulletin & Review 2*, 339– 363. doi: 10.3758/BF03210972

Van den Broek, P., Mouw, J., & Kraal, A. (2016). Individual differences in reading comprehension. In P. Afflerbach (Ed.), *Handbook of individual differences in reading: Text and context* (1 ed., pp. 138-150). Routledge.

Van Heuven, W.J.B, Dijkstra, T. & Grainger, J. (1998) Orthographic neighbourhood effects in bilingual word recognition. *Journal of Memory and Language 39*, 458–483. https://doi.org/10.1006/jmla.1998.2584

Von Bastian, C. C., Langer, N., Jäncke, L., & Oberauer, K. (2012). Effects of working memory training in young and old adults. *Memory & Cognition, 41*(4), 611–624. https://doi.org/10.3758/s13421-012-0280-7

Walczyk, J. J., & Taylor, R. W. (1996). How do the efficiencies of reading subcomponents relate to looking back in text? *Journal of Educational Psychology, 88*(3), 537–545. https://doi.org/10.1037/0022-0663.88.3.537

Wang, J., Tian, J., Han, W., Liversedge, S.P. & Paterson, K. B. (2014) Inhibitory stroke neighbour priming in character recognition and reading in Chinese. *Quarterly Journal of Experimental Psychology 67*, 2149–2171. doi: 10.1080/ 17470218.2014.909507

Waters, G. S., & Caplan, D. (2003). The reliability and stability of verbal working memory measures. Behavior research methods, instruments, & computers: a journal of the *Psychonomic Society, Inc, 35*(4), 550–564. https://doi.org/10.3758/bf03195534

Wiederholt, J., & Blalock, G. (2000) GSRT: *Gray Silent Reading Tests.* PROED Inc. https://www.proedinc.com/Products/9190/gsrt-gray-silent-reading-tests.aspx?bCategory=lra!read

Appendix A – Full stimuli for the sentence reading experiment

Condition	Relatedness	Stimuli	Question
0	0	Mark ran up the stairs and saw a big cat sitting on the couch.	Was the cat on a rug?
0	0	They all agreed that someone else had to build the homeless shelter in the park.	NO QUESTION
0	0	The big dog that lives next door actually helped to find my lost necklace last Christmas.	NO QUESTION
0	0	There are usually bottles everywhere after one of our famous office parties.	NO QUESTION
0	0	It is important to eat well and to get the nutrients that the body needs to function properly.	NO QUESTION
0	0	He is trying to imitate the speaker, but his accent is not very convincing.	NO QUESTION
0	0	The game looked fun. But all the cards were missing and we couldn't play.	NO QUESTION
0	0	Mary was impressed as the old organ in the church was unlike any other she'd ever seen.	NO QUESTION
0	0	The ballerina practised hard for her first performance of Swan Lake, which would be staged at the opera in London.	NO QUESTION
0	0	When the saxophonist walked onto the stage he fell face down because someone had left a banana lying around.	NO QUESTION
0	0	The piano teacher made sure that her pupil recorded her practice times. She thought discipline was of the utmost importance.	NO QUESTION
0	0	Cows like to stand outside and eat grass all day. If a train passes by, they all stop to look at it.	NO QUESTION
0	0	The girl picked the lovely flower out of her garden. She offered it to her grandmother.	NO QUESTION
1	0	He looked for hours in*the dirt*and found*a brass*coin*from the 1860s.	Was the coin new?
1	0	While the scientist measured*the area*of the shape*a bulb*went*out above them.	NO QUESTION
1	0	They were fighting with*their boss*after piercing*the hose*in his*garden during the party.	NO QUESTION
1	0	He felt bad although it wasn't*his task*at all but*the vault*had been*broken into over the weekend.	NO QUESTION
1	0	As she left her shift*the nanny*began*to curse*the difficult*children.	NO QUESTION
1	0	He counted up to*eight*knights that could*sever*the dragon¬¥s*head.	Did he count the number of knights?
1	0	Chad made*a show*by smoking*the joint*in a*public place.	NO QUESTION
1	0	They went to*the fair*and brought*a cake*to give*to the family.	NO QUESTION
1	0	They could see a bright*glow*coming from*the beak*of a*parrot statue in the hall.	Was the statue of a peacock?
1	0	The bride walked to*the bench*quickly with*her gown*in a*shopping bag.	NO QUESTION
1	0	If you drive down*the tiny*street you'll see*mail*all over*the road because of the accident.	NO QUESTION
1	0	Once in the hospital he was forced*to stand*and he started*to wail*in pain*after a while.	Was he hurt?
1	0	They had to abandon*the tent*as it was*so damp*that*there was mould on their sleeping bags.	NO QUESTION
1	0	The little boy took off*his cape*to climb*the mast*on his*pretend pirate ship.	Was the boy playing with robots?
1	0	Katie found a strange*cube*next to*the bead*she had*lost earlier today.	NO QUESTION
1	0	Hannah tried to find peace in*the wind*but*the stark*landscape*made her feel depressed.	NO QUESTION
1	0	The congregation's last*wish*was that*a pope*would*be chosen by the end of the week.	NO QUESTION
1	0	Jenny took her*stick*to the old*willow*and laid*down to sleep.	NO QUESTION
1	0	The creature made of*bone*managed*to slay*all its*enemies in a heartbeat.	NO QUESTION
1	0	There was a big*roar*when*his boot*hit the*concrete floor.	NO QUESTION

1	0	He thought*the door*was beautiful as*his lover*had designed*it.	NO QUESTION
1	0	William had to thoroughly clean*the oven*afterwards as*the pork*had left*grease all over it.	Did William eat pork?
1	0	The assistant wore*a nice*jacket*to greet*everyone*on his first day.	NO QUESTION
1	0	When she raised*her spoon*the chocolate*chip*that*had been stuck to it fell onto the table.	NO QUESTION
1	1	She always wore*a scarf*to hide*the scars*left*by the childhood accident.	NO QUESTION
1	1	Whenever she sat down to*spin*wool she*spit*her tobacco*into a bowl.	NO QUESTION
1	1	She was now ready for*her date*and waited at*the gate*until*the taxi got there.	Was the taxi already at the gate?
1	1	The pen had left an ugly*pink*stain and her*mink*jacket*was now ruined.	NO QUESTION
1	1	Ian wanted to lie in bed and*sleep*but then his*sleek*haircut*might be ruined.	Was it Ian who had a sleek haircut?
1	1	The faculty had*a deal*but*the dean*was not*happy with the outcome.	NO QUESTION
1	1	They tried to photograph the yellow*wall*artistically but*the mall*was ruining*the picture.	NO QUESTION
1	1	Michael received an impressive*mark*for explaining*the Mars*expedition*to the audience.	Did Michael explain the moon expedition?
1	1	They found some*mice*next to*the dice*in the*cupboard where they stored all their games.	NO QUESTION
1	1	I had to pay*the bill*before I got*the pill*the doctor*prescribed.	NO QUESTION
1	1	He walked slowly onto*the steel*ramp which was very*steep*and so*quite dangerous.	NO QUESTION
1	1	He always had to have*meat*for lunch and every*meal*he cooked*was too rich and too salty.	Was he a good cook?
1	1	When I know someone hears me*flush*I tend*to blush*a little*bit.	NO QUESTION
1	1	Carl leaned on*the rail*and watched*the raid*that*was taking place in the village.	NO QUESTION
1	1	The mayor received*the local*kids who were*vocal*opponents*of the reforms he had in mind.	Was the mayor thinking about some reforms?
1	1	The new discovery was a huge*step*in the field of*stem*cell*research.	NO QUESTION
1	1	He could hear*a bell*from*his cell*and that's*what helped him keep track of time.	NO QUESTION
1	1	He looked up*the hill*thoughtfully at*the mill*which*had been standing there for centuries.	NO QUESTION
1	1	He got into the bus by*the rear*door with his hiking*gear*still*wet and dripping on the floor.	NO QUESTION
1	1	They had to turn around while exploring*the river*when his weak*liver*started*failing because of the disease.	NO QUESTION
1	1	The musician would rather be*dead*than become*deaf*before*finishing his composition.	NO QUESTION
1	1	They were baffled by*the news*today that*a newt*had been*found in an Arctic garden.	NO QUESTION
1	1	James played*the game*well and gained*fame*all over*the world.	Did James become famous?
1	1	Clara raised*the rose*closer to*her nose*to smell*it properly.	NO QUESTION
2	0	There was about*a month*left. Then*the file*would*be delivered safely.	NO QUESTION
2	0	He rehearsed*his play*again. In*the park,*no one*paid him any attention while he was practising.	NO QUESTION
2	0	Lucy had to pay by*check.*Her shopping*cart*contained*too many expensive things.	Was Lucy buying things?
2	0	He wished he had better*shoes.*He stood in*muck*on his*way to the party.	Was he going to a funeral?
2	0	Panthers tend*to whine*a bit. They*prowl*around*the forest every day.	NO QUESTION
2	0	There is always a lot of noise at*the shed.*The dogs*bark*at the*sounds outside.	NO QUESTION
2	0	They came back from*the trip*early. No one had*a bruise,*even*though the sea had been rough.	NO QUESTION
2	0	Their garden was gorgeous with its giant*beech*tree.*A vine*was growing*on its trunk.	Was the garden beautiful?
2	0	John chose*a dish.*Two large*bows*were*delicately painted on it.	NO QUESTION
2	0	It was hard to get*a chair*in the front.*The seal*that*could jump nine hoops in a row was too famous.	NO QUESTION

2	0	They lied for their own*gain.*But their*fake*declarations*were soon exposed.	NO QUESTION
2	0	There was*a snap.*He took*his flask*out of*his pocket and started drinking from it.	NO QUESTION
2	0	Leonard was very*sick.*He even*fired*his worst*employee.	NO QUESTION
2	0	She ironed the fabric on*a soft*surface. That way*the flap*would*sit nicely on her new bag.	NO QUESTION
2	0	The long ongoing*gang*wars began stupidly.*A turd*was tossed*towards someone at the zoo.	NO QUESTION
2	0	Harry bought the expensive*lamp.*He also got*the clock*he saw*yesterday.	Did Harry buy the old clock?
2	0	She needed*to study*hard. She believed*the locus*of the*ancient burial site was around the corner.	NO QUESTION
2	0	They went down*the road.*After a winning*streak*at the*rowing club they deserved a break!	NO QUESTION
2	0	She looked resentfully at*the monkey.*She gave it*a carrot*so it*would stop screeching.	NO QUESTION
2	0	They looked at*the wave*quietly.*Their mood*changed*a lot.	NO QUESTION
2	0	He went to*the shore.*He ate*a peach*and a*home-made pie.	Did he eat an apple?
2	0	The nail had made*a tear*in his shoe.*The sole*now*let the water in.	NO QUESTION
2	0	The strange bird would shake*one foot*lazily. Then it would*wink*at him*from the high branch.	Was the bird on a low branch?
2	0	He tried the new*beer*yesterday. He hit*his drum*with*more energy than ever.	NO QUESTION
2	1	Joe shot and hurt*the stag*badly. He had*to stab*it as*it could not be saved.	NO QUESTION
2	1	Susan wanted*to switch.*Her eyes would*twitch*when*she looked at digital screens.	NO QUESTION
2	1	Chris brought a really*sharp*knife. To kill*the shark*that*was circling the boat he had to be quick.	Did Chris want to kill a whale?
2	1	He thought it had a high*price*overall. But*the prime*cut of*beef was definitely worth it.	Did he buy chicken?
2	1	They went ahead and*sold*the tickets.*A bold*man they*met outside got them.	NO QUESTION
2	1	The people watched*the sheep.*They had to see*the sheer*weight*of the wool they had on them.	NO QUESTION
2	1	It was hard not*to faint*then. I had seen*a saint*walking*on water!	NO QUESTION
2	1	The coach's*goal*was bold.*The foal*was to*compete in a major derby before the end of the year.	Was the coach training horses?
2	1	Then it was his turn*to speak.*A metal*spear*was thrown*at him.	NO QUESTION
2	1	She grazed her*skin*today. She tried*to skip*over*the gravel and she fell down.	NO QUESTION
2	1	Paul wanted*to join.*But he needed*a coin*to pay*for it in the end.	NO QUESTION
2	1	Alice suspected that they would*trap*her somewhere.*The tram*station*was the most likely.	NO QUESTION
2	1	They ran through*the haze.*They found*a maze*in the*middle of the forest.	NO QUESTION
2	1	Everyone gathered in*the hall*quickly. So*the ball*could*start on time.	NO QUESTION
2	1	Keep the air in your bedroom*warm*and dry. It will*ward*off sleepless*nights.	NO QUESTION
2	1	The scary house was*brown*and old.*A crown*was painted*over the door.	Was a crown painted on the door?
2	1	The food was served on an oval*plate.*It was made of*slate,*which*looked very fancy.	NO QUESTION
2	1	Jackie went down to*the brook.*She took*a broom*to try*and sweep up the glass.	NO QUESTION
2	1	They had to repair*the sail*immediately.*The hail*had ripped*holes into it in the middle of the ocean.	NO QUESTION
2	1	The clothes were left in*a pile*there.*The vile*person*was taking a shower.	Was the person taking a bath?
2	1	Everything was lying all over*the floor.*Earlier,*the flood*had hit*the area we lived in.	NO QUESTION
2	1	John had ruined*his coat*completely.*The coal*he picked*up in the mine had left a trace.	Did John pick up the coal?
2	1	The police found three tons of*coke*yesterday. It was in*a cove*along*the north coast.	NO QUESTION
2	1	They were too late for*the flight.*They had taken*a slight*left*instead of going straight ahead.	NO QUESTION

3	0	Cutting a lot of*pipes*throughout his long career had made Fred unusually*limber*compared*to others at his age.	NO QUESTION
3	0	The accident didn,Äôt leave*a wound*and even after the man very carefully removed*the brace*from*his leg, nothing could be seen.	Did he have an accident?
3	0	He walked back to*the pool*of the castle during his day out to get*his towel*as he*had forgotten it again.	NO QUESTION
3	0	Alison could feel*the fury*building up as she knew that her hourly*wage*was far*below what she deserved.	NO QUESTION
3	0	The morning,Äôs thin*layer*of snow was quite dangerous but left a beautiful*sheen*on the*new pavement that brightened the day.	NO QUESTION
3	0	They looked in*the house*and found plans to build an intricate metal*base*for the*table.	NO QUESTION
3	0	I uncovered*a letter*that contained a description and an illustration of an iron*cage*from*medieval times.	NO QUESTION
3	0	They tried*to note*where everyone came from and what they did but one*guest*refused*to answer.	NO QUESTION
3	0	It was an old*engine*and when it suddenly stopped running, the helicopter*rotor*started*to slow down.	NO QUESTION
3	0	He was given some*moss*and was told to crush it on his hair to get rid of*the lice*but it*didn't work.	NO QUESTION
3	0	It didn't take long*to clean*the Porsche he had bought two years before with a big*loan*from*the bank.	NO QUESTION
3	0	He told the children a very funny*joke*which involved an elf who only ate*kale*and chickpeas*for breakfast.	Did the elf eat chickpeas?
3	0	Her room was*a dump*and she had a hard time finding*the mesh*bag in*which she had put her sports clothes.	NO QUESTION
3	0	The alarm had a red*stamp*that I noticed far too late after opening*the hatch*to the*cellar of the house.	Did I open the hatch to the attic?
3	0	If you are going*to hire*the crew you'd better make sure they know not*to lean*on the*loose shelf behind the stage.	NO QUESTION
3	0	The group might face some*threat*even though they are in the company of*a ranger*from*the area.	NO QUESTION
3	0	Drinking the old*milk*caused Leif to experience lasting and severe*pains*in his*stomach and he was rushed to hospital.	Was Leif rushed to hospital?
3	0	The teacher felt that this was*simple*knowledge that should have been*the basis*for more*elaborate coursework.	NO QUESTION
3	0	Sarah searched*the shop*just up the street from me and found a new*marker*to use*for her notes.	Did Sarah need a paper towel?
3	0	They felt as if their*value*had decreased significantly after the very long and*tight*match*that they had played.	NO QUESTION
3	0	Connor was always considered*a king*for keeping the number of casualties down*at zero*throughout*the disaster.	NO QUESTION
3	0	Charles had a tight*hold*of the handle of the shopping cart and a huge*grin*on his*face when they entered the mall.	NO QUESTION
3	0	Bees tend*to rush*to defend the hive with all their strength as they*fling*themselves*to their own deaths.	NO QUESTION
3	0	The hockey player noticed a broken*loop*in the rusty chain that surrounded*the rink*that*had to be fixed.	Was the chain intact?
3	1	There was so much*steam*in the room that no one noticed him*steal*the diamond*necklace right from its owner's pocket.	Was he a thief?
3	1	Rick searched*a chest*in his old countryside manor for a book about*chess*which*he needed to study.	NO QUESTION
3	1	The three men*bound*him to a chair and asked where his multimillion*pound*booty*was hidden.	NO QUESTION
3	1	Adam was feeling a lot of*guilt*about the theft that was committed today at*the guild*because*of the unlocked door.	NO QUESTION
3	1	He looked at*the bread*suspiciously for five minutes as its colour made him*dread*eating*any of it.	NO QUESTION
3	1	He took*the gold*sheet of paper and cut along*the fold*to get*a perfect square.	NO QUESTION
3	1	He knew it would*lift*his mood to sit down for the day and*sift*through*the evidence they had collected.	NO QUESTION
3	1	Martin was happy that*his twin*had gone into the woods and brought back*a twig*that*was dry enough.	NO QUESTION
3	1	Everyone thought he was*a fool*for letting himself be used as*a tool*by the*crooked administrator.	NO QUESTION
3	1	He gave a nice*toast*at his daughter's wedding but took the opportunity*to boast*about*his success.	Did his daughter get married?
3	1	Brett couldn't read a specific*word*in the old book he found in the attic as*a worm*had nibbled*at some pages.	NO QUESTION
3	1	He flattened the fabric under*a press*and did not want to use heat as*the dress*would*otherwise shrink.	NO QUESTION
3	1	She bought some*wood*to build a nice box where she could store her*wool*sweaters*away from the moths.	NO QUESTION

3	1	John threw*his fist*and managed to hit his opponent on the nose despite*the mist*that*surrounded them.	Did John miss his opponent?
3	1	The audience made a lot of*noise*but she performed her act with grace and*poise*and impressed*everyone.	NO QUESTION
3	1	He tried not*to waste*too much time on emails as he still had*to paste*a note*on his office door.	NO QUESTION
3	1	They wanted him to eat more*bran*but even mixed into his breakfast the little*brat*would*not touch it.	NO QUESTION
3	1	Sue made scans of*the brain*in her fancy laboratory while twisting*the braid*in her*long hair.	Does Sue work in a laboratory?
3	1	The explorers needed*a train*to arrive on time before they started hiking on*the trail*through*the jungle.	NO QUESTION
3	1	George took*the beef*out of the oven as the loud*beep*of the*fire alarm had woken him up.	NO QUESTION
3	1	He wanted to get*paid*but talking to the manager was a real*pain*every*single time.	Did he like talking to his manager?
3	1	She gave him*a ride*to the new restaurant in town and they had*rice*with*their dumplings.	Did they go to the bar?
3	1	When Lee proposed he stroked Sue‚Äôs*cheek*as he slid the ring on and a huge*cheer*arose*from their families.	NO QUESTION
3	1	The newly appointed police*chief*was satisfied as they were sure to catch*the thief*quite*easily now.	NO QUESTION
4	0	He remembered*the trick.*He must stop the machine from going into a different*mode*and cutting*through all the layers.	NO QUESTION
4	0	He wanted to join*the tribe.*But he could only do that if he was*clad*in the*proper clothing.	NO QUESTION
4	0	There was a horrible*scent.*It might have been a side effect of*the spell*he had*just cast.	NO QUESTION
4	0	Their report made*the lord*angry. They explained that there was still a big*kink*to be*worked out of the plan.	NO QUESTION
4	0	These questionable people are accused of*heading*a large pyramid scheme. It was set up by*a cunning*banker*who got fired.	Is the pyramid scheme large?
4	0	She gave him*a push*in the right direction. Then he finally started*the fudge*shop*he had been dreaming of.	NO QUESTION
4	0	The chicken that Jack wanted*to boil*was in a bad mood. It started*to cluck*when*he advanced on it.	Was the chicken in a good mood?
4	0	Jack often thought about*the crop.*It had been entirely destroyed by a powerful*storm*over*the holidays.	NO QUESTION
4	0	Ed bought a tree he had*to grow.*But when he put it into the ground it began*to slant*and he*had to set it straight.	NO QUESTION
4	0	He was surely going*to jail*anyways. He raised his fist and started*to yell*obscenities*at the*old lady.	NO QUESTION
4	0	The crystal she found was really*thin.*It could quite easily cause some serious*harm*to anyone*who handled it carelessly.	Did she find a diamond?
4	0	They decided*to help*the company. They really liked*the funk*music*they promoted.	NO QUESTION
4	0	It was a bit too*bright.*So he did not manage to throw*the dart*anywhere*near the target.	NO QUESTION
4	0	Faith gives you a lot of*force.*Then you never have to be scared and*cower*in fear*from anything.	NO QUESTION
4	0	Several people got*sore.*Yesterday, an angry monkey suddenly decided*to hurl*rocks*at the audience.	Did anyone get hurt?
4	0	Jo didn't like the book's*theme.*It was a stupid and boring thriller about*a ploy*to take*over the world.	Did Jo love the book?
4	0	The earthquake shook*the cars.*It was so forceful that it tossed*the root*of a*tree through the window.	NO QUESTION
4	0	At the landing*spot*there is a young boy. He always plays with*his kite*whenever*there is a little breeze.	NO QUESTION
4	0	Anne asked John*to give*her his drenched coat. She wanted*to hang*it in*the bathroom.	Was it raining outside?
4	0	Most of the villagers accept*this belief.*There is no such thing as*a potion*to remedy*bad luck.	NO QUESTION
4	0	Clarence noticed*a flag*on the ground. He was about*to leap*over*the edge of the cliff.	NO QUESTION
4	0	The knight received*a blow*from the rest of his friends. His attempt*to slam*into*those two friendly dragons was unwelcome.	NO QUESTION
4	0	The sun had burnt*his palm.*He had been sitting on the white*deck*all day*without any sunscreen.	NO QUESTION
4	0	The group felt that they had*to burn*supplies. Yet the others would probably*stare*at them*in surprise.	NO QUESTION
4	1	Behind me there was a crazy*freak.*He followed me around until I heard the soft*creak*of the*shop doors closing behind me.	NO QUESTION
4	1	The university*sees*the importance of challenging students. They have*to seek*further*information on their own.	NO QUESTION

4	1	Our discussion provided*fuel*to the debate. It ended in an unpleasant*duel*between*them.	NO QUESTION
4	1	He wanted*to mount*a camel in order to cross the desert. But there was*a mound*of big*and smelly droppings he needed to avoid.	NO QUESTION
4	1	The gang had*to crawl*back to their place. They had unexpectedly lost*the brawl*they*had just been in due to the heavy snow.	Had the gang been in a brawl?
4	1	He managed*to save*his dish. He added some fresh*sage*into*the sauce and that did it.	NO QUESTION
4	1	The fox became scared of*the duck.*After losing the fight it finally decided*to tuck*its tail*between its legs and escape.	Did the fox win the fight?
4	1	She only had about*one yard*left. So she had to buy more of the expensive*yarn*to finish*her sweater.	NO QUESTION
4	1	They had looked at*the sign.*They decided together that they would never ever*sigh*at old*people again.	NO QUESTION
4	1	Last year, the whole*cast*was asked to contribute. They bought*a cask*of spirit*for the manager.	NO QUESTION
4	1	Elsa said it was*sweet*to see the girl who works in the clothes shop. She must*sweep*the floor*on weekends.	Did the girl work in a book shop?
4	1	They would*race.*It was the longest distance they had attempted and they knew that*pace*was the*key to finishing.	NO QUESTION
4	1	Ian wanted to be*brief.*He noticed that some people had expressed*grief*due to*a lack of direction.	NO QUESTION
4	1	Ed knew the item was a*cheap*copy. Yet he could not afford it and had*to cheat*to make*sure he won the bid.	Did Ed know the item was a fake?
4	1	He was angry after hurting*his feet.*He tripped on a shovel when he went*to feed*the hungry*horses in the morning.	NO QUESTION
4	1	The wounded man suffered in*the heat.*Meanwhile, the poor woman in the room tried*to heal*him as*well as she could with few ressources.	NO QUESTION
4	1	They noticed*a peak*in petty crime. They made sure no one would*leak*it to*the local media.	NO QUESTION
4	1	He was charged with the full*fine.*He was caught sneaking many boxes of*wine*into*the country.	Was he an honest man?
4	1	Louise decided*to call*the guy she met yesterday. He was*tall*and quite*good-looking.	NO QUESTION
4	1	She was sitting on*the curb.*Someone came running by and*cut off*a curl*of her hair all of a sudden.	NO QUESTION
4	1	Her friends had*a vote.*They must decide whether to buy her a handbag or*a tote*for her*birthday.	Was it her birthday soon?
4	1	The whole*class*looked at him. He drank a huge*glass*of whisky*in front of the teacher.	NO QUESTION
4	1	That valuable*purse*contained a special crystal. People believed it could*purge*any impurities*from one's body.	NO QUESTION
4	1	In the room stood*a bunch*of people he hated. He would have liked*to punch*them*in the face.	NO QUESTION

Appendix B – Excel file for Word Naming Task (the first 20 trials)

	Partipant no:	
	Date of testing:	
	Nb of Errors:	0

TrialNb	Accuracy	Comments
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Appendix C – Scoring Sheet for Digit Span Memory Task

BACKWARD DIGIT SPAN WORKING MEMORY TASK
Walters and Caplan (2003)

Partipant no:

Date of testing:

Total Span: 0

Participant instructions
1. I am going to say a series of numbers to you and I would like you to say them back to me in reverse order
2 For example, if I was to say 1-7, you would say 7-1
3. You should listen carefully and repeat them back to me in reverse order as soon as I have finished speaking
4. We'll start off with just two digits and then the numbers of digits will gradually increase

Adminstration and scoring
1. Score the participant 1 point for each trial that they correctly repeat the numbers in reverse order
2. Always adminster all five items in each block
3. When this is finished, the participant's current span length will be calculated (if they have scored 2 or more correct)
4. However, if the participant scored 0 or 1 in a block, stop testing (the "current span" cell will show STOP)
5. The overall digit span is calculated as the max span length at which the participant scored 3 or more correct
6. An extra 0.5 is added to the score if the participant scored 2 out of 5 correct on the subsequent span block
6. This will all be calcualted in the "total span" cell

Span	Trial	Stimuli								Score		
2	1	8	7									
	2	9	4									
	3	1	5									
	4	3	7									
	5	6	2								Total: 0	Current span: Continue
3	1	6	4	1								
	2	3	5	2								
	3	9	7	8								
	4	5	7	6								
	5	9	2	1							Total: 0	Current span: Continue
4	1	6	3	4	8							
	2	5	2	9	1							
	3	5	1	7	5							
	4	2	8	9	3							
	5	9	8	5	2						Total: 0	Current span: Continue
5	1	4	6	8	3	9						
	2	5	2	1	7	3						
	3	3	2	6	4	9						
	4	5	8	7	1	3						
	5	4	2	7	1	5					Total: 0	Current span: Continue
6	1	9	5	3	4	6	1					
	2	6	4	7	5	9	2					
	3	7	8	6	5	3	4					
	4	1	2	5	8	6	4					
	5	9	7	5	6	1	2				Total: 0	Current span: Continue
7	1	8	6	4	1	7	9	3				
	2	1	9	7	3	8	2	6				
	3	3	1	7	5	9	8	4				
	4	6	1	9	2	3	5	8				
	5	8	9	1	5	4	3	7			Total: 0	Current span: Continue
8	1	4	3	1	9	5	6	2	8			
	2	6	4	8	3	1	5	7	9			
	3	3	1	5	7	6	3	8	2			
	4	4	6	9	8	5	1	7	2			
	5	7	4	8	3	9	5	2	6		Total: 0	Current span: Continue

Appendix D – Scoring Sheet for Word Attack

Partipant no:

Date of testing:

Nb of Errors: 0

List	Item	Word	Score	
1	1	see		
	2	look		
	3	play		
	4	was		
	5	like		
	6	this		
	7	next		
	8	house		
	9	going		
	10	bell		Total: 0
2	1	hang		
	2	stand		
	3	their		
	4	living		
	5	again		
	6	first		
	7	slowly		
	8	score		
	9	found		
	10	bread		Total: 0
3	1	scream		
	2	journey		
	3	suppose		
	4	yawned		
	5	should		
	6	tissue		
	7	caught		
	8	stretching		
	9	tongue		
	10	copies		Total: 0

Appendix E – Participant information and consent form

Project LPDReading

PARTICIPANT INFORMATION SHEET AND CONSENT FORM

INVITATION TO PARTICIPATE IN A RESEARCH PROJECT

SENTENCE READING IN BILINGUALS AND MONOLINGUALS

We are looking for native speakers of Norwegian to take part in a language study investigating reading in English as a second language.

In order to participate in this study you need to be a **native speaker** of Norwegian with no other home languages (other than perhaps English) and have a reasonable proficiency in English as your second language. You should have normal or corrected-to-normal vision and hearing and have no diagnosed language impairments such as dyslexia or stuttering.

The study has four main components:

1. A reading task while your eye-movements are recorded
2. A language background questionnaire
3. Language proficiency measures
4. Cognitive tests

Completing all tasks will take around 1 hour 45 minutes in one session.

The study is conducted by post-doctoral fellow Maud Pélissier (maud.pelissier@uia.no) in collaboration with Linda Wheeldon (linda.r.wheeldon@uia.no), Allison Wetterlin (allison.wetterlin@uia.no) from the University of Agder and Steven Frisson (s.frisson@bham.ac.uk) from the University of Birmingham, UK. Please contact Maud Pélissier (maud.pelissier@uia.no) if you have any queries about the study.

WHAT IS THE STUDY ABOUT?

This study is designed to investigate aspects of word recognition when reading in English as a second language. We are interested in how aspects of bilingual learning and individual profiles relate to language processing. The study has four components:

1. Reading task: You will be seated in front of a screen with your chin in a chin rest, and will have to read sentences silently while the movements of your eyes will be recorded with a camera. You will be asked to answer comprehension questions about some of the sentences. (approximately 30 minutes)
2. Questionnaire: to ascertain your language background and how you rate your own level of proficiency in different aspects of the languages that you speak. (approximately 20 minutes)
3. Simple language tests: to assess vocabulary knowledge in English (approximately 15 minutes).
4. Simple cognitive tests: involving speeded responses to stimuli (approximately 30 minutes).

If, after having read the information below, you decide to take part in the study please complete the consent form at the end of this document.

The study will collect and record personal information about you. However, you will never at any time be mentioned as an individual in relation to this study. Your personal data will be assigned a number code related to your name and stored on a non-networked, password protected PC. Only the laboratory directors and experimenters will have access to your data and to the key relating your data number to your name. In addition we will record the responses you produce during the experiment, this includes key strokes and eye movements. These data will be also be anonymised and treated as described below.

VOLUNTARY PARTICIPATION AND THE POSSIBLITY TO WITHDRAW CONSENT (OPT-OUT)

Participation in the study is voluntary. If you wish to take part, you will need to sign the declaration of consent on the last page of this document. This will allow us to process your data. You can, at any given time and without reason, withdraw your consent. If you decide to withdraw participation in the project, you can ask that your test results and personal data be deleted, unless the data and tests have already been analysed or used in scientific publications.

So long as you can be identified in the collected data you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data.

If at a later point, you wish to withdraw consent or have questions regarding the project, you can contact the principal investigator (Linda Wheeldon). Questions about the study or withdrawing consent can also be directed to the University og Agder's Data protection officer Ina Danielsen ina.danielsen@uia.no or NSD (Norsk senter for forskningsdata AS) by email personvernombudet@nsd.no or telephone: +47 55 58 21 17.

WHAT WILL HAPPEN TO YOUR INFORMATION?

The information that is recorded about you will only be used as described in the purpose of the study.

The results derived from the pooled data will be published. In the interest of being open to the scientific community and others interested in this research we would also like, with your permission, to publish the anonymised data to an open access database. If you agree to this, please sign under "publishing anonymised data to open access database" at the end of this document. The decision you make does not affect your eligibility for this study.

All information will be processed and used without your name or personal identification number, or any other information that is directly identifiable to you.

The principal investigators have the responsibility for the daily operations/running of this research project and that any information about you will be handled in a secure manner. Information about you will be anonymised or deleted a maximum of 5 years after the project end date (01.12.2026).

FINANCE

In appreciation for your time and effort, you will receive a voucher for 200 NOK for either the University book shop or SIA café on completion of this study. No payment will be received for partial participation.

APPROVAL

CONSENT FOR PARTICIPATING IN THE RESEARCH PROJECT

I AM WILLING TO PARTICIPATE IN THE RESEARCH PROJECT

TITLE: SENTENCE READING IN BILINGUALS AND MONOLINGUALS

1) I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
2) I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. I understand that I can withdraw my data at any time during the experiment and after completion of the study until the data is analysed.
3) I understand that data collected during the study will be looked at by researchers from the University of Agder and their academic collaborators. I give permission for these individuals to have access to my data and to use it for research purposes.
4) I agree to take part in the study.

Date Participant's Signature

Participant's Name (in BLOCK LETTERS)

PUBLISHING ANONYMISED DATA TO OPEN ACCESS DATABASE

I confirm that anonymised data can be uploaded to an open access database.

date Participant's Signature

Appendix F – A short version of the instructions for the experimenter

LPD READING - EXPERIMENTAL PROTOCOL SHORT VERSION

OVERVIEW

1. Welcome participant and sign consent form
2. Eye-tracking experiment
3. Additional tasks on other computer
4. LEAP-Q modifications if necessary
5. Gift card and debriefing

Before each participant

The day before the test: send the participant the information letter so they can read it at home + remind them to come in well-rested and **without any eye-makeup.**

- **Restart** stimuli computer (biosemi) **(also in between participants)**
- Then, once that one is fully restarted, start the host (eye-tracker computer) and click on "Tracker"
- **Check the configuration**
  - `Set Options > select Config… > Desktop (remote mode), Target sticker, Binoc/Monoc, 16/25mm lens, RBTABLER (`**`4th from top`**`)`
  - Calibration type: **9 points**
  - "Force manual accept" should be selected (= grey)
- Start the Additional tasks computer. Username: `.\lab`
- **Open Psychopy Coder (v.2022.2.5)** (go in the start menu and start typing "psychopy", it should appear. DO NOT open Psychopy3 but PsychopyCoder 2022).
  - From Psychopy coder, open the file `LPD_Cogtasks_noDS.py` (In `Maud-ET > TestBattery_Clean-2023`).
- Prepare the documents
  - Take a new "Participant Overview" sheet (checklist)
  - Check the list number for that participant and write it in the overview file
  - Check the LEAP-Q sent back by the participant, check that all 3 tabs are filled in
  - Copy the "LPD_ScoringSheets.xlsx" document and rename it by adding the participant number at the end ("`LPD_ScoringSheets_SXX.xlsx`").

PART I: EYE-TRACKING TASK

1. Comfortable set up
2. Target sticker
3. Explain task
4. Start experiment (choose correct list number)
5. Setup the camera (transfer image, A for autofocus, arrows to adjust blue circle)
6. Calibration and validation (ESC then C to calibrate, V to validate)
7. ESC x2 to start experiment
8. Press SPACE when they are looking at the dot

PART II: ADDITIONAL TASKS

1. Start programme in psychopy by clicking on green arrow and enter participant number (no letters)
2. Flanker task -> nothing to do for you
3. Word naming - > write down accuracy in scoring sheet as they go (WordNaming tab)
    - Inaccurate if they start saying the wrong one or say nothing
4. Reading span -> nothing for you to do
5. Digit span -> administer from scoring sheet (WM tab)
6. Word attack -> write down accuracy in scoring sheet (YARC tab)
    - Remember: they must get it right on the first try!
7. LexTALE -> nothing to do for you
8. Authors task -> nothing to do for you

PART III: FINISHING

1. Make sure to check the LEAP-Q and complete it with participant if necessary
2. Give the voucher and have the participant sign the receipt
3. Copy the data to a memory stick and then to teams
    a. Eye tracking data (in `Maud > Maud_ELL_2023_deploy > results` on the stimuli computer. Copy whole folder)
    b. Additional tasks: 6 files starting with LPD_SXX (XX = participant number), in `Maud_ET > TestBattery_Clean-2023`
    c. Word naming recordings: In `WordNaming > Recordings`, folder with your participant's number.

Appendix G – Adapted LEAP-Q questionnaire

REMEMBER TO '<u>SAVE AS</u>' Y + SUBJECT NUMBER (E.G., Pp_01) <u>FIRST</u>!!

General note: cells are locked to prevent formula being changed (you can unlock if necessary by removing the worksheet protection).

Participant number:

Date of testing:

<u>SCREENING QUESTIONNAIRE</u>

Experimenter: Ask participant the following questions and fill in the yellow boxes with their responses.

1	What is your age? (in years)			
2	What is your gender?			
3	Are you a native speaker of Norwegian?			
4	Is Norwegian the only language you speak at home (aside from perhaps English)?		*If no, please specify other home language*	
5	Are you a reasonably good speaker of English?			
6	Do you have normal vision or vision that is corrected to normal with glasses or contact lenses?			
7	Can you confirm that you have no language impairments such as dyslexia, stuttering etc.?			
8	Do you have normal hearing or hearing that is corrected to normal?			
9	Are you left or right handed?			
10	What is country of birth?			
11	What is your current country of residence?			
12	How many years of education do you have?			
13	What is the highest education level you have? (Select from the drop-down options)		*If other, please specify*	
14	Have you participated in any experiments here before?			

2. LANGUAGE BACKGROUND

Participant: please answer these questions below about the different languages you speak.
Please fill in your responses in the appropriate yellow boxes, and ask the experimenter if you have any questions.

Q1 Please list all the languages you speak in order of DOMINANCE (up to 5).

1	
2	
3	
4	
5	

Q2 Please list all the languages you speak in order of ACQUISITION (up to 5).

1	
2	
3	
4	
5	

Q3 Please list what percentage of the time you are on average exposed to each language (e.g. exposure in terms of talking, listening, and reading, including TV, films and music).
(All your answers should add up to 100%)

	Language	%
1		
2		
3		
4		
5		
	Total:	0

Please make sure your answer adds up to 100%

Q4 Please list what percentage of the time you spend speaking each language.
(All your answers should add up to 100%)

	Language	%
1		
2		
3		
4		
5		
	Total:	0

Please make sure your answer adds up to 100%

Q5 Please list what percent of time you typically spend reading in each language.
(All your answers should add up to 100%)

	Language	%
1		
2		
3		
4		
5		
	Total:	0

Please make sure your answer adds up to 100%

Q6 When choosing a language to speak, with a person who is equally fluent in all your languages, what percentage of time would you choose to speak each language? Please report percent of total time.
(All your answers should add up to 100%)

	Language	%
1		
2		
3		
4		
5		
	Total:	0

Please make sure your answer adds up to 100%

Q7 What cultures do you identify with (e.g., Norwegian, British, American, etc)? Please list each culture below (up to 5) and use the scale from 0-10 to rate the degree of identification, whereby 0 = no identification, 5 = moderate identification, 10 = complete identification.

	Culture	Identification
1		
2		
3		
4		
5		

Q8 Do you feel that you were once better in one of your languages and that you have become less fluent?

If yes, which one? *And at what age did you become less fluent?*

Q9 In which language do you usually do the following tasks?

Task	Language
Simple maths (count, add)	
Dream	
Express anger or affection	
Talk to yourself	

3. NORWEGIAN AND ENGLISH PROFICIENCY

Participant: please answer these questions below about your experience with Norwegian and English.
Please fill in your responses in the appropriate yellow boxes, and ask the experimenter if you have any questions.

Q1 Please list the number of years and months you have spent in each language environment.

	Norwegian		English	
	Years	Months	Years	Months
A country where this language is spoken				
A family where this language is spoken				
A school where this language is spoken ALL of the time				
A school where this language is spoken SOME of the time				
A workplace where this language is spoken ALL of the time				
A workplace where this language is spoken SOME of the time				

Q2 Please rate how much the following factors contributed to your learning of each language on a scale of 0-10 whereby 0 = not a contributor, 5 = moderate contributor and 10 = most important contributor.

	Norwegian	English
Interacting with friends / colleagues		
Interacting with family		
Reading (e.g., books, magazines, online material)		
School and education		
Self-instruction (e.g., language learning videos or apps)		
Watching TV / streaming		
Listening to music/media		

Q3 Please rate to what extent you are currently (e.g. in the last month or so) exposed to each language on a scale of 0-10 whereby 0 = never, 5 = half of the time and 10 = almost always.

	Norwegian	English
Interacting with friends		
Interacting with family		
Reading (e.g., books, magazines, online material)		
Self-instruction (e.g., language learning videos or apps)		
Watching TV / streaming		
Listening to music/media		

Q4 Please rate your level of proficiency in the following aspects of each language on a scale of 0-10 whereby: 0 = none; 1 = very low; 2 = low; 3 = fair; 4 = slightly less than adequate; 5 = adequate; 6 = slightly more than adequate; 7 = good; 8 = very good; 9 = excellent; 10 = perfect.

	Norwegian	English
Speaking (general fluency)		
Pronunciation (accent)		
Reading		
Writing		
Grammar		
Vocabulary		
Spelling		

Q5 Please list the AGE (in years) you were when the following occurred for each language.

	Norwegian	English
Started hearing this language on a regular basis		
Became fluent in speaking this language		
Started learning to read in this language		
Became fluent in reading this language		

Q6 When you are speaking do you ever find yourself accidentally mixing words or sentences from Norwegian and English?

(a) If yes, how often does English accidentally intrude in your Norwegian on a scale of 0-10 (whereby 0 = never, 5 = half of the time. 10 = all of the time)?

(b) And how often does Norwegian accidentally intrude into your English on a scale of 0-10 (whereby 0 = never, 5 = half of the time. 10 = all of the time)?

Q7 When you are speaking with a person who also knows both Norwegian and English do you ever find yourself intentionally mixing words or sentences from Norwegian and English?

(a) If yes, how often do you intentionally use English words when speaking Norwegian on a scale of 0-10 (whereby 0 = never. 5 = half of the time. 10 = all of the time)?

(b) And how often do you intentionally use Norwegian words when speaking English on a scale of 0-10 (whereby 0 = never. 5 = half of the time. 10 = all of the time)?

END OF QUESTIONNAIRE - THANK YOU FOR YOUR TIME!

Appendix H

Full list of words for Word attack task

List 1: see, look, play, was, like, this, next, house, going, bell.

List 2: hang, stand, their, living, again, first, slowly, score, found, bread.

List 3: scream, journey, suppose, yawned, should, tissue, caught, stretching, tongue, copies.

List 4: medicine, strengthen, source, creative, material, eventually, hygiene, despite, calm, journalism.

List 5: excitable, dehydration, persuade, aggrieved, originate, courageous, atmospheric, familiarise, scenic, recurrence.

List 6: ferocious, excursion, coincidental, abysmal, endeavour, rheumatism, haemorrhage, liaise, pseudonym.

List 7: lacerate, bureaucracy, endogenous, coerce, archaic, facetious, pharmaceutical, ochre, fruition, paediatrician.

List of words for LexTALE

Words

denial	festivity	ingenious
generic	screech	bewitch
scornful	savoury	plaintively
stoutly	shin	hasty
ablaze	fluid	lengthy
moonlit	allied	fray
lofty	slain	upkeep
hurricane	recipient	majestic
flaw	eloquence	nourishment
unkempt	cleanliness	turmoil
breeding	dispatch	carbohydrate

scholar
turtle
cylinder
censorship
celestial
rascal
muddy
listless
wrought

Nonwords

Platery
Alberation
Exprate
Kilp
Magrity
Fellick
Pulsh
mensible
plaudate
rebondicate
interfate
abergy
destription
quirty
kermshaw
spaunch
skave
crumper
proom
Purrage
pudour

List of authors for Author Recognition Test

Real authors

Virginia Woolf
J.B. Priestly
Ian Fleming
Markus Zusak
Veronica Roth
Ian McEwan
J.D. Salinger
Jane Austen
Ernest Hemingway
Harper Lee
George Orwell
George Elliot
Sir Arthur Conan Doyle
Alice Sebold
Michael Morpurgo
Cormac McCarthy
Eoin Colfer
Paulo Coelho
Mary Shelley
Margaret Atwood
William Blake
Suzanne Collins
Louise Rennison
Marcel Proust
Anton Chekov
Carol Ann Duffy
Stephen King
Rudyard Kipling
Haruki Murakami
Thomas Keneally
J.R.R. Tolkien
Anthony Horowitz
Kazuo Ishiguro
Phillip Pullman
Robert Louis Stevenson
Leo Tolstoy
Dan Brown
Arthur Miller
J.K. Rowling
Charlotte Brontë
William Golding
James Patterson
Terry Pratchett

Lewis Carroll
Wilfred Owen
Malorie Blackman
Roald Dahl
Jonas Jonasson
George R.R.
Martin
Cassandra Clare

Distractors

William
Reynolds
Nadine Breen
Andrew
McQueen
Luke Oaks
Blake Seymour
Rudy Knight
Bruno Jasper
Allison
Ian Elliott
Robert Addison
Nore Yasagami
Jane Andrew
Forsyth
Akihiro Takeba
Sam Pritchard
William J. Ross
Fiore McCloud
Melissa
Newcomb
Mahmoud Akhtar
Geoffrey
Llewellyn
Fern Elizabeth
Rogers
Akemi Demura
Emily J. Johnson
Carol Bateson
Agnes Lacey
Tiffany Goodwin
Elizabeth
Barrows
Dean Skillbeck
Anastasia
Peterson
Rashid Zafir
Lazarus Kane
Eilish Rownan
Lewis Ogden
Sir Gerald
Vineyard
Clara Dains
Jeffrey Leavens
Eliza Woodward
Julius Yairi
R.D. Lynas
Ben French
Catherine Irving
Dmitry
Abakumov
Joseph Bush
Alice Gold
Hugo Lightfellow
Leopold Rutter
Lazlo de Kuldes
Anton Gillespie
Elizabeth Brown
Michael Godwin
George Ramona
Andrew Blaze