Did I hear that right? The impact of bilingual experience on spoken word recognition.

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I Statement of Authorship

The Candidate confirms that the present project is original and has not been submitted for examination elsewhere. The Candidate further certifies that this thesis does not, to the best of her knowledge, infringe on anyone's copyright or violate any proprietary rights, and that material sourced from other authors has been cited and credited accordingly. Copies of such material has been made openly available in the Appendices.

The Candidate acknowledges the contribution of Professor Monika Schmid as co-author of Study 1, and Dr Laurel Lawyer as co-author of Study 2, which are presented in Chapters 2 and 3, respectively. Study 3 was authored solely by the Candidate and is presented in Chapter 4. The Candidate certifies authorship and publication status of the Studies presented in this thesis as follows:

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II Abstract

The study of bilingual spoken word recognition (SWR) has provided substantial evidence regarding the interaction between the bilingual's first language (L1) and second language (L2) in the linguistic system, particularly in terms of parallel activation and crosslinguistic competition. While existing research primarily focuses on between-language competition, emphasising onset information (i.e., cohort competition), very little is known about how diverse bilingual experiences influence the SWR process. This research project takes a comprehensive approach to bilingual SWR, examining within-language competition dynamics in both L1 and L2 across the bilingual development spectrum using the visual world paradigm (VWP). The studies collectively offer crucial insights into the nuanced landscape of lexical competition resolution in bilingual SWR.

Study 1 examined L2-immersed Spanish-English late bilinguals (also known as bilingual attriters), revealing distinct L1 competition dynamics influenced by L1 attrition. This study significantly contributes to understanding how prolonged exposure to an L2-dominant environment impacts mechanisms of SWR in the L1. Study 2 explored lexical competition dynamics among sequential bilinguals, uncovering analogous underlying mechanisms within both L1 and L2 SWR processes. The study also highlighted the collective influence of individual differences, enriching our comprehension of the interplay of factors shaping within-L1 and within-L2 competition in L1-dominant environments. In Study 3, the focus shifted to the influence of diverse bilingual experiences within-L1 competition. Three distinct bilingual populations exhibited unique competition resolution strategies, showcasing the substantial impact of bilingual variability on L1 SWR. This study contributes to the growing literature on the adaptability of the bilingual language system in response to varied linguistic experiences.

These findings underscore the dynamic nature of bilingual SWR, revealing how diverse bilingual experiences among other factors impact this process across the bilingual continuum. The observed variations emphasise the necessity for a comprehensive understanding of the bilingual language system, providing a foundation for future investigations into the complexities of bilingual development in SWR.

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1 Chapter 1: Literature Review

1.1 Introduction

As James McQueen and Anne Cutler, two pioneering researchers in spoken word recognition (SWR), once claimed, "the proportion of the world's population that is kept awake at night worrying about spoken word access processes is, undoubtedly, vanishingly small." (McQueen & Cutler, 2001:469). More than two decades have passed since McQueen and Cutler stated this, yet its truth remains evident. Although the world at large may not lose sleep over the intricacies of spoken word recognition, we, as psycholinguists, find this topic exceptionally captivating. Despite our fervent encouragement to delve into the mechanisms enabling us to comprehend speech, the research area of spoken word recognition is still, in the grand scheme of things, undoubtedly small.

Since McQueen and Cutler wrote these words more than twenty years ago, much work has been done in the research field of spoken word recognition. A couple of decades after researchers in the field started theorising about how monolingual speakers map the auditory information from the speech signal onto the lexical representations stored in the mental lexicon, researchers began paying a great deal of attention to a different type of *listener*: the bilingual speaker. Part of the field rapidly became interested in how bilingual speakers identify spoken words, particularly, whether bilinguals can map the speech signal from one language while ignoring the lexical representations from the language not being used.

In the early 2000s, Spivey and Marian conducted a series of seminal studies that opened the field to a myriad of questions, as their findings indicated that bilinguals temporally coactivate both languages when processing a single language (Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999). This discovery changed the field of bilingual spoken word recognition as we know it, and since then, in an active group-effort, a high quantity of quality research studies have focussed on how bilinguals process spoken words.

Thanks to the pioneering studies conducted by Spivey and Marian, much of that body of research has centred their efforts on investigating spoken word recognition in the bilingual domain from a crosslinguistic perspective. This approach helps us better understand to what extent both languages interact in the bilingual language system (e.g., Canseco-Gonzalez et al., 2010; Ju & Luce, 2004; Thierry & Wu, 2007; Weber & Paris, 2004; Weber & Cutler, 2004; Cutler et al., 2006). The research boom caused by the generated interest regarding the novel findings of parallel activation and crosslinguistic interference in the research field of bilingual SWR was also heightened by the novelty of the methodological approach that was being used to investigate this topic: eye-tracking technology (Cooper, 1974; Tanenhaus et al., 1995).

As will be reviewed in this Chapter, this methodological research tool became a very important contributor to the rapidly increasing body of research on bilingual spoken word recognition. It allows researchers to assess theoretical predictions on how information is accessed in the linguistic system via the exploration of the automatic mechanisms that take place in auditory language processing through the lens of real-time eye movements (Berends et al., 2015).

Even though a great deal of research has investigated the spoken word recognition process in bilinguals, little is still known about how bilinguals' diverse degrees of multilingual experience influence this process. Just like twenty years ago when researchers in SWR started to investigate the bilingual language system, in recent years several researchers have started to push for a new change of paradigm in the study of bilingualism. In this vein, it has been suggested that just like bilinguals are not two monolinguals in one, the term *bilingual* should not be used to describe a homogeneous category, but a quite heterogeneous one (e.g., de Bruin, 2019; Voits, de Luca, & Abutalebi, 2022).

The acknowledgement of the complex variability that characterises bilingual populations promises to improve our understanding of how spoken word recognition is modulated by different bilingual experiences and individual differences. By investigating bilingual spoken word recognition across the bilingual development spectrum, we will be able to discern what underlying mechanisms from the SWR process are universal across populations and which ones are fundamentally different or adaptable to change.

Starting from the premise of the inherently dynamic nature of the spoken word recognition process (Shook & Marian, 2013), in the present research project, I hope to pay tribute to the work of previous psycholinguists that paved the way for bilingual spoken word recognition research. The aim is to provide a more comprehensive account of how bilingual variability modulates this process across different bilingual populations with diverse bilingual experiences.

The structure of this thesis is as follows: this Chapter starts by providing an overview of influential theoretical models (COHORT, TRACE, NAM, Shortlist, BIA+ and BLINCS) of monolingual and bilingual spoken word recognition, followed by an exploration of the evolution and efficacy of the Visual World Paradigm, an eye-tracking methodology, in investigating auditory language processing. Finally, this Chapter also reviews relevant literature on monolingual and bilingual research on SWR at the word level and concludes by summarising the main objectives of this research project.

Chapter 2 introduces Study 1, which explores bilingual spoken word recognition in the context of first language attrition, focusing on the competition dynamics of L2-immersed Spanish-English late bilinguals (also known as bilingual attriters) in within-L1 and within-L2 lexical competition, in addition to a group of Spanish and English monolingual controls. It also addresses the impact of individual differences in SWR.

Chapter 3 introduces Study 2, which further investigates the competition resolution mechanisms employed by L1-Spanish and L1-English sequential bilingual populations during L1 and L2 SWR and whether their varied degrees of bilingual experience influence these processes.

In Chapter 4, Study 3 examines the impact of diverse bilingual experiences on within-L1 competition during L1 spoken word recognition across the bilingual development spectrum. Focusing on three distinct Spanish-English bilingual groups (i.e., L2-immersed late bilinguals or bilingual attriters, L1-immersed sequential bilinguals, and heritage speakers), the study explores how bilingual variability and diverse levels of L2 experience shape the participants' L1 competition dynamics.

Chapter 5 provides a summary of the main findings reported across the three studies and relates them to theoretical perspectives on the adaptability of the bilingual language system and SWR theories supporting bilingual variability. It also outlines the limitations of the research project and offers a series of suggestions for future research.

1.2 Spoken word recognition

Over the past 50 years, a substantial body of literature has developed around the field of spoken word recognition (SWR), driven by a growing interest in understanding the intricate processes underlying the perception of spoken words. The exploration of word recognition theories has not only inspired current empirical research but has also laid the foundation for comprehending the contemporary challenges faced by the field. To gain insights into the present state of SWR research, it is essential to delve into the influential models that have significantly shaped this domain. This section provides an overview of some of the most influential models on spoken word recognition, focusing particularly on their treatment of two crucial components in the

SWR process: lexical activation and competition. Additionally, an examination of key findings resulting from the empirical testing of these models will be presented.

1.2.1 The Cohort model

The Cohort model, pioneered by Marslen-Wilson and colleagues, (Marslen-Wilson, 1987; Marslen-Wilson & Tyler, 1980; Marslen-Wilson & Welsh, 1978) was the first psycholinguistic model that accounted for the online sequential nature of the spoken word recognition process (see also Cole, 1973; Cole & Jakimik, 1978; 1980; Marslen-Wilson, 1973; Marslen-Wilson & Tyler, 1975). In this model, the recognition process can be categorised in three stages: access, selection, and integration.

During access, the model proposes that as the speech signal unfolds, the acoustic information at the onset of the spoken word simultaneously activates a set of lexical candidates in memory, which phonologically overlap with the onset of the spoken word, constituting the word-initial *cohort*. The activation of multiple lexical candidates that match the speech input to some extent is considered a crucial component in SWR, and therefore has been implemented in all subsequent models (Weber & Scharenborg, 2012). An earlier version of the Cohort model emphasised the role of onset overlap as only items that exactly matched the acoustic-phonetic onset input (i.e., cohort competitors) could be activated to be part of the competitor set (Marslen-Wilson & Welsh, 1978). Consequently, the model did not predict that lexical candidates that matched the speech signal at the offset (i.e., rhyme competitors) could be activated – even when the rhyme candidate overlapped with the spoken word in all but one feature (for example, the spoken word *battle* could not activate *cattle*, Magnuson & Crinnion, 2022).

This version of the model was widely questioned in the literature as it also considered sensory bottom-up input as the solely responsible component for this *all or none* activation process, while pre-selection based on syntactic or semantic criteria was not allowed (e.g., Allopenna et al., 1998; Marslen-Wilson, 1987; McClelland & Elman, 1986). The emphasis made by the model on the decisive role of acoustic-phonetic information in determining which lexical items shape the cohort set of candidates on an all-or-none basis (i.e., words are in the cohort set or out of it), could lead to speech recognition problems. The model posits that during selection, the activation of the competing lexical items decreases as mismatches of more than one feature are perceived between the lexical representations and the incoming speech input. Any minimal variation in the speech signal (e.g., mispronunciations) could hamper the recognition of the correct candidate, as the item would be dropped from the pool of candidates or even earlier in the access stage, when the word did not meet the speech input's matching criteria (Marslen-Wilson, 1987). Moreover, the Cohort model initially proposed that lexical competitors are discarded based on bottom-up and top-down information. However, top-down information was not incorporated until the integration stage where semantic and syntactic properties were retrieved and validated in relation to the target spoken word until a single item was selected and word recognition achieved (also known as the unique word-choice or unique word-candidate, Marslen-Wilson & Tyler, 1980).

According to the model, for the successful recognition of a lexical item, a perfect match between the word-candidate and the sensory and contextual input should take place. This formulation is rather impractical as some studies have demonstrated that listeners are able to recognise words despite acoustic or contextual mismatches (Cole, 1973). In fact, variation in the speech signal or speech recognition in noisy environments where the signal input might not provide optimal acoustic cues are common situations that listeners overcome in everyday speech interactions (Allopenna et al., 1998; Grosjean & Gee, 1984; Norris, 1982; Thompson, 1984). Activation may therefore not function on an all-or-none basis, nor be solely dependent on the sensory information available.

A refined version of the model (Cohort II) addressed these issues by adjusting its architecture to a full bottom-up perspective (Marslen-Wilson, 1987, 1990; Marslen-Wilson, Brown, & Tyler, 1988). The new model proposed that candidates are not activated based on an all-or-none basis, as the assumption of a successful recognition dependent on a perfect match between the lexical candidate and the speech input is rather unrealistic. Instead, selection depends on the relative goodness of fit of the lexical candidate to the sensory input as well as on its activation levels. This assumption would allow the activation and potential recognition of items that present minimal discrepancies with the signal input (Marslen-Wilson, 1987).

The degrees of activation accounted for in Cohort II were connected to the emerging findings on word-frequency (e.g., Taft & Hambly, 1986). Frequency effects were found to affect activation of the lexical candidates, early in the word, in a transient manner in the selection process (e.g., Zwitserlood, 1985). Higher-frequency words showed a rise of their activation levels when compared to lower-frequency candidates, which resulted in a facilitation effect and faster recognition of those lexical items. Therefore, the model assumed that lexical items are dependent on degrees of activation, which can temporarily facilitate recognition if one of the candidates is a high-frequency word (Marslen-Wilson, 1987).

In order to account for potential limitations to the acoustic cues, the model implemented another aspect. The earlier model decided at the pre-lexical stage (phoneme level) whether a feature matched the sensory input. In the newer version of the model, the decision is delayed to the lexical level, which, according to the author, would allow more time to test the validity of the speech signal (Marslen-Wilson, 1987, but see Jusczyk & Luce, 2002, for a review).

Regarding the selection stage, Cohort II still assumes a restrictive competition process in which the lexical candidates that shape the cohort set compete with the target for recognition, without affecting the activation levels of the other candidates (i.e., there is no active parallel competition among the candidates that form the cohort set). These competitors are responsible for monitoring the incoming speech signal and for detecting upcoming discrepancies between the input and the cohort set (via sensory and contextual information). Thus, the acoustic-phonetic information functions as a *locator* of the cohort, while the recognition system closely tracks the information removing the discrepant alternatives until a unique item matches the signal and the recognition decision takes place (Marslen-Wilson & Tyler, 1980). Conversely, subsequent word recognition models have proposed that competition effects are partially responsible for regulating the potential set of items through inhibition, the reduction in activation of other competitor candidates (e.g., lateral inhibition, McClelland & Elman, 1986). This ongoing debate will be further discussed below.

Finally, the model adjusted the relevance of contextual information in the process of word recognition, prioritising phonetic (bottom-up) over contextual information (Marslen-Wilson, 1987). Lexical access ensures the availability of the grammatical and semantic information associated with the candidates, which is evaluated against the developing speech input, updating the levels of activation of the cohort set of lexical items. Thus, contextual information compensates the recognition system when the sensory input is limited and filters word recognition after bottom-up information drives activation. In this respect, both sources of information are rapidly integrated, making word recognition faster in sentence contexts than in isolated words (Weber & Scharenborg, 2012).

Overall, the Cohort model (Marslen-Wilson, 1987) makes several strong predictions regarding the nature of lexical activation (referred to as *multiple access and assessment*), which were central to the development of subsequent models (e.g., Gaskell & Marslen-Wilson's Distributed Cohort Model, 1997; but see Weber & Scharenborg, 2012, for a review). Moreover, it also raises novel questions concerning the time-structure of spoken word recognition. Particularly, it provides a theoretical basis for the prediction of the recognition point in the word. Nevertheless, as stated earlier, the current model also presents some limitations.

Its main weaknesses are the emphasis placed on the strict lexical competition process, the rejection of sublexical levels of representation between the feature and the word level, and the assumption that words can be recognised before word offset (Weber & Scharenborg, 2012). Regarding the latter, some studies found that listeners are not able to correctly recognise most words until after the offset of the word (Bard, Shillcock & Altmann, 1988). Consequently, subsequent models have not just considered the relevance of the onset when accounting for word recognition, but also other segments of the word, as will be discussed in more detail below (e.g., the TRACE model by McClelland & Elman, 1986).

1.2.2 The TRACE model

Extensive research has evidenced that there are multiple sources of information that can be used in the recognition of words (e.g., Bagley, 1900). The TRACE model (McClelland & Elman, 1986) was the first computational model that proposed an account which could integrate or constrain diverse input sources in the process of word recognition (both written and spoken forms). Based on the interactive activation framework, the model posits that "information processing takes place through the excitatory and inhibitory interactions among a large number of processing elements called units" (McClelland & Elman, 1986:2). These processing devices are organised in a complex network of connections that interact in three processing levels: phonetic features, phonemes, and words.

According to the model, the importance of these processing elements lies in their interactivity among the levels. Units are connected via excitatory and/or inhibitory interactions between and within levels, respectively. These connections influence the degree of activation of the *nodes* (units) and, therefore, are responsible for raising or lowering activation in the network. The model, via a novel interactive activation process, also proposes that multiple lexical candidates are activated simultaneously independently of the portion of the speech input that matches those units, thus allowing the activation of units that partially deviate from the signal input. As we will recall from the previous model, the Cohort model did not allow the activation of lexical items that did not match the onset of the input word, which made recognition in ambiguous or distorted speech environments difficult. In TRACE, a less restrictive process takes place as units are activated depending on their degree of fit to the input and on the activation levels from other units.

In this respect, units are constantly receiving information (excitatory or inhibitory) from other lexical items, with activation being continuously updated. If a unit reaches a certain activation threshold it will pass its activation through excitatory connections to other units (for example, from the phonetic feature to the phoneme level), while inhibiting the activation of other competitors in the same level, making them less likely to be recognised.

This interactive activation process serves two purposes: it validates the evidence from the signal input and helps the processing system to categorise the information in the processing levels (feature, phoneme, and word). For example, a speech signal consistent with the voiced consonant /b/ will cause the activation of the voiced feature with the consonant in question, which will activate all voiced phonemes in the next level that are consistent with that feature, leading to the activation of words containing those phonemes (Jusczyk & Luce, 2002). Given this, some features receive more excitatory information than others, being those who reach a certain activation threshold the ones who compete for recognition. Thus, as candidates are activated, competition takes place and, therefore, the speech recognition process requires a mechanism that facilitates the resolution of word competition. TRACE proposes that competition is solved through lateral inhibition. The lexical candidates with the highest activation levels will inhibit the competitors with lower activation in the same processing level, leading gradually to the recognition of the prevailing candidate that best matches the portion of input (McClelland & Elman, 1986). Therefore, cohort competitors, which overlap with the onset of the input, are predicted to be activated earlier due to the sequential nature of the SWR process, followed by rhyme competitors, which will also be activated but less strongly due to this lateral inhibition process (Magnuson & Crinnion, 2022).

As the lexical candidates compete for recognition in the word level, TRACE proposes another simultaneous component in the process to aid recognition, particularly in noisy contexts, the lexical feedback loop. The model posits that a bidirectional feedback mechanism takes place from words to phonemes to features and vice versa influencing word recognition. For example, a particular unit is highly activated in the phoneme level imposing its activation at the feature level (top-down), which, according to the model, speeds up the recognition process by helping a lexical candidate at the word level to win competition. Alternative autonomous accounts argue that perceptual processing is strictly bottom-up with the impact of lexical and semantic contextual information emerging only at a subsequent decision stage (e.g., Norris, McQueen & Cutler, 2000). Therefore, this top-down lexical effect, has been widely questioned by the autonomous models arguing that information feedback from later to earlier processing stages is not necessary nor does it benefit word recognition (McQueen et al., 2009; the Shortlist model by Norris, 1994; but see McClelland et al., 2005; 2006; Strauss et al., 2007, for a supportive view on interaction accounts).

Overall, TRACE proposes an effective explanation for word recognition in ambiguous or distorted speech contexts (e.g., noisy environments) as it accounts for an interactive, unrestrictive mechanism that allows the activation of words with distorted onsets (Allopenna et al., 1998; McClelland & Elman, 1986; Magnuson et al., 2018). Moreover, the model has been able to simulate an extensive variety of behavioural findings (e.g., Ganong, 1980), and it has also successfully predicted word activation in the spoken word recognition process over time (e.g., Allopenna et al., 1998; Magnuson et al., 2003).

This approach, however, suffers from some shortcomings. Particularly, two components are controversial: its interactive lexical feedback loop, which was reviewed earlier, and its questionable architecture. Regarding the latter, to predict word recognition over time, TRACE's entire lexical network needs to be duplicated for each acoustic feature. This means of accounting for the temporal dynamics of spoken word recognition has been challenged by the research literature as the computational simulations made by the model are based on an unrealistic small lexicon, which does not resemble the broad human mental lexicon (Jusczyk & Luce, 2002; Norris, 1994; Weber & Scharenborg, 2012, but see Magnuson et al., 2018). Another problem with this model is that it fails to consider the role of word frequency or the influences of contextual information in the process of word recognition. Although McClelland and Elman (1986) acknowledged these limitations in the model, the impact of frequency was not implemented until an amendment was proposed by Dahan, Magnuson, and Tanenhaus (2001).

1.2.3 The NAM model

The influence of word frequency was firstly integrated into a spoken word recognition model via the Neighbourhood Activation Model (NAM) (Luce, 1986; Luce & Pisoni, 1998). According to Magnuson and Crinnion (2022), this model employs a *lexical dimensions* approach to study phonological similarity via the words' frequency and neighbourhood density, which can be defined as the number of words that differ by no more than one phonemic feature from the target word. Consistent with the Cohort model, NAM posits that the acoustic signal activates a *neighbourhood* of similar-sounding lexical candidates in the mental lexicon.

However, Luce and Pisoni proposed that global phonological similarity is more relevant during the competition process than previously believed. Similarly to TRACE (McClelland & Elman, 1986), non-cohort competition is also accounted for in the NAM model. Following the DAS rule, the authors argued that given a spoken word, neighbour words that differ by one phoneme via deletion (e.g., *CAT* and *AT*), addition (e.g., *CAT* and *CAST*) or substitution (e.g., *CAT* and *BAT*) can also be activated and compete for recognition.

Another difference between NAM and the Cohort model is that NAM does not consider the time course of the spoken word recognition process. Instead, it focusses on parallel activation and competition. According to the model, the lexical neighbours are stored as acoustic-phonetic patterns and are activated via bottom-up input and lexical information such as lexical frequency. These levels of activation are measured by a computed frequency-weighted-neighbourhood probability for each lexical candidate. These acoustic patterns then activate lexical decision units via a version of Luce's choice rule (Luce, 1959). A spoken word will be selected if its decision unit reaches a certain threshold.

Notably, the NAM model makes a series of predictions about the effects of neighbourhood density and word frequency on the SWR process. When frequency is maintained constant, spoken words that share many phonologically similar neighbours are identified more slowly and with lower accuracy compared to words with only a few neighbours. Similarly, if neighbourhood density is controlled, high-frequency words are recognised faster than low-frequency words. A considerable number of research studies on SWR have extensively evidenced these predictions supporting the view that phonological neighbourhood density is a strong predictor of the ease of recognising words in the auditory domain (e.g., Magnuson et al., 2007; Vitevitch & Luce, 1998; 1999; Goldinger et al., 1989). This density effect has been replicated across monolingual (e.g., Taler et al., 2010), and bilingual populations (e.g., Bradlow

& Pisoni, 1999) attributing NAM a large impact on subsequent studies on spoken word recognition (Weber & Scharenborg, 2012).

Regarding its limitations, Magnuson and colleagues (2013; 2022) have pointed out that the NAM model primarily focusses on monosyllables that differ from the spoken target word by only one phoneme, failing to explain the robust cohort competitor effects on longer words predicted by the Cohort model, and which have also been extensively reported in the SWR literature (e.g., Allopenna et al., 1998). As we reviewed earlier, the Cohort and NAM models strongly disagree on how the competitor set is shaped. While the Cohort model predicts that any competitor that phonologically overlaps with the target's onset will be activated, regardless of their length, the NAM model proposes that global similarity is a much more crucial predictor than onset overlap, arguing that any word that differs by only one phoneme with the target will compete for recognition. In agreement with the findings from the SWR literature, the NAM model incorrectly excludes onset competitors that mismatch the target word in more than one phoneme. Subsequent studies have demonstrated that onset competitors compete more strongly and earlier for recognition than any other lexical candidates due to their privileged position in the time course of the SWR process, a crucial component in the process, which the NAM model does not account for (e.g., Magnuson et al., 2007). In this vein, Weber and Scharenborg (2012) have also highlighted that the NAM and its connectionist instantiation model, PARSYN (Luce et al., 2000), are not able to recognise words in continuous speech, which further restricts their scope as spoken word recognition models as they cannot account for word segmentation.

1.2.4 The Shortlist model

In response to TRACE's criticised feedback loop and architectural limitations, Norris (1994) developed the Shortlist model, a feed-forward connectionist model providing an alternative perspective. The Shortlist model proposes that during a lexical search the bottom-up input activates a similar-sounding group (or *shortlist*) of lexical candidates. In this activation stage, the lexical search computes a score that represents the degree of fit between the candidate and the auditory input per segment (1 point is given to each phoneme that matches the input, while 3 points are removed for each mismatching phoneme). This scoring mechanism prevents the activation of lexical candidates that greatly mismatch the onset of the bottom-up input (e.g., rhyme competitors) (Magnuson et al., 2003). Once activated, the shortlist of lexical representations spreads to a network of word units, reminiscent of TRACE's lexical level, where they compete through lateral inhibitory links for word recognition. Consistently with TRACE, Norris (1994) argues that during the competition stage, the words with the highest levels of activation will inhibit candidates with lower activation until the best candidate is identified. However, this model is entirely driven by bottom-up evidence. In addition, it uses a more realistic size for the lexicon than the TRACE model and includes lexical stress as a factor that can constrain activation.

Notably, one of its main discrepancies with the TRACE model is that Shortlist, as an autonomous model, posits that the flow of information is unidirectional and bottom-up, supporting the notion that top-down lexical information cannot influence phoneme processing and thus word-phoneme feedback is redundant (e.g., Cutler et al., 1987; Jusczyk & Luce, 2002; Massaro, 1989; MQueen, 1991; Norris, 1994). While the TRACE model explains a series of effects (e.g., Ganong, 1980) via the lexical feedback, Shortlist proposes that those effects can also be simulated without this mechanism based on an autonomous framework. For example, Norris and colleagues (2000), through the Merge model, argue that lexical knowledge, rather than influencing activation at the sublexical level, can be employed to moderate the decision process at a later stage. The ongoing debate between interactive and autonomous frameworks remains a central point of contention in the field and, in agreement with Magnuson and

Crinnion (2022), the unresolved nature of this debate highlights the need for more realistic models in the evolution of spoken word recognition.

Overall, this model has successfully predicted word activation over time as well as simulated the time course of the SWR process (e.g., McQueen et al., 1994; Norris et al., 1995). However, similar to other SWR models, its first version (now called Shortlist A for *activation*) did not take into account word frequency effects, but a newer version, Shortlist B (Norris & McQueen, 2008), incorporated word frequency to its implementation, aligning with empirical findings and expanding the model's scope.

1.2.5 The BLINCS model

The previously examined models of spoken word recognition laid the foundation for understanding this process within the monolingual language system. Despite ongoing debates regarding the underlying mechanisms, these models collectively underscore the significance of two fundamental processes – activation and competition – for the accurate identification of spoken words (Luce & Pisoni, 1998; Marslen-Wilson, 1987; McClelland & Elman, 1986; Norris, 1994). However, it is noteworthy that none of these models accounted for the potential influence of an additional language on the process of spoken word recognition, as they were primarily focused on a monolingual framework. Building upon these foundational theoretical models and previous findings on how the monolingual system processes spoken language, subsequent models in the realm of bilingual spoken word recognition have endeavoured to address this gap by adapting models of speech perception to accommodate the nuances of the bilingual linguistic system. For instance, the Bilingual Model of Lexical Access (BIMOLA, Grosjean, 1988; 1997) drew inspiration from the established TRACE model, while the Bilingual Interactive Activation Plus (BIA+, Dijkstra & van Heuven, 2002) evolved as an extension of the Interactive Activation model (McClelland & Rumelhart, 1981). In this section, a summary of the Bilingual Language Interaction Network for Comprehension of Speech model (BLINCS, Shook & Marian, 2013) will be provided as it delves into the intricacies of bilingual spoken word recognition, acknowledging the dynamic nature of the bilinguals' linguistic system.

Regarding the previously reviewed processes of activation and competition in the monolingual domain, research on bilingual processing has extensively demonstrated that bilingual individuals do not only manage the activation and competition of lexical candidates from the language being employed, but also co-activate crosslinguistic competitors from the language not being used during SWR (e.g., Canseco-Gonzalez et al., 2010; Ju & Luce, 2004; Marian & Spivey, 2003a; 2003b). These crosslinguistic interactions are assumed to be bidirectional influencing both first (L1) and second language (L2) processing across different levels of representation (Blumenfeld & Marian, 2007; Bobb et al., 2020; Desroches et al., 2022).

In light of the extensive findings on parallel activation and crosslinguistic competition in the bilingual system, the BLINCS model was developed to better understand how both languages interact within the bilingual's language system and the resulting implications for bilingual language processing. This computational model integrates elements from distributed and localist models, effectively simulating the process of bilingual spoken language comprehension. Notably, it places a particular emphasis on accounting for the inherent variability within the bilingual system, which can be influenced by factors related to bilingual experience. These range from long-term predictors like age of acquisition, language proficiency or dominance to short-term predictors like language exposure. In addition, Shook and Marian (2013) posit that bilingual processing can be influenced not only by these bilingual-related factors, but also by the lexical factors that have been previously observed in monolingual processing, such as word frequency or neighbourhood density, whether within or across languages.

Looking at the model's architecture, BLINCS was developed as a network of self-organising maps, also named SOMs, which are interconnected across four levels of representation (phonological, phono-lexical, ortho-lexical, and semantic). Consistently with the Interactive framework, these SOMs are organised bidirectionally, allowing for the interaction of bottom-up and top-down information. In addition, Shook and Marian (2013) implemented a simulation of the impact of visual information on language processing through connections to the phonological and semantic levels as previous research has demonstrated that visual cues can influence speech recognition via auditory and contextual information (e.g., McGurk & MacDonald, 1976; Spivey et al., 2002).

The model's degree of interconnectivity within and across levels aims to simulate the dynamic nature of the bilingual language system. Within each level, all representations are included in the same space, and competition between languages is a result of lateral links as well as their proximity within the map. According to the authors, items that are closely mapped tend to be simultaneously activated but can also inhibit each other. The interactivity across levels is managed by bidirectional excitatory connections via Hebbian learning. For instance, when a lexical representation and its semantic interpretation are simultaneously presented to the model, their connection is strengthened.

BLINCS focusses on the activation process of candidate words over time during speech comprehension. During activation, the phonological vectors of a given spoken word, together with a minimum added noise to make the stimuli more variable, are presented one by one for a number of cycles until BLINCS selects the *best-match-unit* from the shared phonological SOM, activating also neighbouring *nodes*. Given this, the model is able to activate the target phoneme or a best-match-unit that is located near the target phoneme, as items that are closely mapped within the same level are simultaneously activated. At this point in the process, activation can also be influenced by visual information (e.g., see McGurk & MacDonald, 1976). Those nodes that are farther from the best-match-unit are inhibited, while the active node at the phonological level spreads its activation to lexical candidates that contain that phoneme in the same location at the phono-lexical level.

At this level, the model assumes that both languages are separated into regions or *islands* that can interact cross-linguistically, with highly overlapping crosslinguistic representations (e.g., cognates, which can be defined as translation equivalents that overlap orthographically, phonologically and/or semantically: *baby* (English) and *bebé* (Spanish)) located at the limit of these language regions. The lexical items that continue to match the input as more phonemes are presented receive stronger activation, while the activation of those that do not match the input starts to decline. Activated lexical representations can inhibit nearby items as a function of their levels of activation. It is also at this level of representation where the model accounts for neighbourhood density and frequency effects. The phono-lexical units spread their activation to their corresponding units at the ortho-lexical and semantic levels, which activate other neighbours based on their distance to the activated unit.

Consistent with the phono-lexical level, the ortho-lexical level similarly operates as a semi-integrated network where languages are clustered as a function of their orthographic similarity, leading to better integration among languages with similar orthographies. Within the framework of these integrated SOMs, BLINCS categorises words by language region based on phonotactic rules and their spelling-similarities. Notably, cognate words represent a distinct case, allowing both languages to interact within a shared lexical space. For instance, words such as *tobacco* (English) and *tabaco* (Spanish) will be closely mapped due to their phonotactic, orthographic and semantic similarities across languages (Shook & Marian, 2013). This proximity indicates a facilitation effect for cognate activation, as evidenced by previous studies demonstrating a boost in parallel language activation through faster activation and more accurate processing of cognates compared to non-cognates in the bilingual mind (e.g., Blumenfeld & Marian, 2007; Costa, Caramazza & Sebastián-Gallés, 2000).

It is important to note that BLINCS is not the first model to predict this facilitation effect. Previous models like the BIA+ model (Dijkstra & van Heuven, 2002) also accounted for cognate facilitation effects in the visual and auditory recognition domains, leading to cross-linguistic coactivation. According to BIA+, the visual representation of a word (e.g., the English word *HOOD*) will activate a group of cross-linguistic competitors that are orthographically similar (e.g., the English word *FOOD* and the Dutch word *LOOD* for Dutch-English bilinguals), which will also activate associated cross-linguistic phonological and semantic representations (e.g., FOOD activating /fu:d/). Thus, the BIA+ model also accounts for the non-selectivity lexical access to an integrated linguistic system through the cognate facilitation effect.

Returning to BLINCS and its ortho-lexical level, activation can travel back to the phono-lexical level in an interactive fashion, allowing items that are orthographically and/or semantically similar to the target word to also be activated. According to the organisation of the lexicons, BLINCS proposes that language-specific patterns of activation can also emerge at the phono-lexical and ortho-lexical levels of representation. These levels are divided by within-language clusters of lexical representations via a learning mechanism (see Li, 1998). When a given word continually activates a set of associated words, the system learns from it by linking those items together resulting in language-specific activation patterns, aiding the identification of the target word. According to the authors this structural division might also have implications for the control process, as the activation of language-specific patterns could guide language selection (Shook & Marian, 2013). Following previous findings on the impact of lexical knowledge on phoneme perception (e.g., McClelland et al., 2006), phono-lexical information can also be fed back to the phonological level.

Overall, BLINCS represents a significant leap forward in the field of bilingual spoken word recognition. Its distinctive strength lies in its meticulous consideration of an extensive array of factors, including the inherent variability of the bilingual system, that can potentially shape the process of spoken word recognition. This unique feature empowers the model to make nuanced predictions about how these factors modulate the overall process. BLINCS excels in its ability to faithfully simulate the interactivity of the bilingual speech comprehension process. It reliably predicts crucial phenomena, encompassing crosslinguistic activation effects (Marian & Spivey, 2003a; 2003b), cognate facilitation effects (Blumenfeld & Marian, 2007), cohort and rhyme competitor effects both within and across languages (Bobb et al., 2020; Sarrett, Shea & McMurray, 2022), as well as the impact of orthographic and semantic and visual information on lexical processing (Rastle et al., 2011; Yee & Sedivy, 2006). Of particular note is BLINCS' ability to account for individual differences and their impact on the activation process, which should provide invaluable insights into the workings of the bilingual system. The model can be effectively trained to simulate shifts in bilingual experience, including variations in language proficiency or age of second language acquisition, as well as changes in bilingual processing due to aphasia (Zhao & Li, 2010; Grasemann et al., 2011).

In summary, the theoretical models reviewed – COHORT, TRACE, NAM, Shortlist, and BLINCS – collectively provide a solid foundation for understanding the mechanisms involved in spoken word recognition. These models have proposed diverse theoretical perspectives about how information is accessed in the linguistic system, contributing to our understanding of monolingual and bilingual auditory language processing. Each model offers unique insights into the intricate activation and competition mechanisms, for instance, COHORT emphasises the influence of onset information and the sequential nature of the SWR process; TRACE introduces interactive activation and the lexical feedback loop; NAM delves into neighbourhood activation and word frequency effects; Shortlist proposes a feed-forward alternative to TRACE, and BLINCS pioneers in conceptualising bilingual spoken word recognition via a comprehensive approach, providing valuable insights into the dynamic nature of language processing in bilinguals.

To empirically evaluate these theoretical assumptions, psycholinguistics research has employed a diverse array of methodological tools. Building on this groundwork, the forthcoming section will delve into the implementation of eye-tracking technology in the field of auditory language processing. This technological approach offers a unique and precise means to scrutinise the assumptions posited by these models. By exploring real-time language processing through the lens of eye tracking, we aim to contribute nuanced insights that bridge theoretical predictions with empirical observations, advancing our understanding of spoken word recognition in both monolingual and multilingual contexts.

1.3 Exploring language processing through eye movements: The Visual World Paradigm

We are surrounded by visual input that competes constantly for our attention, acting as a filter that helps us select relevant information while ignoring the rest. This intricate link between visual information and our attentional or cognitive resources has fostered a compelling belief: that our eye-movements serve as a nuanced reflection of our underlying cognitive processing mechanisms (Conklin et al., 2018). Acknowledged as a robust methodological approach, eye-tracking technology allows the real-time assessment of gaze and cognitive processing interrelation.

This technology not only unveils the direction of our gaze but also delves into the temporal intricacies of cognitive effort. It provides information on where our gaze is directed, the proportion of looks to a specific point and its duration. Moreover, it measures the cognitive effort based on the complexity of a certain task, operationalised as the duration of the gazes to the input. Thus, the more difficult or complex the task is (e.g., reading), the longer the gaze will be towards that fixation point in the input (Castelhano & Rayner, 2008; Conklin et al., 2018).

Over the past decades, eye tracking technology has been widely implemented in a variety of research areas such as cognitive psychology, computational science, or psychophysics, to name a few (Duchowski, 2017). This section delves into the evolution of eye-tracking technology in psycholinguistics. Particularly, this exploration focusses on the psycholinguistics' exploitation of how eye-movements reflect the cognitive processes that take place in the mind to account for a better understanding of the highly automatic processes that are involved in language processing (Berends et al., 2015).

1.3.1 The Visual World Paradigm: A methodological approach for the study of language processing

The first linguistically centred eye-tracking study was carried out by Cooper in 1974. In this groundbreaking experiment, participants listened to spoken utterances while looking at a number of objects. By tracking their eye-movements, Cooper observed that gaze was directed to objects that were mentioned in the spoken utterances, even though the instructions did not constrain the participants' gaze (Cooper, 1974). The participants' eye-movements were also time-locked to the spoken input, as fixations landed on the critical objects while the target object was being mentioned or within 200 ms after word offset, revealing an intricate connection between auditory input and visual attention.

Despite its significance, Cooper's work was largely disregarded by the research community until 1995 when Tanenhaus, Spivey-Knowlton, Eberhard, and Sedivy applied a similar methodology, leading to the birth of the Visual World Paradigm (VWP).

Visual world studies involve participants listening to spoken utterances while simultaneously viewing a corresponding visual display containing a number of experimental objects which may be related to the speech input to some extent. These visual items are categorised in three roles: i) the objects that are mentioned in the spoken utterance are the targets; ii) the competitors overlap with the target word, as they share some phonological, orthographic, or semantic similarities with the spoken item; and iii) the unrelated words serve as distractors. As participants perform the task, their eye-movements are simultaneously tracked and recorded in real-time for later analyses. Whether or not the participants' gazes are directed to the critical objects and, if so, at what point in time, is a crucial question in language processing research (Berends et al., 2015).

In this respect, the time at which fixations (i.e., looks at a specific point in the visual display), and saccades (i.e., eye-movements from one location to another) are launched towards an item from the spoken utterance, provides an approximation of when the linguistic variable (e.g., a word) has been recognised (Conklin et al., 2018). This is particularly important for understanding how speakers achieve lexical access, as this process can be estimated based on the analysis of the proportion of looks to a critical item and the time at which the auditory input is presented.

The VWP, an innovative methodological approach, has had a major impact in the psycholinguistics body of research, and although it has been applied to investigate both language comprehension and production domains, it has been primarily used to explore how information is accessed in the listener's mind, playing a pivotal role in unravelling the intricate interactions between eye movements, attention resources, and spoken language processing (Huettig et al., 2011). Thanks to the VWP, the relationship between the visual objects and the speech input can be manipulated (e.g., the use of visual objects vs printed words), thus allowing researchers to assess the adequacy of previous theoretical approaches on how information is accessed in the linguistic system (Berends et al., 2015). In that way, spoken word recognition models can be tested and refined based on the findings from VWP research studies (e.g., Allopenna et al., 1998). This will be further discussed in the following section.

Depending on the linguistic domain to be investigated, researchers have modulated the original paradigm by employing different experimental sets of visual and lexical input in order to accommodate specific research questions to this methodological approach. In the original version of the VWP, the visual array contained a set of real-world objects that were manipulated by the participants according to determined spoken instructions (e.g., "*Put the apple on the towel in the box",* Tanenhaus et al., 1995). Newer versions have modified the visual array by implementing a varied set of visual displays ranging from line drawings of semi-realistic scenes to visual media (e.g., films) (e.g., Chambers & Cooke, 2009; Tincoff & Jusczyk, 2012) or by replacing the objects for printed words on a computer screen (e.g., McQueen & Viebahn, 2007).

The use of visual arrays of objects has been found to be especially useful when investigating the speaker's access to conceptual and lexical information in word recognition. By means of the visual representations, recent research studies have been able to examine the processing of semantic information (see Huettig et al., 2011 for a review). However, the implementation of printed words in visual world studies has proven to be more sensitive to phonological modifications than the version with visual items (Huettig & McQueen, 2007).

Other changes in the paradigm involve the speech input. Some versions auditorily present instructions allowing participants to manipulate the objects on a workspace (e.g., Tanenhaus et al., 1995) or on a computer screen (e.g., "*Pick up the beaker*", Allopenna et al., 1998). Other research studies have adapted the way in which the task is presented by merely asking the participants to listen to a spoken utterance that describes a scene (e.g., "*She will pick up the bottle and pour the wine carefully into the glass*", Altmann & Kamide, 2009), while looking at a screen with a display of related objects (i.e., a bottle, a glass). The latter has, for example, been used to study the effects of sentence context (Altmann & Kamide, 2009).

As abovementioned, the malleability of the visual world paradigm allows researchers to test a wide range of scenarios in language processing. The decision of applying one version of the model or another depends ultimately on the research questions posed (Huettig et al., 2011).

1.3.1.1 Advantages of the VWP

The VWP provides a number of methodological advantages over other behavioural research tools. As previously stated, this methodological approach has been proven as an excellent tool to examine language comprehension in real-time by exposing processing mechanisms that listeners are unaware of (Conklin et al., 2018). Moreover, participants are not required to perform meta-linguistic judgements while carrying out the task, which could otherwise encourage the participant's use of their explicit linguistic knowledge. Thus, this method solely relies on the listener's predisposition to launch gazes towards the relevant parts of the visual array as they are revealed by the incoming speech input (Huettig et al., 2011).

Another advantage is that the VWP allows researchers to test speech perception with great precision, as the instrument provides eye-tracking data in a high temporal resolution timescale (milliseconds). This is a crucial factor when evaluating spoken word recognition models, as the method can estimate the time at which a lexical item has been partially activated as well as the point in time when more than one visual object competes for recognition. Lastly, this methodological approach favours the study of a variety of topics under quasi-natural, realistic conditions. Participants look at a visual display while listening to relevant linguistic variables (i.e., words or sentences) in a fairly natural manner (Berends et al., 2015).

1.3.1.2 Potential confounding factors

It has been proposed that our eyes are able to indicate what we are paying attention to and how much cognitive effort is needed for us to process the input we are fixating at, without us being conscious of the complex processes involved. According to this assumption, referred to as the *eye-mind* hypothesis, when an eye-movement lands on an specific item (particularly during reading), it can be said that the mind is processing said item (Just & Carpenter, 1980). This hypothesis should be carefully examined outside the research area of reading, as it might lead to the following oversimplification: what is being perceived by our eye-movements reflects what is being considered. Even in tasks such as reading, humans not only consider the word that is being encountered, but also previous information that might aid the processing system to account for new input (Conklin et al., 2018). Therefore, when investigating the implications of eye-movements in cognitive processing, it is important to take into account potential confounding factors that might obscure the results.

Eye-tracking research must be carefully controlled for possible confounding variables when addressing the interplay between vision, attention and language processing. Visual, auditory and attentional confounding factors play a determinant role on how individuals perceive visual input as well as on where, and at what point in time they direct their eye-movements to (Berends et al., 2015). In this respect, visual world studies in which an array of objects (pictures of real objects or line drawings) are presented require careful consideration of the experimental design as well as a control of the properties of the visual and auditory stimuli to be used.

Visual properties, such as salience, size, naming reliability, familiarity or visual complexity, to name a few, might influence the participants' eye-movements. For example, Loerts and colleagues (2013) found that the salience of some colours attracts more attention than others. Similarly, the use of images portraying real objects facilitates their recognition as real pictures are more detailed than black and white line drawings. However, the visual complexity of this type of stimuli might vary across items, as some objects are more recognisable than others, thus affecting participants' fixation time (Dussias et al., 2013). Accordingly, the use of line drawings from a pre-normed picture database, such as the one created by Snodgrass and Vanderwaart (1980), may be a better option when developing an experimental task.

The number of objects in the display also affects the proportion of eye-movements that are launched towards the experimental visual stimuli. For example, in a study on the interpretation of garden-path sentences, Ferreira and colleagues (2013) found that more complex displays (e.g., arrays containing more items) require more effort from the participant to interpret the sentence. In addition, the location of the items in the computer screen or workspace is also relevant. According to Berends and colleagues (2015), participants might have predisposed tendencies towards particular positions depending on the reading direction in their first language. In order to control for biased location patterns, researchers should counterbalance the positions of the visual stimuli in the visual world task.

While designing a visual world experiment, the visual stimuli should be carefully normed for the abovementioned properties. However, researchers should also take into consideration the influence exerted by the selected auditory stimuli on the participants' eye-movements. Word-frequency, for example, can affect the speed with which an item is accessed in the mental lexicon. As we will recall from the section on spoken word recognition models, word-frequency plays a role in the competition process being faster the activation of high-frequency words when compared to low-frequency ones (e.g., Marslen-Wilson, 1987). Word-frequency effects have been found in visual world studies where the proportion of eye-movements towards a phonological high-frequency competitor has been higher than to a lower-frequency competitor (Dahan et al., 2001). In conclusion, while eye-tracking technology offers unparalleled insights into language processing, researchers must navigate the intricate interplay of factors influencing eye movements to derive accurate and meaningful conclusions from their studies.

Overall, the Visual World Paradigm, facilitated by eye-tracking technology, stands as a robust methodological approach for investigating auditory language processing. The interplay between vision, attention, and the linguistic system unravels through the lens of real-time eye movements. As researchers navigate the complexities of spoken word recognition, the VWP provides a unique avenue for bridging theoretical predictions with empirical observations. The subsequent section will delve into specific research studies that leverage this methodological tool, expanding our understanding of spoken word recognition in diverse linguistic contexts.

1.4 Studies on Spoken Word Recognition: language processing at the word level

This section delves into monolingual and bilingual perspectives on spoken word recognition research, exploring the modulating factors, methodologies, especially the visual world paradigm (VWP), and theoretical frameworks that have contributed to our understanding of this intricate process.

1.4.1 Monolingual word recognition

The activation mechanism in spoken word recognition (SWR) is believed to be modulated by acoustic-phonetic information, as discussed in the previous section on SWR models (Marslen-Wilson, 1987; McClelland & Elman, 1986; Weber & Scharenborg, 2012). The nature of this modulation, whether solely derived from the phonological onset of the spoken word (Cohort model, Marslen-Wilson, 1987; Marslen-Wilson & Tyler, 1980; Marslen-Wilson & Welsh, 1978) or potentially involving phonological information accessed later in the word (i.e., word-final information), has been a longstanding subject of debate (Luce and Pisoni, 1998; McClelland & Elman, 1986; Norris, 1994).

Empirical evidence strongly supports the notion that the onset of an incoming word activates a set of lexical candidates with phonological onset overlap (i.e., *beaker-beetle*), constituting the cohort that competes for recognition (Cole & Jakimik, 1980; Marslen-Wilson et al., 1989, Marslen-Wilson & Zwitserlood, 1989; Nooteboom, 1981; Salasoo & Pisoni, 1985; Zwitserlood, 1989; 1996). However, as a result of continuous mapping models (McClelland & Elman, 1986; Norris, 1990, 1994, Luce, 1986; Luce & Pisoni, 1998) that also predicted the activation of lexical candidates with mismatching onsets (e.g., *beaker-speaker*) as the word unfolds, led to exploration of the role of word-final acoustic information during spoken word recognition, broadening the competitor set to include rhyme competitors.

Several studies have explored the nature of the competitor set in the spoken word recognition process, investigating whether potential lexical items with onset mismatches and phonological rhyme overlaps compete for activation (e.g., Andruski et al., 1994; Emmorey, 1989; Marslen-Wilson & Zwitserlood, 1989; Radeau et al., 1995; Slowiaczek et al., 1987). However, evidence for the activation of rhyming words in the competitor set from previous reaction time and priming studies on monolingual speakers has been inconclusive (see Zwitserlood, 1996, for a review). Several studies using phonological priming have documented rhyme facilitation effects in real words (e.g., *tango-cargo* in Emmorey, 1989; *cold-gold* in Slowiaczek et al., 1987; Radeau et al., 1995). Nonetheless, these results have been attributed to pre-lexical effects (priming at the phoneme/feature level) rather than to effects located at the lexical level (e.g., Marslen-Wilson & Zwitserlood, 1989).

Using the cross-modal priming paradigm, Marslen-Wilson and Zwitserlood (1989) investigated the directionality of mapping hypothesis (i.e., whether input is matched from a word-initial location during lexical access) in real and nonwords in Dutch, examining the role of word onsets in lexical access. Earlier studies had used the same task to demonstrate how word-initial segments were effective primes of an associate word (e.g., [kæpt] – [kæptən] – SHIP) (e.g., Marslen-Wilson, 1987; Zwitserlood, 1989). In Marslen-Wilson and Zwitserlood's study no evidence of rhyme priming effects was found even when primes diverged from the target by only one feature (e.g., *honing-woning* in Dutch). Subsequent analyses evidenced weak rhyme activation effects as a result of the rhyme primes in certain items, which could indicate how words with mismatching onsets could enter the lexical competition stage.

Using the same paradigm, Conine, Blasko and Titone (1993) also reported activation of base words via rhyme priming. In contrast to Marslen-Wilson and Zwitserlood's (1989) findings, evidence of rhyme facilitation was documented in nonwords which diverged from the base word's initial phoneme by only one or two features. Subsequent studies using rhyme priming have investigated the role of *phonological closeness* finding significant priming effects with rhyme nonwords with mismatching onsets in sparse competitor environments (e.g., *pomaat**-*tomaat* in Dutch; Marslen-Wilson et al., 1996). Although these results are similar to the ones obtained in previous research (e.g., Conine et al., 1993), Marslen-Wilson and colleagues pointed out that the rhyme nonwords (e.g., *dask*) were not as effective priming associate words as the source words (e.g., *task*).

Together these studies provided new insights into the tolerance of the word recognition process, as rhyme priming was documented. However, these investigations were limited in scope, primarily concentrating on nonwords. This limitation fails to illustrate whether rhyme candidates with closely matching onsets can be integrated into lexical representations since nonwords lack access to lexical entries (Allopenna et al., 1998; Desroches et al., 2008). Moreover, much of the research carried out at that time was largely based on the priming paradigm. The usefulness of such an approach for measuring activation levels of partially matching lexical candidates was questioned by some authors due to its lack of sensitivity (Allopenna et al., 1998). For instance, it had been argued that priming effects can be difficult to report in cross-modal tasks (e.g., Marslen-Wilson et al., 1996). These effects tend to be numerically small even with full primes, which led to the question of whether partial priming effects could even be detected by this type of approach. The cross-modal priming paradigm could have obscured the results obtained in previous studies underestimating the effects of the rhyme candidates that are potentially activated later in the word. This rationale led researchers to test the potential effects of rhyming competitors via a more fine-grained methodological approach, the visual world paradigm (VWP).

As discussed earlier, the VWP is an eye-tracking research method that allows us to explore the automatic processes that take place during language processing in real time. As the speech stream unfolds, participant's eye movements are assessed towards a visual display in a time-locked manner. Since it was introduced by Tanenhaus and colleagues (1995), the visual world paradigm has attracted a lot of interest from the psycholinguistic research community. To date, several studies have used this method to investigate how information is accessed in the linguistic system, as the timing of the eye movements to particular instances in the speech input provides a continuous measure of the temporal lexical activation and competition effects that take place during spoken word recognition.

A key study by Allopenna and colleagues (1998) using the VWP investigated the role of cohort and rhyme phonological competitors in spoken word recognition. In this visual world study participants would see a visual array of objects on a computer screen while they were asked to move one of them (e.g., "*Pick up the beaker. Now put it below the …*"). Each array would consist of four objects including a target word that was mentioned in the instructions (*beaker* in this example), a cohort competitor (i.e., *beetle*), a rhyme competitor (i.e., *speaker*) and an unrelated distractor (i.e., *carriage*). The study aimed to assess the predictions of the TRACE and Shortlist models, examining whether the unfolding speech input is continuously mapped onto lexical representation. This process would entail the activation of lexical candidates with a partial onset mismatch to the target word later in the speech stream (i.e., when hearing *beaker*, the rhyme competitor, *speaker*, would also be activated).

They found that both types of potential lexical candidates, with onset and rhyme overlap to the target, compete for lexical activation, as participants would be more likely to look at one of the two competitors (*beetle*, cohort; *speaker*, rhyme) than to an unrelated item (*carriage*) when hearing the target word (*beaker*) during the VWP task. These results corroborate the evidence presented by previous studies on the effect of rhyming lexical candidates in the word recognition process. In order to investigate this effect further, Allopenna and colleagues (1998) also performed a series of analyses on the first eight 100-ms time-windows to illustrate how competition developed over time. Consistent with the predictions made by previous models on SWR, cohort activation was reported earlier and more strongly than rhyme activation, while a later activation effect was reported for the rhyme candidate as rhyme overlap occurs later in the word. The results clearly demonstrated how both cohort and rhyme candidates compete for activation during word recognition, regardless of whether they share the onset with the target word or differ from it.

Moreover, the findings from this study evidenced for the first-time robust activation effects from rhyme competitors which diverged by more than one feature from the target word (e.g., *beaker*-*speaker*). These results could be attributed to the high sensitivity of the eye-tracking methodology used to detect transient effects as speech unfolds. As discussed earlier, the inconsistent rhyme effects presented in previous research may be due to the methodologies used, as it has been suggested that tasks such as cross-modal priming or the gating task are not able to detect the subtle activation effects of the rhyme lexical candidates because of their reliance on final processing reaction time measures.

Magnuson, Tanenhaus, Aslin, and Dahan (2003) replicated these findings using an artificial word lexicon, further substantiating the role of frequency in lexical activation and competition. In this version of the VWP, participants had to learn novel words by selecting the word that matched the novel object mentioned in the spoken utterance (e.g., *click on the /pibo/*). During the training, feedback was provided to the participants. In the critical sessions without feedback, the participants' eye movements were recorded in order to investigate further the time course of lexical activation and competition during spoken word recognition. The authors investigated whether the word recognition process of an artificial lexicon would report similar processing effects to the ones documented on real words (e.g., Allopenna et al., 1998). To examine this question, Magnuson and colleagues (2003) investigated how low and high frequency novel words were processed with cohort and rhyme competitors that also varied in frequency. These competitors differed from the target word in their last phoneme (e.g., *pibo-pibu*) or in their initial one (e.g., *pibo-dibo*) to compare the results from a study using an artificial lexicon to the results obtained by Allopenna and colleagues (1998) using real words. Moreover, word frequency was introduced and manipulated in the artificial lexicon to examine the extent to which competition effects are modulated by item frequency, following Dahan, Magnuson, and Tanenhaus´ (2001) results on the relevance of frequency during lexical activation.

The results reported in this study replicated the competition effects documented by Allopenna and colleagues (1998) in real words and the temporal course of frequency effects in the spoken word recognition process illustrated by Dahan and colleagues (2001). Magnuson and colleagues also found that both rhyme and cohort competitors were modulated by frequency, which further supports the activation of rhymes in the candidates' set as predicted by previous theoretical models (e.g., TRACE and NAM).

Supporting the above findings, several other visual world studies have investigated how acoustic information is mapped onto linguistic representations in memory as the speech stream unfolds over time during spoken word recognition. Magnuson, Dixon, Tanenhaus and Aslin (2007) also replicated the effects of word frequency, previously reported by Dahan and colleagues (2001), and explored how cohort density and neighbour density influence the competitor set over time. As previously stated, neighbourhood density refers to the number of words that diverge from the target stimulus by one phoneme (e.g., *cap* and *bat* are neighbours from *cat*), while cohort density comprises those words with matching onset overlap to the target item. It has been predicted that words within a dense neighbourhood, consisting of high frequency words (i.e., many high frequency words phonetically similar to the target word), are more difficult to be recognised than words within sparse neighbourhoods (Cluff & Luce, 1990; Gaskell & Marslen-Wilson, 2002; Luce & McLennan, 2005; Luce & Pisoni, 1998). In their visual world study, participants would follow the spoken instructions "click on the..." and select one of the images from the visual display (one target item and three unrelated distractors). The results replicated the findings from previous visual world studies on auditory spoken word recognition (Allopenna et al., 1998; Magnuson et al., 2003). Magnuson and colleagues also reported crossover effects for neighbourhood density; from an advantage for high density neighbourhoods at the beginning of the spoken word, to a later advantage for low density ones, which suggested that the competitor set is amenable to change over time.

Taken together, these studies further support the assumption that the recognition system in monolingual speakers is more tolerant to phonological mismatches than previously believed. While offset information proves significant during the word recognition process, onset information holds a distinct status in lexical access, dominating the competitor set. Considering the extensive evidence from previous visual world studies, research in lexical processing has evolved significantly providing fine-grained information about how phonological competitors interact (e.g., both cohort and rhyme candidates compete for recognition), and which factors (e.g., neighbourhood size, word frequency) affect their activation during spoken language recognition (Dahan, Magnuson, & Tanenhaus, 2001; Dahan, Magnuson, Tanenhaus & Hogan, 2001; Magnuson et al., 1999; Tanenhaus et al., 2000).

Despite the richness of these monolingual studies, a notable bias exists, as they predominantly focus on English native speakers, potentially limiting insights into language-specific mechanisms influencing spoken word recognition (Kapnoula et al., 2024; Magnuson et al., 2003). Furthermore, investigating monolingual individuals falls short in capturing the dynamic interaction between two or more languages during the SWR process. This inherent monolingual bias has prompted criticism and raised questions about the generalisability of findings across diverse linguistic contexts, particularly those involving bilingual populations, as bilinguals are not the sum of two monolingual language systems (Cook, 2003; Kroll & Bialystok, 2013; Kroll et al., 2014; Kroll et al., 2012). Acknowledging this limitation, psycholinguistic research has shifted its focus in the past decades to include bilingual populations, offering a unique perspective on how languages interact during SWR and lexical processing. The exploration of bilingual individuals not only enriches our understanding of language processing but also provides valuable insights into the intricate mechanisms that may be obscured when studying monolingual populations alone. As we delve into bilingual research in the subsequent section, it becomes evident that this broader approach is essential for a comprehensive understanding of the complexities inherent in spoken word recognition across diverse linguistic contexts.

1.4.2 Bilingual word recognition

The exploration of bilingual spoken word recognition over the past decades has unveiled a fundamental aspect of language processing – both languages are activated in parallel and compete for recognition to some extent in the bilingual's linguistic system. In other words, bilinguals, unlike monolinguals, not only activate competitors that overlap with the language being heard, but also activate competitors from the language not in use (Marian & Spivey, 2003a; 2003b; Spivey & Marian, 1999).

Parallel activation and crosslinguistic competition have been extensively evidenced via the visual world paradigm reviewed in the previous section (see Huettig et al., 2011 for an overview on the VWP). In its bilingual version, participants listen to a spoken utterance in their L1 or L2, while looking at an array of pictures containing a target item, an interlingual competitor that overlaps with the target to some extent, and a distractor. This innovative version of the VWP was pioneered by Spivey and Marian in 1999 where Russian-English bilinguals listened to sentences in Russian such as "Poloji marku nije krestika", which means "Put the stamp below the cross" in English, while they looked at four objects including a target ("marku", s*tamp* in Russian), an interlingual competitor in the irrelevant language (*marker*) and two distractors. Notably, the English word *marker* phonologically overlaps with the onset of the Russian target word, "marku" (*stamp*). By tracking the participants' eye-movements to the four objects displayed as the sentence was produced, the authors found that when participants heard "*mark…*" more looks were directed to the interlingual cohort competitor in the unrelated L2 than to the L1 distractors, suggesting the temporal coactivation of the participants' L2.

Although previous studies have indicated that the robustness of parallel activation in bilingual SWR is asymmetric, favouring the dominant language (e.g., Ju & Luce, 2004; Shook & Marian, 2016; Weber & Cutler, 2004), the coactivation and crosslinguistic interference of both languages during SWR are assumed to be bidirectional. For example, the parallel activation of the unintended language (L1 and L2) has been replicated in a variety of language pairs (e.g., Canseco-Gonzalez et al., 2010; Ju & Luce, 2004; Weber & Paris, 2004; Weber & Cutler, 2004; Cutler et al., 2006), and has been observed even in the absence of overt phonological overlap (i.e., when recognising the English target word *duck,* "pato" in Spanish, Spanish-English bilinguals have been reported to look more at the object *shovel*, "pala" in Spanish, than at the unrelated English item, indicating the phonological activation of the Spanish language via top-down input; Shook & Marian, 2019) (see Bobb et al., 2020 for similar findings employing ERPs via the intermodal priming paradigm). These findings corroborate the proposed interactive nature of both languages in the bilingual language system by connectionist models like BLINCS (Shook & Marian, 2013).

1.4.2.1 Bilingual variability

As previously revised, BLINCS underscores the dynamic nature of the bilingual language system as it can be influenced by diverse degrees of multilingual experience. Within this framework, existing research indicates that bilingual individuals may manifest variations in disambiguating spoken word recognition, particularly when managing the mechanisms of activation and competition. These disparities are associated with the modulating effects of various linguistic and non-linguistic factors, encompassing language proficiency (Blumenfeld & Marian, 2013; Botezatu et al., 2022; Sarrett et al., 2022), language dominance (Marian et al., 2008), age of acquisition (Canseco-Gonzalez et al., 2010), cognitive control skills (Mercier et al., 2014) or the linguistic environment in which bilinguals were immersed at the time of testing

(Bruggeman & Cutler, 2019; Shin et al. 2015; Spivey & Marian, 1999). Importantly, while numerous studies have explored the impact of these factors on the process of spoken word recognition in isolation, a comprehensive understanding of their collective influence is crucial to discern to what extent these factors shape bilingual SWR as well as to identify which factors wield greater relevance in this intricate process.

Recent studies challenge previous assumptions about the rigidity of SWR, emphasising its adaptability, even in the monolingual domain (see Kapnoula et al., 2024 for an overview). For instance, researchers have reported that SWR adapts to the listener over time. Rigler and colleagues (2015) evidenced how a group of young children exhibited slower competition resolution strategies to suppress phonological cohort and rhyme competitors during a visual world task when compared to an older group of adolescents as a result of the influence exerted by their language experience, emphasizing the plasticity of the SWR process across the life span. In the bilingual context, bilingual variability emerges as a critical factor influencing the spoken word recognition process (Shook & Marian, 2013).

Recent studies targeting different bilingual populations across the bilingual development spectrum (e.g., L2-immersed late bilinguals or bilingual attriters, heritage speakers) have unveiled discrepancies in competition dynamics. For example, while Bruggeman and Cutler (2019) found no evidence of L1 or L2 rhyme competition in a group of L2-immersed Dutch-English bilinguals, who emigrated to the L2 environment as adults for an extended period of time, Shin and colleagues (2015) found robust L2-English cohort and rhyme competition effects in a group of heritage speakers of Korean, which were comparable to the effects exhibited by the English monolingual speakers under investigation. The observed discrepancies in competition dynamics across different bilingual populations could be attributed to their differences in bilingual experience.

In recent years, researchers have acknowledged that *bilingualism* encompasses a broad range of populations with diverse bilingual experiences (e.g., de Bruin, 2019; Kaushanskaya & Prior, 2015; Voits, de Luca, & Abutalebi, 2022). But what do they mean by *bilingual experiences*? As de Bruin (2019:2) points out, "even though bilinguals are often compared to monolinguals as two distinct groups, no two bilinguals (or monolinguals) are the same. Bilinguals can differ from each other in many different ways, including their age of acquisition, language proficiency, use, and switching practices in daily life". For example, factors such as moving to a linguistic environment where their majority language is not your first language, the length of residence in that context (e.g., Köpke & Schmid, 2017), the age at which you started learning a second language (i.e., from birth vs later in life) and how you learnt it (e.g., Canseco-Gonzalez et al., 2010), or how often you use both languages and in which contexts these interactions take place (e.g., Beatty-Martínez et al., 2019; Kroll et al., 2022; Miller & Rothman, 2020) are going to influence the experiences of every bilingual speaker.

Voits and colleagues (2022) agree noting that bilingualism should be viewed as a spectrum of experiences were various factors lead to different adaptations in the brain. By considering bilingual speakers as part of a heterogeneous community within this spectrum, researchers can better understand how this inter-variability modulates different linguistic and cognitive processes.

Turning back to the research area of spoken word recognition, little is known about how varying degrees of bilingual experience affect this process (Kapnoula et al., 2024). To date, no studies have explored how SWR compares across the bilingual development spectrum.

1.4.2.2 Rhyme competition in bilingual spoken word recognition

Moreover, in contrast to the extensive research on crosslinguistic competition, particularly from a focus on cohort competitors due to their strong competition effect, within-language competition, especially involving rhyme competitors, remains inadequately investigated in bilingual SWR. As it was previously discussed, the monolingual framework of SWR has extensively investigated how individuals disambiguate the competition process by employing a wide range of competitors (cohort and rhyme competitors) (e.g., Desroches et al., 2006; Magnuson et al., 2003; McQueen & Huettig, 2012; McQueen & Viebahn, 2007).

Conversely, very few studies have introduced rhyme competitors in the bilingual domain (e.g., Ben-David et al., 2011; Bruggeman & Cutler, 2019; Shin et al., 2015). Nevertheless, further exploration is warranted given the intriguing discrepancies that have been revealed in how different bilingual groups resolve lexical competition. For example, Ben-David and colleagues reported differences in the competition dynamics of bilingual speakers as a function of age. Older bilinguals exhibited increased rhyme effects in comparison to younger bilinguals during a visual world task. Interestingly, the observed differences across groups were attributed to their distinct manner of employing suprasegmental cues.

1.4.2.3 The role of language-specific features

Overall, bilingual SWR is intricately shaped by a variety of factors related to the concurrent activation and competition of both languages in the bilingual's linguistic system, the impact of bilingual variability and the bilingual's degree of bilingual experience. Notably, existing evidence also suggests that listeners may employ language-specific cues to modulate the spoken word recognition process (e.g., Ju & Luce, 2004; Kapnoula et al., 2024). For example, factors like grammatical gender have been proposed as predictors influencing SWR in languages such as French (Dahan et al., 2000) or Spanish (Lew-Williams & Fernald, 2007).

In this context, the present project also delves into the role of grammatical gender, especially in Spanish, as a morphosyntactic cue during SWR. Spanish adopts a grammatical gender system classifying nouns into masculine and feminine categories based on suffixes (i.e., -o for masculine and -a for feminine). Spanish gender-specific information is generally conveyed through transparent word endings (i.e., -o for masculine and -a for feminine) and extends to associated elements (e.g., articles, adjectives), ensuring agreement (Harris, 1991). Previous research has suggested that Spanish prenominal determiners can prompt the gender of the incoming noun, serving as a cue in resolving competition during SWR as it can modulate the set of lexical candidates that compete for recognition to those that agree with the gender of the presented determiner. In other words, if an individual listens to the feminine determiner "la", anticipation of a feminine noun occurs restricting the activation of masculine candidates (Dussias et al. 2013; Lew-Williams & Fernald, 2010). In contrast, the absence of gender information in the preceding word extends the time needed to process and identify the subsequent noun (Bates et al., 1996). Empirical evidence supports the idea that Spanish native speakers exhibit heightened sensitivity to word endings, using this phonologically transparent morphosyntactic cue to aid word identification during language comprehension (Caffarra & Barber, 2015; Hernández et al., 2004). Moving forward, it becomes imperative to investigate how language-specific elements, like grammatical gender in Spanish, interact within the dynamics of bilingual spoken word recognition, introducing an additional layer of complexity to the interplay between languages within the bilingual language system (Kapnoula et al., 2024).

1.5 The Current Study: Aims

This literature review underscores critical gaps in our understanding of bilingual spoken word recognition. Firstly, although existing studies have delved into the individual impact of bilingual experiences on spoken word recognition, there is a notable absence of a holistic understanding regarding how these various linguistic and non-linguistic factors collectively shape this intricate process. Secondly, the influence of bilingual variability across the bilingual continuum on spoken word recognition remains insufficiently explored. To date, there is a significant gap in the literature regarding the comparative analysis of L1 and/or L2 spoken word recognition processes across different points in the bilingual development spectrum. Lastly, within-language competition, particularly concerning rhyme competitors, is an aspect of bilingual spoken word recognition that has received insufficient attention. The exploration of these gaps is essential for advancing our comprehension of bilingual spoken word recognition processes.

Therefore, this doctoral project seeks a comprehensive understanding of bilingual spoken word recognition, specifically delving into the nuanced competition processes influenced by bilingual variability and diverse linguistic and non-linguistic factors across the bilingual development spectrum. The overarching goals are achieved through three distinct studies, each employing the Visual World Paradigm to investigate within-L1 and/or within-L2 competition strategies, including the examination of both cohort and rhyme competition effects, across various monolingual and bilingual populations. Specific aims of all three studies are as follows:

Study 1 aimed to examine the competition dynamics of a group of L2-immersed Spanish-English late-bilinguals (also known as bilingual attriters) and compare them to the competition resolution strategies employed by Spanish and English monolingual speakers. By utilising the Visual World Paradigm and manipulating onset/rhyme overlap in both languages, the study explored within-L1 and within-L2 competition. Additionally, Study 1 sought to understand how diverse degrees of linguistic experience (e.g., language proficiency, language use, length of residence among other factors) modulate the competition dynamics of monolingual and bilingual speakers during both L1 and L2 SWR.

Following Study 1, Study 2 delved into the intricacies of within-L1 and within-L2 competition among L1-Spanish and L1-English sequential bilinguals. The principal objectives were twofold: firstly, to scrutinize whether sequential bilinguals, regardless of their native language, employ analogous competition mechanisms in both L1 and L2 spoken word recognition, with a specific focus on cohort and rhyme competition patterns. The study aimed to explore whether these bilinguals manifest similar competition dynamics to those observed in monolingual speakers, emphasizing stronger competition from word-onset competitors than from rhyme candidates during L1 and L2 SWR.

Secondly, Study 2 sought to explore the variations in competition resolution mechanisms across bilingual groups, considering the collective influence of external factors such as inhibitory control skills, proficiency levels, and language use. Additionally, the study aimed to shed light on the disparities in competition dynamics between L1 and L2 spoken word recognition processes among speakers of the same language. It further probed whether L2-Spanish or L2-English speakers exhibit distinct competition resolution patterns compared to their L1 counterparts when assessed in the same target language. Anticipating an L1 advantage in terms of faster word recognition, the study aimed to explore potential differences in cohort and rhyme fixations between L1 and L2 bilingual speakers, investigating how L2 processing demands may influence spoken word recognition.

Building on the findings of Study 1 and 2, Study 3 aimed to explore how bilingual variability influences within-L1 competition during spoken word recognition by investigating the within-L1 competition dynamics in three distinct Spanish-English bilingual populations: heritage speakers, L2-immersed late-bilingual speakers, and sequential bilinguals residing in an L1-dominant environment. The study sought to shed light on the complex interplay of language-related factors and L2-to-L1 interactions influencing bilingual competition processes. It aimed to discern distinct patterns in how the L2 shapes the L1 among different bilingual groups, providing insights into the influence of the L2 on within-L1 competition across the bilingual spectrum. Key objectives included understanding the role played by bilingual variability during competition resolution in the native language, examining within-L1 competition dynamics, and exploring the collective impact of external factors and bilingual experience on L1 spoken word recognition.

Study 3 took a comprehensive approach by considering a range of predictors, including linguistic environments, degrees of L1 and L2 proficiency, dominance, exposure frequency, age of L2 acquisition, or language aptitude, to name a few. The goal was to offer a holistic understanding of the intricate mechanisms governing within-L1 competition in bilinguals, examining how these multifaceted factors and linguistic interactions interrelate with lexical competition dynamics. Additionally, the study incorporated the influence of word-final cues to grammatical gender observed in Spanish monolinguals, particularly focusing on variations in how different bilingual populations use this cue during spoken word recognition. It aimed to discern whether the bilingual populations would display variations in utilising this gender cue.

In summary, this thesis aims to contribute novel insights into the complexities of bilingual spoken word recognition by systematically examining competition mechanisms across diverse bilingual populations. The research endeavours to bridge critical gaps in understanding how bilingual experiences, linguistic environments, and individual differences collectively shape the competition process within the bilingual language system.

2 Chapter 2: Study 1

2.1 Introduction

Upon the onset of speech, listeners engage in the processing of incoming acoustic information by activating multiple candidate words that bear partial resemblance to the speech input (Weber & Scharenborg, 2012). These competing candidates must be promptly activated and discarded in order to effectively resolve the temporal ambiguity arising from the unfolding speech input and to achieve successful word recognition.

The role of phonological information in the disambiguation process of lexical competition has been a subject of debate among researchers. Early models, such as the COHORT model (Marslen-Wilson, 1987), suggested that competition was solely influenced by the phonological onset of the auditory signal. In contrast, the TRACE model (McClelland & Elman, 1986) proposed that later-accessed phonological information within the word also played a crucial role. Research on lexical competition indicates that lexical competitors sharing the onset of the target word (cohort competitors) exhibit a greater tendency to compete for recognition compared to competitors matching the word's ending (rhyme competitors; Allopenna et al., 1998; Magnuson et al., 2003). However, the competition process is dynamic and influenced not only by the evolving acoustic match of the input but also by the structure of the lexicon from which candidate words are activated (e.g., neighbourhood density, word frequency) (Magnuson et al., 2007; Shook & Marian, 2013).

Despite substantial research in spoken word recognition (SWR), the effects of lexicon structure, the nature of acquisition (first versus second language), and the role of additional languages in bilingual speakers have not been extensively investigated from a bilingualism perspective.

Since Spivey and Marian's (1999) landmark eye-tracking study on crosslinguistic activation in Russian-English bilinguals, research on bilingual lexical processing has focused primarily on investigating lexical activation and competition from a crosslinguistic perspective through eye-tracking in the Visual World Paradigm (VWP) (Blumenfeld & Marian, 2007; Canseco-Gonzalez et al., 2010; Tanenhaus et al., 1995). This experimental paradigm has been widely employed to examine both monolingual and bilingual lexical processing due to its high sensitivity to transient effects, such as lexical access (Huettig et al., 2011).

One of the major advantages of the VWP is its ability to investigate the time-course of spoken word recognition in real-time. Participants listen to a spoken utterance while simultaneously observing a visual scene comprising various objects, including items (images or written words) that may be mentioned in the speech input (targets, e.g., *carrot*), items that partially overlap with the target (competitors, e.g., *carriage* and *parrot*), and unrelated distractors (e.g., *ladle*). By tracking participants' eye movements on the display, researchers gain insights into the considered visual items, the timing of consideration, and the duration of consideration. This information is crucial for understanding how speakers achieve lexical access and evaluating the adequacy of previous theoretical approaches in spoken word recognition (Berends et al., 2015).

While research using the VWP has addressed lexical competition in monolinguals and crosslinguistic interactions (CLI) in bilinguals, the lexical competition process along the bilingual development spectrum remains poorly understood.

The bilingual experience varies considerably depending on factors such as age of acquisition, linguistic proficiency, and language use and exposure (e.g., de Bruin, 2019; Grosjean, 1989). Although bilingualism is used as an umbrella term to describe all communities that speak more than one language, existing research has documented this inter-variability among bilingual populations by exploring how differences within this heterogeneous group affect various linguistic processes (Dussias & Sagarra, 2007; Karayayla & Schmid, 2019; Miller & Rothman, 2020). Given the above, if bilinguals with diverse degrees of proficiency or language use can exhibit perception and production discrepancies along the continuum, it makes sense to investigate whether there are also differences in lexical access and competition mechanisms.

Recent studies have highlighted competition differences in lexical processing among bilinguals considering proficiency, age of acquisition, linguistic environment, and linguistic experience (Bruggeman & Cutler, 2019; Sarrett et al., 2022; Shin et al., 2015). However, further investigation is needed to understand how first language (L1) and second language (L2) lexical competition processes compare in bilinguals with diverse linguistic and extralinguistic factors (e.g., L2 learners, sequential bilinguals, heritage speakers, language attriters). Investigating these issues will allow us to better understand the complex dynamics of this process as well as to take into account the heterogeneity within the bilingual continuum.

This study aims to examine spoken word recognition at the word level in the context of L1 attrition. From an L1 attrition perspective, the bilingual's native language can be subject to a myriad of changes as a result of the co-activation of languages, crosslinguistic competition and reduced L1 input and use due to long-term L2 exposure (Schmid & Köpke, 2017). By investigating potential changes in an attrited linguistic system during L1 spoken word recognition, we can uncover novel processes in bilingual lexical processing and enhance our understanding of the bilingual development spectrum.

Although previous research on L1 attrition has demonstrated how the L2 influences L1 lexical access during visual word recognition (Segalowitz, 1991), no studies have explored L1 attrition in the context of spoken word recognition by examining bilinguals' L1 and L2 lexical processing using online measures.

2.2 The study

This study examines lexical competition dynamics in Spanish-English attriters[1], Spanish and English monolingual speakers (control groups) during two visual world eye-tracking experiments. We manipulate onset/rhyme overlap within each language to investigate within-L1 and within-L2 lexical competition. Additionally, we explore the role of external factors from the language attrition literature, such as language proficiency, language aptitude, length of residence, L1 and L2 use and exposure, age, sex, and educational level (Schmid & Dusseldorp, 2010), in the competition process.

We predict that English monolinguals will demonstrate a "cohort effect", a stronger and earlier tendency to attend to cohort competitors over rhyme and unrelated candidates before selecting the target referent image (Allopenna et al., 1998). While no prior research has investigated onset/rhyme competition among Spanish monolinguals, we anticipate a similar disambiguation process in Spanish and English. However, the specific properties of Spanish may impact the competition process.

Grammatical gender serves as a morphosyntactic cue during word recognition facilitating lexical disambiguation. Evidence from studies on SWR suggests that grammatical gender, particularly, the gender-marked information encoded in the article preceding the noun (e.g., *la* [f.] *casa* [f.] – *the house*), modulates lexical activation by constraining phonological cohort competitors that mismatch the gender of the target spoken word in monolingual (Dahan et al., 2000; Lew-Williams & Fernald, 2007) and bilingual domains (Dussias et al., 2013; Morales et al., 2015).

[1] In keeping with the terminology proposed by Schmid and Köpke (2017), we will refer to the experimental group under investigation as attriters. By using this name, we do not presuppose that any changes have, in fact, taken place in their L1.

Spanish grammatical gender is primarily conveyed through transparent nominal suffixes (-o for masculine and -a for feminine, (Corbett, 1991; Franceschina, 2005; Harris, 1991). Spanish natives seem to exhibit a heightened sensitivity to these canonical endings as these cues can help learners classify nouns into gender categories and facilitate gender processing and retrieval in language comprehension via a form-based route (Caffarra & Barber, 2015; Gollan & Frost, 2001; Hernández et al., 2004; Pérez-Pereira, 1991). Considering this, Spanish grammatical gender, as a system that manifests at the rhyme of the noun and contributes to lexical ambiguity resolution, may influence the competition mechanisms of L1 monolinguals. This influence could be attributed to the interplay between phonological similarity and gender overlap at the rhyme of the word, which may lead to increased rhyme competition effects.

Regarding bilingual-attriters, only one study has explored within-L1 competition with onset/rhyme phonological overlap in bilinguals who emigrated to an L2 environment with reduced L1 use (Bruggeman & Cutler, 2019). Interestingly, Dutch-English bilinguals in that study exhibited different competition dynamics compared to their L1 Dutch monolingual counterparts, showing lower rhyme competition during L1 SWR. The authors suggested that the participants' extensive length of residence and L2 exposure in the L2 environment could account for these differences. However, they did not specifically address L1 attrition. This study aims to investigate whether attriters' within-L1 competition is affected by L1 attrition, potentially replicating reduced activation of rhyme competitors seen in previous research (Bruggeman & Cutler, 2019).

2.3 Materials and methods

2.3.1 Participants

Sixty-five Spanish-English attriters (43 female and 22 male; 32 from Mexico and 33 from Spain), 50 Castilian-Spanish monolingual speakers[2] (48 female and 2 male) and 63 British-English monolingual speakers (42 female, 20 male and 1 non-binary) with normal or corrected-to-normal vision and hearing were paid for their participation and included in the analyses (see Table 1 for more information on the participants' characteristics).

[2] The monolingual speakers under investigation were classified as such due to their restricted exposure to a second language, primary limited to their educational curriculum in their respective home countries until the age of 16. Although they had encountered a second language during their schooling, their understanding was either non-existent or extremely limited, as indicated by their responses to the personal background questionnaire.

Table 1. Participant characteristics by group (Study 1).

Variable	Spanish-English bilinguals			Spanish monolinguals			English monolinguals		
	M	SD	Range	M	SD	Range	M	SD	Range
Age	28.7	9	19 - 51	25	8.5	18 - 56	26.11	10.65	18 - 60
Age at onset of bilingualism (AoO)	6.67	3.54	3 - 16		__			__	
Age of Arrival (AoA)	24	6.32	17 - 43		__			__	
Length of Residence (LoR)	5	6	2 - 32		__			__	
Length of L2 Instruction (L2Inst)	11.38	5.16	2 - 20		__			__	
Education Level	10 PhD Degree 28 Master's Degree 23 Bachelor's Degree 4 Voc. Training			__ 5 Master's Degree 35 Bachelor's Degree 10 Voc. Training			2 PhD Degree 11 Master's Degree 47 Bachelor's Degree 3 Voc. Training		

2.3.2 Linguistic and extralinguistic factors

Sociolinguistic and Personal Background Questionnaire (SPBQ).

General information about the participants´ personal background and language use was gathered online through the Schmid and Dusseldorp´s (2010) sociolinguistic and personal background questionnaire (SPBQ) (see Appendix 1). A principal component analysis (PCA) with Varimax rotation (30) was performed on the Likert scale questions relevant to the participants´ linguistic identification, language exposure and language use (see Table 2 below).

Table 2. Summary of the predictor variables extracted from the PCA (Study 1).

Composite predictor variables	Items	Cronbach's α	Variance	KMO	Bartlett's test
L2 Exposure	L2 receptive exposure and use	.720	15.9%	.5	<.001
BIMOD_FAM	L1 use with family and cultural attitudes	.725	13.7%	.5	<.001
L1 Exposure	L1 receptive exposure	.759	7.9%	.5	<.001
BIMOD_PART	L1 use with partner	.978	6.9%	.5	<.001

Aptitude Test. Language aptitude was assessed using the LLAMA Language Aptitude tests (Meara, 2005). This computer-based battery includes four subtests for vocabulary acquisition (LLAMA B), sound recognition (LLAMA D), sound-symbol correspondence (LLAMA E), and grammatical inferencing (LLAMA F). The participants´ score percentages from the four subtests were averaged and a compound variable was calculated.

Proficiency Tasks. Language proficiency in both L1 and/or L2 was evaluated online using a C-test (Grotjahn, 1987; Keijzer, 2007; Mehotcheva, 2010) and a Can-Do scale (ALTE, 1998), sourced from Schmid´s Language Attrition webpage (Schmid, n.d.). To analyse the data, accurate responses from the C-tests were aggregated for each test, and the total percentage of accurate responses was calculated. The participants' responses from the Can-Do scales were classified and then averaged per main linguistic skill (i.e., listening, speaking, reading, and writing). Then, a total variable was calculated for each version of the test (see Table 3 for a summary on the participants' language aptitude and proficiency scores).

Table 3. Language aptitude and language proficiency scores across groups (Study 1).

Variable	Spanish-English bilinguals			Spanish monolinguals			English monolinguals		
	M	SD	Range	M	SD	Range	M	SD	Range
Language Aptitude	50.50	12.30	22.5 - 75/100	43.43	13.5	16 - 78/100	46.23	14.15	10 - 73.7/100
Spanish C-test	61	3.46	45 - 66/66	62.14	3.49	51 - 66/66		__	
English C-test	8.28	0.93	6 - 9.5/10		__		8.34	0.88	6.70 - 9.25/10
Spanish Can-Do	4.78	0.30	3 - 5/5	4.85	0.17	4 - 5/5		__	
English Can-Do	4.34	0.72	3 - 5/5		__		4.39	0.55	3 - 5/5

Flanker Task. The Flanker Task (Eriksen & Eriksen, 1974) assesses participants' inhibitory control and selective attention (i.e., the capacity to attend to a specific input while simultaneously inhibiting irrelevant information triggered by a stimulus). The task consists of 3 conditions (congruent, incongruent, and mixed). In each condition, 5 black chevrons (Font size 18, Courier New) appear in the centre of the screen, pointing in different directions (left or right), while participants indicate the direction of the target chevron situated in the centre by clicking on one of the two keys selected from the keyboard.

The task was administered in-person on a computer screen with E-Prime 2.0 (Schneider et al., 2002). The participants´ accuracy and response times were recorded. Inhibitory control was assessed by measuring the response time (RT) interference scores.

2.3.3 The Visual World Tasks: Design and materials

Two visual world eye-tracking experiments were designed for this study, one for each of the languages under investigation. Each experimental set included a visual display containing four line-drawings (target, cohort competitor, rhyme competitor, and unrelated item) and a question mark sign (see Figure 1 below). Both versions of the task consisted of 15 practice trials. Five practice trials presented an auditory word that was not represented visually on the display. This design aimed to encourage participants to select the question mark response option when the spoken word did not match any of the other items on the screen, thus discouraging guessing (Botezatu et al., 2022). Forty experimental trials were included in the Spanish version and 33 experimental trials in the English version due to word selection constraints specified below. All stimuli were black and white pictures of inanimate and animate items to avoid colour bias.

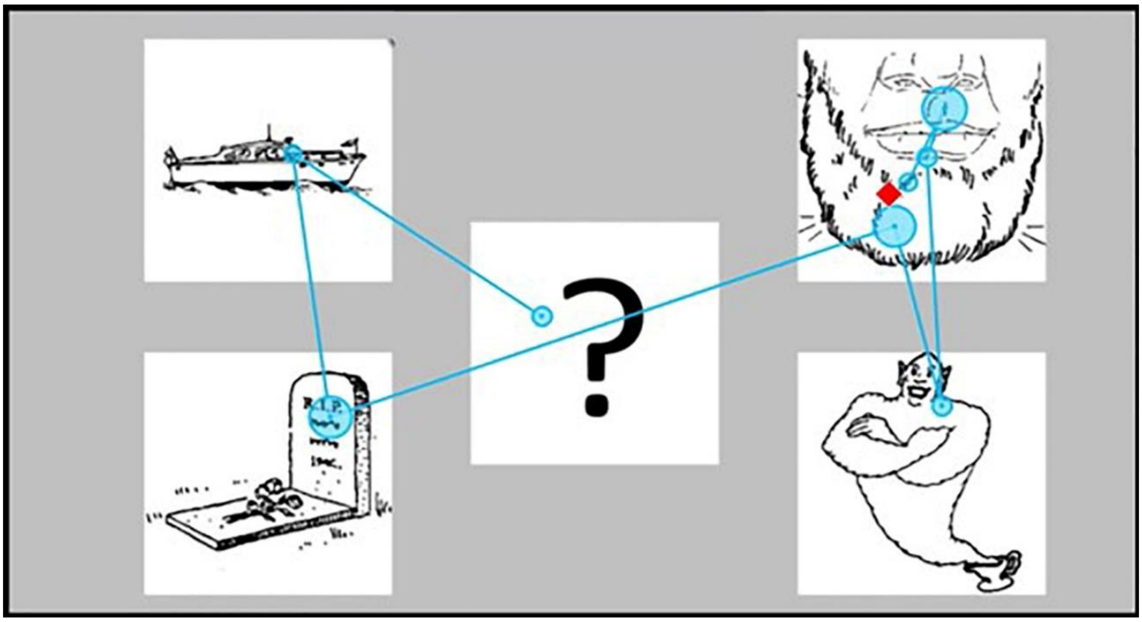

Figure 1. Scan Path Data View. Sample experimental trial from the VWP task with items from Snodgrass and Vanderwart´s (1980) dataset. Clockwise order of components from upper left corner: cohort competitor (*barco-ship*), target item (*barba-beard*), unrelated item (*genio-genie*), rhyme competitor (*tumba-grave*), and central picture question mark.

Most of the stimuli[3] were selected from the On-line Resource for Psycholinguistic Studies (Szekely et al., 2004) and Snodgrass and Vanderwart´s (1980) set of pictures, as all items were normed for name agreement, image agreement, familiarity, and visual complexity in both languages under investigation (Berends et al., 2015). All the items were also normed for stress, word frequency, neighbourhood density, and number of syllables in each language (see Appendices 2 and 3 for more information on the selected picture stimuli). To control for Spanish and English stress patterns, all lexical items were selected to have two syllables and were stressed on the initial syllable (Domínguez Martínez & Cuetos Vega, 2018; Fudge, 1984).

[3] Out of the 292 pictures used, 33 were created by a professional graphic designer. These images were also controlled for name and image agreement, stress, frequency, and number of syllables. Prior to application in the study, all the visual stimuli were piloted (see Appendix 4 for more information).

All auditory stimuli were recorded separately by a female native speaker of Castilian Spanish and a female native speaker of British English in a quiet room. The recordings were then adjusted to a standardized intensity level of 60 dB. Following Botezatu and colleagues' (2022) approach, white noise (62 dB) was added using PRAAT software (Boersma & Weenink, 2017) to challenge word recognition (resulting in a speech-to-noise ratio of -2 dB). Phonological overlap was manipulated by selecting cohort and rhyme competitors that overlapped with the first or last two phonemes of the spoken target word (e.g., *button* (target), *bucket* (cohort competitor) and *onion* (rhyme competitor).

2.3.3.1 Procedure

The eye movements of the experimental and English control groups were tracked with an SMI RED 250[4] desktop mounted eye-tracker and the E-Prime 2.0 software at the University of Essex (UK). Data from the Spanish control group were obtained from two populations in Spain: at the University of Zaragoza using a portable SMI RED 250 eye-tracking device and at the University of Murcia using a portable Tobii Pro X3-120 eye-tracking device.

Participants were seated at a comfortable distance of 60 centimetres from the screen. Instructions were given in the participant's L1. Following Botezatu and associates (2022), bilinguals were tested in their L1-Spanish prior to being tested in their L2-English to avoid L1 inhibition following L2 performance.

After a 9-point calibration, participants viewed a trial preparation screen on a computer display (1680x1050) for 2000 ms. Then, each trial was presented to the participants. Auditory stimuli

[4] Eye-tracking data collected at 250 Hz was downsampled to 120 Hz (see Data analysis section for more information).

were presented 200 ms after picture display onset, and participants selected the corresponding word using a mouse. Pictures were pseudo-randomized to ensure even presentation.

The order of the in-person tasks (Flanker, visual world, and language aptitude) was counterbalanced within each participant group. Data collection included one in-person session and one online session via the Moodle X platform, with an estimated duration of approximately 1 hour (30 minutes per session).

2.3.4 Data analysis

To assess within-L1 and within-L2 lexical competition, we conducted two sets of analyses on the eye-tracking data: one on total looking time to each competitor (cohort/rhyme), and one on the time course of the visual world task as the participants' eye-movements were launched towards the two types of competitors in question. Specifically, we compared Spanish attriters' and Spanish monolinguals' eye-movements towards L1 phonological competitors (cohort and rhyme), and Spanish attriters' and English monolinguals' fixations towards English competitors.

For both analyses, blinks and saccades were discarded. To process and analyse all the gathered eye-tracking data uniformly, the data obtained from eye trackers operating at 250 Hz underwent a downsampling procedure, reducing the sampling rate to 120 Hz. This adjustment was implemented to ensure consistency in the analysis and to facilitate comparison between different sources of eye-tracking information.

Total duration of looks at rhyme and cohort phonological competitors per trial were analysed using linear mixed-effects models (LMM) with the lme4 R package (Version 1.1.26; Bates, et al. 2015) in R (Version 4.0.3; R Core Team, 2020). To analyse competitor fixations over time, we employed generalized linear mixed-effects models (GLMM) with a logistic link function via the lme4 R package.

Following Godfroid's (2020) approach, data points were collapsed into time bins (40 msec) to calculate the aggregate measures via the eyetrackingR R package (Version 0.2.0; Forbes et al., 2021) and were entered as a continuous covariate in the analysis. The dependent variable, odds of fixating on the rhyme or cohort competitor versus other looks, was computed by taking the ratio of fixations to non-fixations and then applying a logarithmic transformation (logit) (Barr, 2008).

2.4 Results

2.4.1 Accuracy and reaction time

All analyses in this study are restricted to the time window from the onset of the spoken word until the participants clicked on the referent picture (target item) (Magnuson et al., 2007). The cut-off point for each group was selected by excluding any reaction time data of the mouse click-response two standard deviations above the grand mean, the point by which fixation proportions tended to asymptote for the three groups. The main analyses were performed on the first 1000 ms of trial duration, beginning from the first 200 ms. Reaction time data were analysed by group and linguistic task by means of linear mixed-effects models (LMM, Baayen, Davidson & Bates, 2008) using the lme4 R package.

Trials with over 25% trackloss were excluded. Equipment malfunctions and trackloss led to 17.7% of missing values (data from 40 participants were excluded: 19 Spanish monolinguals, 10 Spanish bilingual-attriters, 11 English monolinguals). Only correct responses, meaning participants accurately matched the spoken word with the corresponding picture, were included in the analyses. Participants who selected the incorrect item in over half of the total trials per language were excluded from further analyses (data from 10 participants were excluded: 6 Spanish monolinguals, 3 Spanish bilingual-attriters, 1 English monolingual).

Reaction times averaged as follows: bilingual group (Spanish version): 1476.15 ms (SD = 553,58 ms); (English version): 1809.14 ms (SD = 705,23 ms); Spanish monolingual group: 1582.67 ms (SD = 464,79 ms); English monolingual group: 1655.44 ms (SD = 579,27 ms). The bilingual group correctly identified 90% (Spanish) and 76% (English) of the target items on average. The Spanish monolinguals identified 70% on average and the English monolinguals identified 87.8% on average.

Spanish bilinguals were faster in recognizing the correct Spanish target words compared to the Spanish monolingual group (estimate = -0.08, SE = 0.03, $t(139) = -2.497$, $p < 0.05$). Regarding the English task, the Spanish bilinguals were slightly slower in recognizing the correct English target words compared to the English monolingual group (estimate = 0.06, SE = 0.03, $t(130) = 1.761$, $p = 0.08$). In addition, the participants with higher proficiency in English were faster at recognising the target word (estimate = -0.07, SE = 0.02, $t(119) = -4.230$, $p < 0.001$).

Given the lower accuracy and overall speed of Spanish monolinguals in the visual world task, we conducted a follow-up experiment with a group of 15 Spanish monolingual participants, manipulating background noise presence. By controlling for background noise, we aimed to address potential noise-related effects observed in the study (e.g., lower accuracy rates for Spanish monolinguals) without influencing the reliability of the results. The analyses performed across both conditions will be discussed in the following section.

2.4.2 Within-L1 lexical competition

Separate mixed-effects models were built for each competitor to analyse participants' gaze behaviour towards L1 competitors. We employed a forward model selection approach (Barr et al., 2013) to determine the random and fixed-effects structure based on model comparisons. The final models included a two-way interaction (Time Bin x Group) with a quadratic term (orthogonalized to remove collinearity) to better capture the data (see Figure 2), along with random intercepts for participant and item.

Covariates encompassed external variables potentially impacting both Spanish L1 groups, such as gender, age, L1 proficiency, education level, language aptitude, and Flanker task interference scores. Additionally, specific external factors affecting the experimental group were included, including age of arrival (AoA), age at onset of bilingualism (AaO), L2 proficiency, L1 and L2 exposure, length of residence (LoR), and length of L2 instruction (L2Ins).

Figure 2 below shows the average proportion of fixations to the Spanish items over time. From word onset, the bilingual group seems to fixate for longer on the cohort competitor and on the target word than on the rhyme competitor or the distractor before returning to baseline levels. The Spanish monolinguals present a very different looking behaviour, as they seem to pay more attention to the rhyme competitor from earlier.

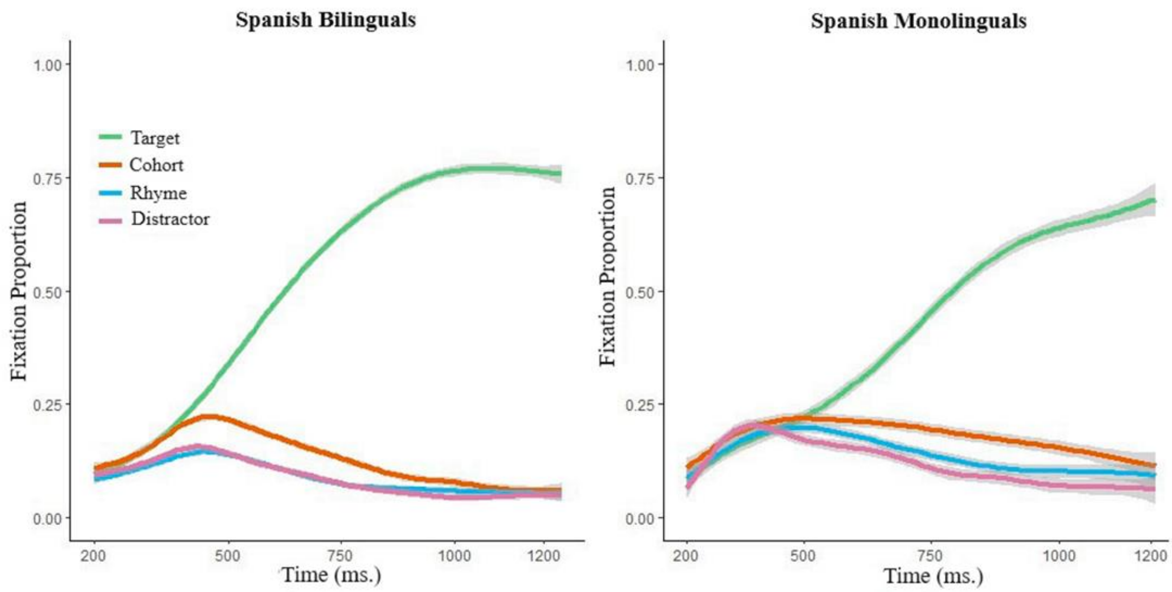

Figure 2. Average fixation proportions towards the Spanish L1 candidates across time. Comparison between the Spanish bilinguals and the Spanish monolinguals.

2.4.2.1 Looks to the L1 rhyme competitor

The GLMM used to assess the odds of looking at the rhyme over time by group (Spanish attriters vs L1 monolinguals) indicated that the bilingual-attriter group was less likely to look at the rhyme competitors (estimate = -0.48, SE = 0.08, $z(49370) = -5.990$, $p < 0.001$) than L1 monolinguals. This model accounted for 44% of the variance. Further within-group GLMMs on the first four 200 ms time windows from the spoken word's onset confirmed a rhyme effect in both groups, with participants fixating more on the rhyme competitors compared to the distractor items. However, the timing of this effect differed between both groups. The Spanish monolinguals exhibited early competition from the rhyme candidates starting around 450 ms (estimate = -0.18, SE = 0.02, $z(7882) = -6.285$, $p < 0.001$), whereas the Spanish bilinguals did not show rhyme competition until later at 700 ms (estimate = -0.18, SE = 0.02, $z(20968) = -7.07$, $p < 0.001$).

A linear mixed-effect model on total duration fixations to the L1 rhyme competitor, containing group (experimental vs control) as the predictor, also indicated that the experimental group looked less to the rhyme competitors than the monolingual control group (estimate = -0.51, SE = 0.08, $t(71) = -6.073$, $p < 0.001$).

Additional LMMs were fitted to account for the external factors that could affect the attriters' total duration of looks to the rhyme competitors. One model, incorporating length of residence and L2 proficiency and accounting for 9% of the variance, showed that the Spanish attriters who had spent more time in the L2 context (UK) (estimate = -0.069, SE = 0.02, $t(65) = -2.541$, $p < 0.05$; effect size = -0.63), and highly L2-proficient bilinguals (estimate = -0.079, SE = 0.03, $t(67) = -2.501$, $p < 0.05$; effect size = -0.61) looked less at rhyme competitors (see Figure 3).

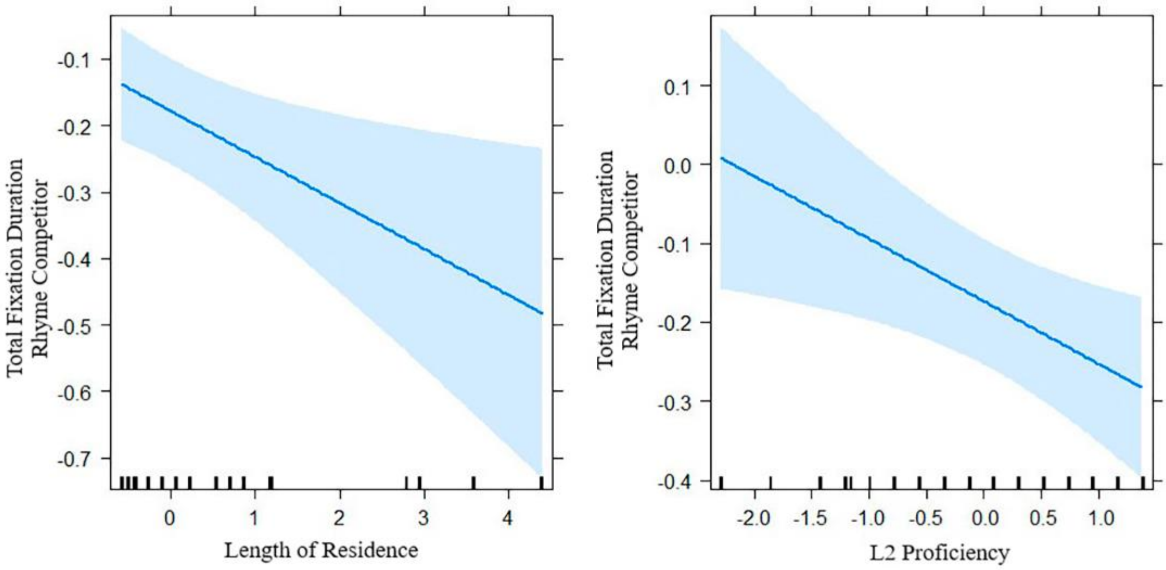

Figure 3. Length of residence and L2 proficiency predictor effects for the L1 rhyme candidates among the Spanish bilingual group.

2.4.2.2 Looks to the L1 cohort competitor

The GLMM assessing the odds of looking at the L1 cohort competitor by group over time showed no significant difference between groups (estimate = -0.27, SE = 0.18, $z(50042) = -1.486$, $p = 0.137$), explaining 56% of the variance. Further within-group models on the first four time windows confirmed a cohort effect (i.e., stronger competition from the cohort competitors than the rhyme or distractor items) for both groups, starting during the 200 to 400ms interval (Spanish bilinguals: estimate = -0.32, SE = 0.01, $z(56626) = -34.871$, $p < 0.001$; Spanish monolinguals: estimate = -0.13, SE = 0.02, $z(14478) = -5.923$, $p < 0.001$). However, the duration of this effect differed between the two groups. The Spanish bilinguals' cohort effect remained significant until the 800 ms (estimate = -0.56, SE = 0.02, $z(31687) = -23.064$, $p < 0.001$), while the Spanish monolinguals' cohort effect persisted beyond the first 1000 ms time window (estimate = -0.68, SE = 0.04, $z(8163) = -15.391$, $p < 0.001$).

The LMM for total duration of fixations towards the cohort L1 competitors across groups revealed no significant distinctions between the Spanish monolingual and attriter groups (estimate = 0.06, SE = 0.08, $t(113) = 0.746$, $p = 0.457$). However, higher language aptitude, particularly higher scores in the sound-symbol correspondence LLAMA subtest, led to longer fixations at the cohort competitor (estimate = 0.12, SE = 0.03, $t(120) = 3.390$, $p < 0.001$; effect size = 0.62) (see Figure 4).

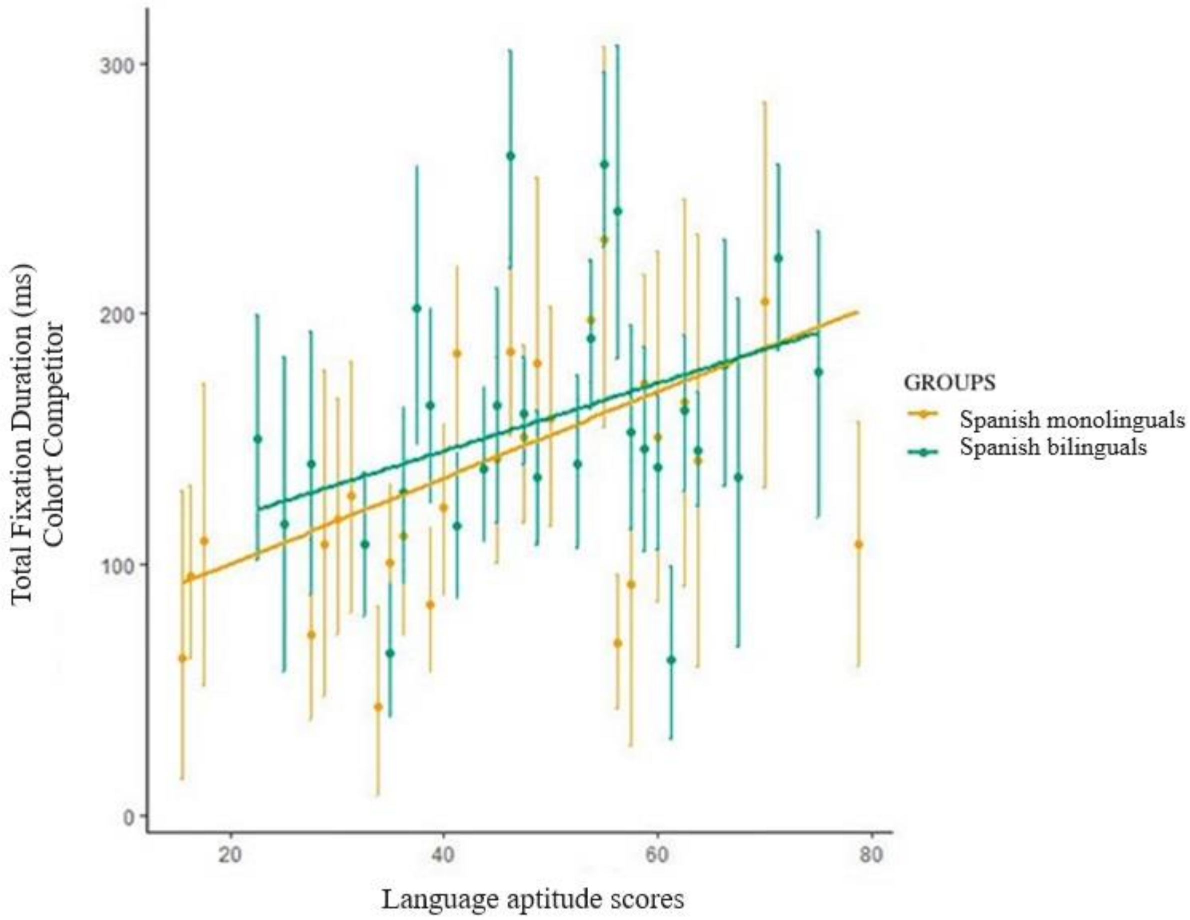

Figure 4. Total fixation duration towards the L1 cohort competitor by language aptitude scores across groups (Spanish bilinguals and Spanish monolinguals).

A separate LMM performed only on the attriters' L1 showed that length of residence and self-perceived L2 proficiency influenced their looking patterns towards the L1 cohort competitors. Attriters who spent more time in the L2 context (estimate = 0.13, SE = 0.04, $t(64) = 2.840$, $p < 0.01$; effect size = 0.70), and those with higher self-rated L2 proficiency (estimate = 0.09, SE = 0.04, $t(65) = -2.099$, $p < 0.05$; effect size = 0.51) looked at cohort competitors for longer (see Figure 5).

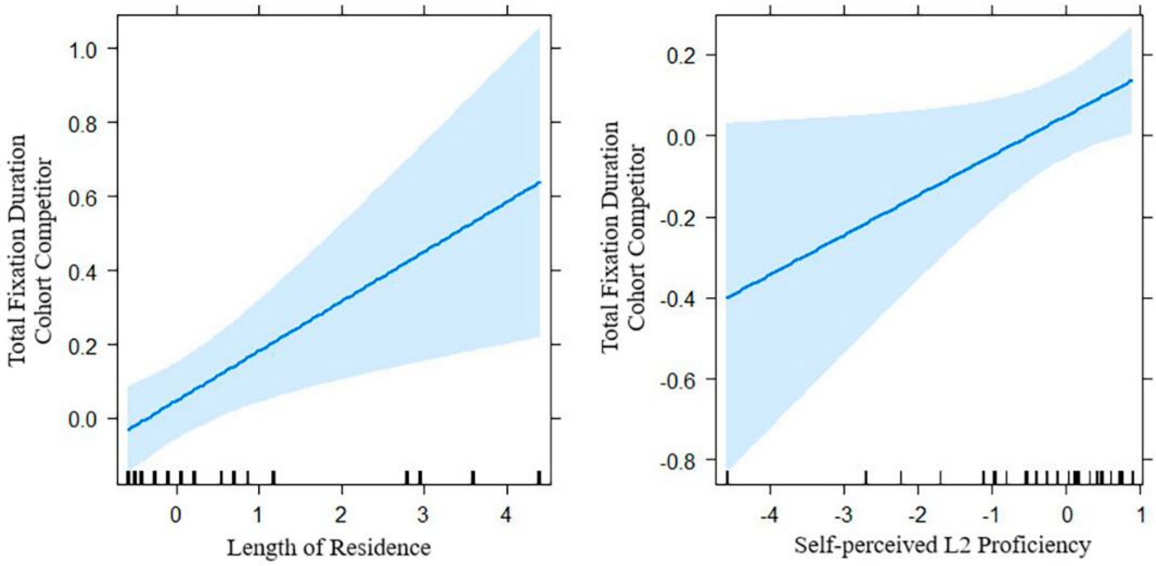

Figure 5. Length of residence and self-perceived L2 proficiency predictor effects for the L1 cohort candidates among the Spanish bilingual group.

2.4.2.3 Follow-up analyses: absence of noise

To control for the background noise of the experimental tasks and to ensure the reliability of the results from the current study, we conducted additional GLMMs on the Spanish monolinguals' odds of fixating on the rhyme and cohort competitors during the visual world task in the absence of noise. The analyses in the quiet condition replicated the cohort (estimate = -0.40, SE = 0.03, $z(20106) = -13.110$, $p < 0.001$) and rhyme effects (estimate = -0.29, SE = 0.03, $z(20106) = -8.545$, $p < 0.001$) observed in the noisy condition, supporting the previous findings. Notably, accuracy rates increased during the quiet condition (92%), whereas reaction times remained consistent (M = 1565.53 ms, SD = 419.86).

2.4.3 Within-L2 lexical competition

To compare the attriters' and English monolinguals' looking behaviour towards the rhyme and cohort English candidates, we followed the same statistical approaches we employed earlier to analyse the L1 candidates, including the same covariates. These models included random intercepts for participant and item and random slopes for group across items.

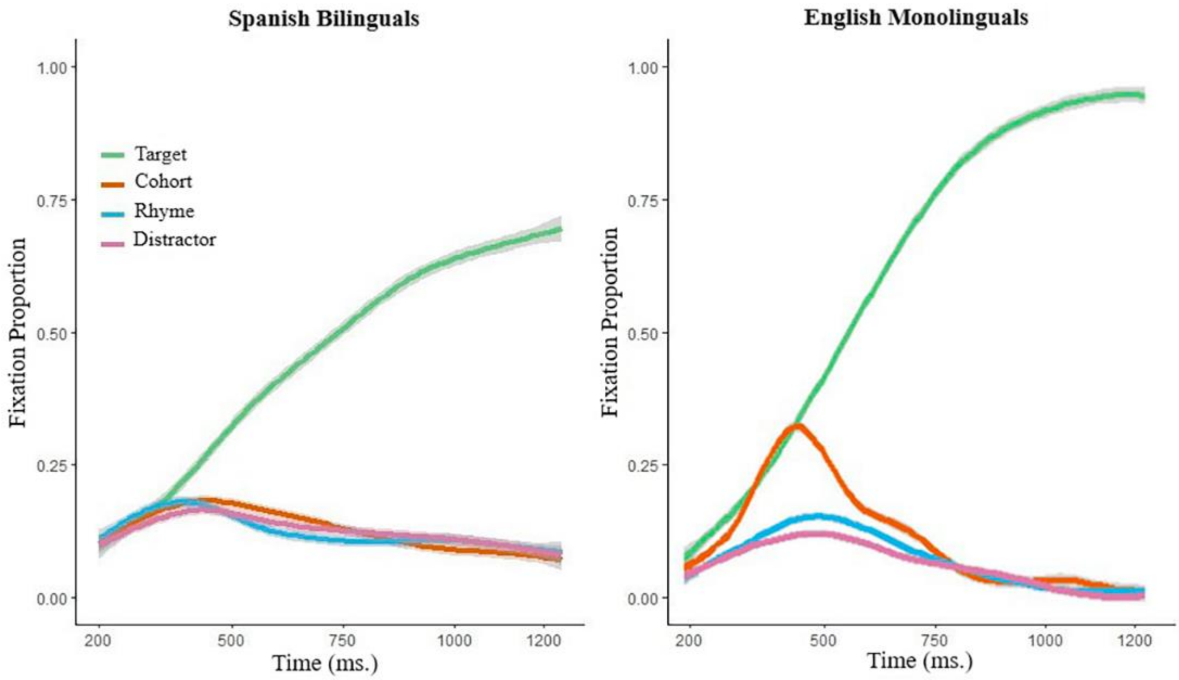

Figure 6. Average fixation proportions towards the English candidates across time. Comparison between the Spanish bilinguals and the English monolinguals.

In the figure above, it is evident that English monolinguals exhibited stronger cohort competition compared to their looks towards the rhyme, which were almost indistinguishable from looks towards the unrelated item. The Spanish attriters seemed to prioritise the cohort competitor briefly before inhibiting both competitors and the distractor simultaneously.

2.4.3.1 Looks to the L2 rhyme competitor

The GLMM examining the odds of looking at L2 rhyme candidates by group (Spanish attriters vs English monolinguals) across time, accounting for 46% of the variance, indicated that the bilingual group was more likely to look at the rhyme competitor (estimate = 0.38, SE = 0.10, $z(73478) = 3.584$, $p < 0.001$) than the English monolingual group. However, the within-group

GLMMs revealed that the Spanish bilingual group did not show significant rhyme competition during the visual world task in English, as the odds of looking at the rhyme competitors did not differ from those of the distractor items (estimate = -0.03, SE = 0.01, $z(91446) = -2.779$, $p = 0.06$). Conversely, English monolinguals presented a rhyme effect during the 400-800 ms interval (estimate = -0.17, SE = 0.01, $z(21484) = -9.811$, $p < 0.001$).

The linear mixed-effects model assessing total fixation duration on English rhyme competitors across groups revealed that group and L2 proficiency influenced participants' looking behaviour. The experimental group paid more attention to the English rhyme competitors than the English monolinguals (estimate = 0.17, SE = 0.06, $t(70) = 2.665$, $p < 0.01$), and highly proficient speakers of English paid less attention to the rhyme candidates (estimate = -0.09, SE = 0.03, $t(108) = -3.219$, $p < 0.01$; effect size = -0.73) (see Figure 7).

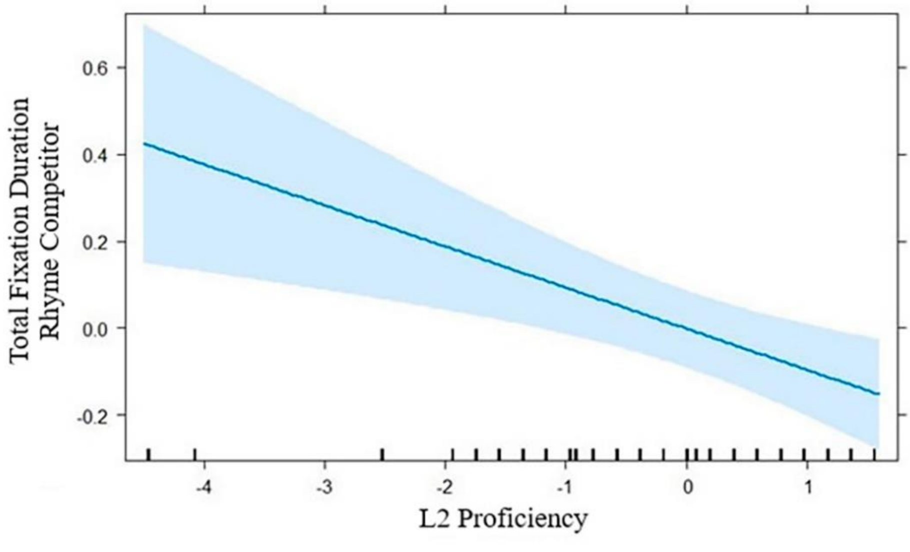

Figure 7. English proficiency predictor effects for the L2 rhyme candidates across groups (Spanish bilinguals and English monolinguals).

2.4.3.2 Looks to the L2 cohort competitor

The GLMM assessing the odds of looking at the English cohort competitors by group across time indicated no significant difference between the attriter and English monolingual groups (estimate = 0.11, SE = 0.09, $z(73478) = 1.276$, $p = 0.202$). This model explained 48% of the variance. According to the within-group GLMMs, both groups presented a cohort effect. In the case of English monolinguals, this effect began at the 200-400 ms interval (estimate = -0.43, SE = 0.01, $z(32238) = -21.872$, $p < 0.001$), while for Spanish bilinguals, it initiated at the 400-600 ms interval (estimate = -0.12, SE = 0.02, $z(14034) = -6.138$, $p < 0.001$). Additionally, a linear mixed-effects model on total fixation duration of English cohort competitors across groups showed no significant distinction between the attriter and English control groups (estimate = -0.06, SE = 0.07, $t(60) = -0.978$, $p = 0.332$).

2.5 Discussion

To better understand how lexical competition influences lexical processing in bilinguals' first and second languages from a language attrition context, this study sought to explore within-L1 and within-L2 lexical competition dynamics in Spanish-English bilingual-attriters during SWR. The results revealed that the bilingual-attriters' L1 competition dynamics differed from their monolingual counterparts during the Spanish visual world task. Specifically, they exhibited delayed activation and reduced competition from L1 rhyme competitors compared to the Spanish monolingual group. Additionally, the Spanish-English bilinguals did not employ similar competition dynamics to disambiguate both L1 and L2 processes, rapidly inhibiting both English competitors prior to recognising the spoken target word.

Given that spoken word recognition can be influenced by bilingual experience (e.g., Shook & Marian, 2013), we hypothesized that certain features of lexical items, particularly those relevant for lexical access, may be interpreted differently. In Spanish, the rhyme of a word holds important information such as gender distinctions, which facilitate gender retrieval (Corbett, 1991; Gollan & Frost, 2001), contributing to the disambiguation of the competition process (Lew-Williams & Fernald, 2007). Conversely, in English, the rhyme of a word does not carry similar weight and is less likely to serve as a cue for lexical access.

Our findings confirm these assumptions, particularly underscoring the Spanish monolinguals' language-specific sensitivity to transparent endings. As illustrated in Figure 2, Spanish monolinguals retained information from the rhyme competitor longer, suggesting reliance on the rhyme for competition resolution. In contrast, as shown in Figure 6, the English monolinguals suppressed the rhyme competitor earlier, retaining only the target and cohort as the two 'viable' candidates. We argue that, unlike in English, Spanish rhyme candidates matched the target's gender and phonologically overlap with the target's word ending, heightening their activation levels, thereby leading to increased rhyme competition during the SWR process. Interactive approaches like TRACE (McClelland & Elman, 1986) propose that lexical information can influence pre-lexical representations to enhance speech perception (McClelland et al., 2006). Therefore, it is plausible that Spanish monolinguals used this gender-marked information as a cue for lexical access, facilitating word recognition when the gender cue is presented sequentially (Dahan et al., 2000) but increasing rhyme competition when presented simultaneously in both rhyme and target items.

Interestingly, the Spanish attriters exhibited very different L1 competition dynamics from the Spanish monolinguals, as they relied less on L1 rhyme information, resembling the patterns observed in English monolinguals. This difference may indicate that their process of lexical access and lexical selection has been influenced by their L2 experience, where word endings contribute less to disambiguation.

According to the Competition model (Bates & MacWhinney, 1987; MacWhinney, 2019), the availability and reliability of a cue are crucial factors during language learning. Spanish monolinguals might rely on the cues at the end of the word as they have learned through frequent L1 use and exposure that important information is stored at the rhyme of the word (e.g., gender). The model contends that these cues become more dependent on their reliability over time and that entrenchment, the repeated use of that cue, is central to L1 maintenance. Nevertheless, prolonged influence from the L2, particularly in an L2-dominant context, together with L1 disuse, can affect how this protective factor operates in the L1.

Although the susceptibility of a particular linguistic feature to L2 transfer seems to depend on their L1-L2 similarities (MacWhinney, 2019), previous research has demonstrated how the L2 can impact L1 patterns even in very distinct languages (Malt et al., 2015). In other words, L1 features that are not highly similar across languages (like gender marked endings in Spanish vs English) could still be affected by the L2.

Moreover, while the lexical competition process in SWR is not language-specific, previous studies have highlighted how the competition dynamics can be modulated by the bilingual development experience (e.g., Bruggeman & Cutler, 2019; Sarrett et al., 2022; Shin et al., 2015), or individual differences (e.g., McMurray et al., 2010), regardless of the similarity between the bilinguals' L1 and L2. Thus, it is possible that transfer from L2 to L1 lexical competition dynamics can occur, as evidenced by the weakened effects of L1-Spanish rhyme competitors observed in this study. Consequently, we posit that the changes in the L1 competition dynamics exhibited by the Spanish attriters align with the Competition model and should be considered as a consequence of L1 attrition.

Further support for this interpretation comes from the analyses of the predictor variables related to bilingual experience. The shift in L1 looking patterns, which prioritises information contained in the onset rather than the rhyme, becomes more pronounced over time and with an increase in L2 proficiency. These results corroborate previous findings linking these two factors to L1 attrition effects (e.g., Dussias & Sagarra, 2007; Segalowitz, 1991).

Language aptitude, particularly its phonetic/phonemic coding component from the sound-symbol correspondence LLAMA subtest, also intensified the duration of cohort competition effects for both attriters and Spanish monolinguals. Participants who were more skilled at identifying speech sounds and establishing sound-symbol associations presented longer fixations on cohort competitors. This outcome finds support in the extensive evidence on SWR where a more robust cohort competition prevails over rhyme candidates due to their initial advantage at the activation stage (Allopenna et al., 1998; Magnuson et al., 2003). We propose that participants with enhanced phonetic/phonemic coding abilities could have experienced heightened sensitivity to the word's onset information due to its initial phonetic similarity to the target, resulting in a greater reliance on rapidly activated cohort competitors over rhyme-aligned ones.

In terms of L2 competition dynamics, the Spanish attriters swiftly activated and suppressed both cohort and rhyme candidates. However, distractor candidates received comparable attention, indicating a lack of strong bias towards either type of competitor. This suggests they did not rely on them to resolve temporal ambiguity during within-L2 competition. The absence of significant effects from cohort and rhyme competitors can be attributed to the participants' high levels of L2 proficiency. More experienced L2 users, particularly older and more proficient L2 speakers, exhibited quicker suppression of L2 competitors, aligning with existing literature (e.g., Blumenfeld & Marian, 2013; Botezatu et al., 2022; Sarrett et al., 2022).

2.6 Conclusion

The present study provides evidence that Spanish-English attriters employ distinct competition dynamics from the ones presented by their L1 monolingual counterparts when disambiguating auditory input during L1 spoken word recognition. In terms of L1 processing, the attriters rely less on the rhyme, which is typically more informative for disambiguation processes in their L1, but they exhibit performance driven by their L2. Additionally, the Spanish attriters with higher English proficiency are able to disambiguate the L2-English spoken word more quickly, relying less on competitors. Two external factors linked to L1 attrition - L2 proficiency and length of residence - influenced the participants' performance. Highly proficient bilinguals with longer exposure in the L2 environment adjust their competition dynamics to align more closely with monolingual L2 users. Based on the Competition model, we argue that the observed changes in the bilinguals' L1 competition resolution dynamics provide evidence of L1 attrition, as the prolonged transfer from the L2 has likely influenced the protective factors that typically safeguard the L1, such as entrenchment. Consequently, the attriters in our study demonstrated a shift in their L1 competition mechanisms, aligning more closely with their L2, where the rhyme of the word contributes less to the competition resolution.

The study's demonstration of contrasting lexical processing between the attriter and monolingual systems contributes to a better understanding of the fine-grained changes occurring during spoken word recognition across the bilingual development spectrum. Particularly, it addresses how bilingual attriters, an understudied population, manage the lexical competition process and how their competition resolution mechanisms are modulated by individual differences and specific bilingual experience. However, many questions remain unanswered regarding how other bilingual populations with different levels of proficiency and exposure navigate this complex competition process. Additional research should investigate how the linguistic attriter system differs from other bilingual systems, such as heritage speakers and sequential bilinguals, in order to explore the extent to which bilingual variability impacts lexical competition in both first and second languages.

3 Chapter 3: Study 2

3.1 Introduction

3.1.1 The role of competition dynamics

The resolution of lexical competition is fundamental to the accurate perception of spoken language. A considerable amount of research has focused on how monolinguals resolve lexical competition during spoken word recognition (SWR). Most theoretical models assume that the unfolding acoustic-phonetic information is temporally mapped onto lexical items stored in the listeners' mental lexicon that partially match the auditory signal. Initially, several of these items are activated and compete for recognition until the best candidate is recognised and selected (Luce & Pisoni, 1998; Marslen-Wilson & Welsh, 1978; McClelland & Elman, 1986; Norris, 1994; Norris & McQueen, 2008). Experimental evidence from a range of tasks has shown that this process is influenced by multiple cues (ranging from acoustic to lexical). In particular, cohort competitors that match the onset of the spoken word compete stronger for recognition than those that rhyme with the target word due to the sequential nature of the auditory signal (e.g., Allopenna et al., 1998).

While the competition dynamics used to disambiguate spoken words in the native language have been extensively researched in the monolingual domain, bilingual research has mainly centred on between-language competition with a focus on cohort competitors (e.g., Blumenfeld & Marian, 2007; Canseco-Gonzalez et al., 2010; Ju & Luce, 2004; Marian & Spivey, 2003; Spivey & Marian, 1999). Two central findings are the parallel activation and crosslinguistic competition of both languages in the bilingual's mind, which have been widely demonstrated using the Visual World Paradigm (VWP; Tanenhaus et al., 1995).

The bilingual version of this eye-tracking paradigm, as outlined by Blumenfeld and Marian (2007), follows a similar approach to the monolingual paradigm as it involves participants listening to a spoken utterance, which contains the label of a visually presented target object, while they are instructed to identify that object from an array of pictures. Importantly, this version introduces a visual display featuring a target item (e.g., the English word *marker*), an interlingual cohort competitor (e.g., *marka*, Russian for *stamp*), which phonologically overlaps in the non-target language with the onset of the target item in the target language, and two unrelated distractors (e.g., Marian & Spivey, 2003a; 2003b; Spivey & Marian 1999). The participants' eye movements are monitored using eye-tracking technology until the target object is selected.

Findings from this experimental task demonstrated that when bilinguals heard the target word in their second language (L2) (e.g., *marker*), more looks would be directed to the between-language competitor in the irrelevant first language (L1) (e.g., "*marka*") than to the L2 unrelated items. This design has been extensively employed to replicate the parallel activation of both languages across different language pairs, demonstrating how this paradigm allows for the assessment of the crosslinguistic competition process during SWR in real time (Canseco-Gonzalez et al., 2010; Marian et al., 2008; Weber & Paris, 2004; Weber & Cutler, 2004; Cutler et al., 2006). The temporal activation of a word-onset competitor during a visual world task (known as "the cohort effect") has also been replicated when examining bilinguals' within-L1 (Marian & Spivey, 2003a), within-L2 (Sarrett et al., 2022) and L2 to L1 between-language competition dynamics (Marian & Spivey, 2003a; Spivey & Marian 1999).

However, despite consistent findings of rhyme competition effects in monolingual studies (Desroches et al., 2006; Magnuson et al., 2003; McQueen & Huettig, 2012; McQueen & Viebahn, 2007), the evidence regarding the impact of rhyme competitors on bilinguals' within-or between-language competition process remains inconclusive. For example, Ben-David and colleagues (2011) found competition resolution discrepancies between younger and older bilingual adults, as older bilinguals presented higher rhyme competition effects than younger bilinguals during within-L1 competition, particularly when perceiving speech in noise. To explain these competition differences the authors pointed to a change in how these two groups employ informational cues during lexical competition based on the participants' age (e.g., older bilinguals would depend more on suprasegmental cues than younger bilinguals).

In another study, Shin and colleagues (2015) identified substantial L2 rhyme effects during within-L2 competition in Korean-English bilinguals, who had migrated to the L2-dominant environment before puberty, comparable to the rhyme effects observed in the monolingual English control group. The authors argued that the robust cohort and rhyme effects exhibited by bilinguals in their L2 during a mouse-tracking task suggest that native-like competition dynamics can be found in L2 speakers under certain circumstances.

However, recent studies on bilingual speakers immersed in an L2-dominant environment since adulthood have yielded opposing results when assessing within-L1 and within-L2 competition processes. For instance, Bruggeman and Cutler (2019) found no evidence of rhyme competition in either language when evaluating within-L1 and within-L2 competition in L2-immersed Dutch-English bilinguals. Interestingly, the authors observed that the levels of L1 rhyme competition exhibited by the participants were lower compared to previous studies conducted on Dutch monolinguals. They suggested that proficient immersed bilinguals may lack the working memory capacity to resolve lexical competition in the same manner as monolinguals due to the coactivation of multiple between- and within-language phonological competitors. Similarly, Soto and Schmid (2023) found that Spanish-English L2-immersed bilinguals (also named bilingual attriters) exhibited delayed activation and weaker rhyme competition compared to Spanish monolinguals during L1 SWR. Building on Bruggeman and Cutler's (2019) findings, the authors attributed the differences in competition resolution between bilingual and monolingual speakers to the prolonged influenced of the L2 on the L1, particularly in an L2-dominant context. Late-bilingual speakers with higher L2 proficiency and more extended immersion in the L2 environment exhibited the most significant discrepancies with their monolingual counterparts, while resembling the competition dynamics of the English monolinguals under investigation during the L1 competition process.

Two important themes arise from the studies discussed so far. Firstly, these conflicting results on the role of competition dynamics in bilinguals' first and second languages are likely due to the differences in overall bilingual experience observed among these bilingual populations (e.g., different levels of proficiency and amount of exposure, age of acquisition, linguistic environment). Previous studies on bilingual spoken word recognition have demonstrated that varied levels of linguistic experience can modulate said process (e.g., Botezatu et al., 2022; Fricke, 2022; Sarrett et al., 2022). Furthermore, from a theoretical approach, models of bilingual spoken word recognition such as the Bilingual Language Interaction Network for Comprehension of Speech model (BLINCS; Shook & Marian, 2013) have also proposed that bilingual experience can influence spoken word recognition. Therefore, to develop a full picture of the spoken word recognition process in bilinguals, it is crucial to investigate the impact of individual differences on both between- and within-language lexical competition processes. Secondly, the observed discrepancies in the management of the rhyme competition effects across bilingual populations further support the need for additional research on a wider range of competitors to better understand how these competition dynamics compare across the bilingual continuum.

3.1.2 The role of individual differences

Previous research examining spoken word recognition in bilinguals and monolingual speakers suggests that while both populations exhibit the same fundamental competition dynamics to resolve within-L1 competition (e.g., a strong cohort effect followed by a weaker rhyme effect), there are qualitative differences between bilinguals and monolinguals in relation to how they mediate these mechanism (Blumenfeld & Marian, 2011; Botezatu et al., 2022). This section delves into the exploration of such differences in competition resolution, specifically examining the influence of individual differences during SWR.

Blumenfeld and Marian (2011) found that monolinguals seem to take longer to disengage from inhibiting competitors, while bilinguals resolve competition in a more efficient manner. This may have to do with cognitive control, a domain-general mechanism, which has been linked to efficient lexical competition resolution in bilinguals (Green, 1998). For example, Mercier and colleagues (2014) reported that those bilinguals who exhibited better (domain general) inhibitory control skills were also better at suppressing phonological cohort competitors during within-language competition.

This ability to resolve competition in a more efficient manner has been associated with the bilinguals' linguistic control. Contrary to monolinguals, bilinguals need to suppress not only within-language competitors from the target language, but also cross-linguistic competitors from the unrelated language when resolving lexical competition, even in monolingual settings (e.g., Blumenfeld & Marian, 2007; Canseco-Gonzalez et al., 2010; Marian et al., 2008). Evidence from studies on inhibitory control during bilingual spoken word recognition suggest that the cross-linguistic co-activation of multiple lexical representations in the bilinguals' mental lexicon trains their competition resolution dynamics favouring their cognitive control skills, particularly in highly proficient L2 bilinguals (Blumenfeld & Marian, 2013; Singh &

Mishra, 2007). In other words, second language proficiency may increase the parallel activation of L2 competitors during SWR (Segalowitz & Hulstijn, 2005), leading to better cognitive control skills to efficiently manage the multiple representations that become activated.

According to the Bilingual Interactive Activation + model (BIA +; Dijkstra & van Heuven, 2002; van Heuven et al., 1998) and the BLINCS model (Shook & Marian, 2013), parallel activation and cognitive control take place during spoken word recognition. However, the effects are not assumed to overlap during the time course of spoken word recognition as parallel activation emerges early during comprehension, while the cognitive control mechanisms arise later to help disambiguate word competition and achieve word selection. These theoretical frameworks were supported by Blumenfeld and Marian's (2013) findings which evidenced how the relationship between parallel activation and cognitive control skills changed as time passed. Highly L2 proficient bilinguals with better cognitive control abilities increased parallel activation at the beginning of the spoken word recognition process while they lowered crosslinguistic activation later during competition.

While some studies have attributed bilinguals' efficiency at resolving competition to their inhibitory control skills, Botezatu and colleagues (2022) offered opposing results as they could not find evidence of a connection between lexical competition resolution efficiency and better cognitive control in either bilingual or monolingual groups. Interestingly, they reported that bilinguals with higher L2 discourse and semantic fluency demonstrate more efficient competition resolution dynamics during L1 spoken word recognition, supporting the influence of language experience on lexical competition.

Existing studies have indicated that higher levels of bilingual proficiency are associated with increased parallel language activation (Blumenfeld & Marian, 2007), more efficient competition resolution dynamics (Botezatu et al., 2022), and, in certain cases, improved cognitive control skills (Blumenfeld & Marian, 2013) during L1 spoken language processing. Based on these findings, it appears that language experience plays a critical role in capturing variations in how different bilingual groups may employ competition dynamics in their native language. However, to date, very few studies have investigated how these findings relate to L2 spoken word recognition, particularly in within-L2 competition.

Previous research on L2 spoken word recognition suggests that auditory L2 processing may be more demanding and less efficient (slower) compared to L1. This includes the inaccurate activation of L2 words that compete for recognition due to difficult acquisition of L2 phonemic categories or inaccurate L2 phoneme perception (Best, 1995; Broersma & Cutler, 2011; Strange, 1995; Weber & Cutler, 2004), as well as the more demanding use of working memory resources due to parallel activation and cross-linguistic competition of multiple lexical items (Bruggeman & Cutler, 2019).

Recently, Sarret and colleagues (2022) examined within-L2 and crosslinguistic competition in adult L2 learners of Spanish as well as their association to L2 proficiency. They reported that within-L2 competition does not fully resolve in adult L2 learners as the fixations directed to the cohort competitor did not return to baseline levels, compared to the looks to the unrelated items. Sarret and colleagues (2022) suggest that this finding could be linked to the participants' levels of L2 proficiency, as language users with lower proficiency are less prone to effectively inhibit competing lexical candidates by the end of the lexical competition process (McMurray et al., 2010). Critically, the authors observed that the most proficient L2 users exhibited similar mechanisms to the ones reported in L1 development: more exposure to the target language speeds up early word recognition processes.

Additionally, previous studies on reading measures have reported how L2 usage can modulate L1 and L2 word processing in younger bilinguals (e.g., Whitford & Titone, 2017). In view of these findings, language use could help capture how different individual factors affect spoken word recognition as the degree of language usage may modulate how demanding the lexical competition process is. Overall, further research exploring individual differences could enhance our understanding of bilingual spoken word recognition by shedding light on the specific mechanisms that are likely to exhibit variability in the bilingual's first and second languages.

3.2 The study

The present study investigated how sequential bilingual speakers - individuals who acquired both languages successively, without undergoing immersive experiences in the second language - resolve within-language competition during spoken word recognition by testing sequential L1 Spanish/L2 English and L1 English/L2 Spanish bilinguals across within-L1 and within-L2 visual world tasks. Given the limited exploration of rhyme effects in the domain of bilingual spoken word recognition, the current study aimed to examine the L1 and L2 competition dynamics of the bilinguals under investigation by comparing their fixation patterns to phonologically similar lexical candidates, cohort and rhyme competitors, and target items during the time-course of spoken word recognition.

We were particularly interested in whether participants would exhibit similar competition dynamics to the ones evidenced in monolingual speakers in the literature, that is, stronger competition from the word-onset competitors than from the rhyme candidates during within-L1 competition (e.g., Allopenna et al., 1998). This study also sought to examine how L1 and L2 lexical competition processes differ in the same bilingual speakers (i.e., L1 vs L2 SWR) as studies focusing on within-L2 competition have received limited attention. If both competition processes employ similar competition dynamics to disambiguate L1 and L2 spoken word recognition, we should expect comparable competition resolution mechanisms (i.e., cohort and rhyme effects) to those observed in the L1 (Sarret et al., 2022).

Building upon the observed differences in receptive language processing between bilinguals' L1 and L2, our study furthermore aims to investigate how spoken word recognition in L1 and L2 compare among groups of native and L2 bilingual speakers under the same task demands (e.g., L1-Spanish-English bilinguals and L1-English-Spanish bilinguals on a visual world task in Spanish). From a lexical competition perspective, we seek to explore whether L2-Spanish and L2-English speakers exhibit different competition resolution patterns compared to L1-Spanish and L1-English bilingual speakers, when assessed in the same target language, shedding light onto the nature of L2 lexical competition. In line with previous findings, we anticipate an overall L1 advantage in terms of faster word recognition for L1 words compared to L2 users processing L2 candidates in the same task, which is expected to show slower spoken word recognition (Sarret et al., 2022; Weber & Cutler, 2004). We aim to determine whether differences in the form of competition mechanisms (variation in cohort and rhyme fixations) will emerge between L1 and L2 bilingual speakers.

Finally, given previous findings on how bilingual competition dynamics may be modified as a function of language experience and cognitive control, we also assess to what extent individual differences in language proficiency, language use and inhibitory control skills, alongside personal background factors, would modulate both within-L1 and -L2 competition processes among sequential bilingual speakers. This approach allows us to evaluate the potential relationship between individual variability in a non-linguistic measure of cognitive control (Flanker task) and a set of measures of language experience, and how these factors may influence the parameters involved in resolving lexical competition during spoken word recognition. Successful identification of such a relation would contribute to a better understanding of how spoken word recognition works in bilinguals' first and second languages, which in turn may also contribute to the refinement of SWR theoretical models.

3.3 Methods

3.3.1 Participants

Out of a pool of 114 individuals, data from 46 native English speakers of Spanish (33 females) living in the United Kingdom (UK) and 43 native Spanish speakers of English (32 females) living in Spain were analysed in this study (see Data analysis section for more information on the excluded data). The L1-English and L1-Spanish bilingual participants were recruited from the Universities of Essex (UK) and Murcia (Spain), respectively, and were paid for their participation in the study. All participants reported normal or corrected-to-normal vision and hearing (see Table 4 for more information on the participants' linguistic and cognitive background characteristics).

Table 4. Participant characteristics by group (Study 2).

Variable	English sequential bilinguals			Spanish sequential bilinguals		
	M	SD	Range	M	SD	Range
Age	33.9	14.96	18 - 65	21.79	3.89	18 - 33
Age at onset of bilingualism (L2 AoO)	12.85	7.83	2 - 49	5.24	2.18	2 - 11
L2 Instruction (L2Inst)	10.40	4.68	3 - 27	14.38	3	6 - 21
Education Level	1 PhD Degree 7 Master's Degree			1 PhD Degree 1 Master's Degree		

	25 Bachelor's Degree 4 Voc. Training	36 Bachelor's Degree 2 Voc. Training

3.3.2 Materials

Each participant completed a set of tasks measuring i) L1 and L2 spoken word recognition through the visual world paradigm (Tanenhaus et al., 1995), ii) language aptitude through the LLAMA test (Meara, 2005) and iii) cognitive control through a Flanker task (Eriksen, 1974). Participants also completed iv) a sociolinguistic and personal background questionnaire (SPBQ) (Schmid & Dusseldorp, 2010), v) proficiency C-tests, and vi) proficiency self-rating Can-Do scale tasks in Spanish and English. Each task will be described below.

3.3.2.1 Visual World Tasks

Within-L1 and -L2 competition processes were assessed using two visual world eye-tracking tasks in Spanish and English, respectively. The experimental trials consisted of a visual display of four black and white drawings including a target, a cohort competitor, a rhyme competitor, and a distractor item (Allopenna et al., 1998) (see Figure 8 below). Additionally, to avoid random selection, each trial included a question mark sign in the centre for participants to select in case they did not recognise the target spoken word (Botezatu et al., 2022).

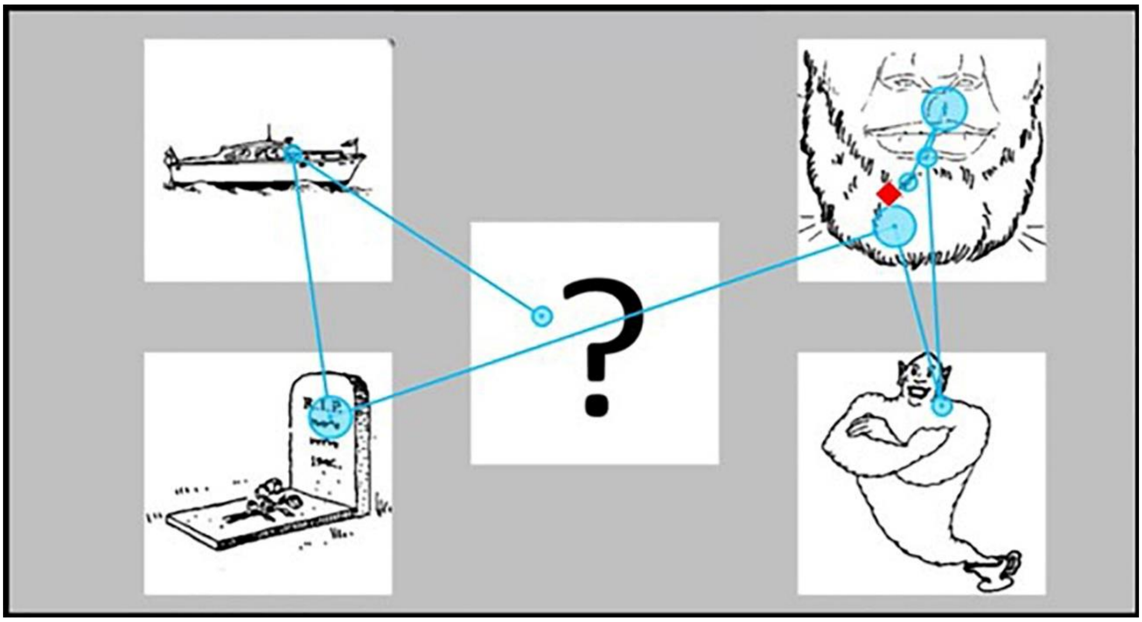

Figure 8. Scan Path Data View. Sample experimental trial of VWP from Soto and Schmid (2023) with items from Snodgrass and Vanderwart´s (1980) dataset. Clockwise order of components from upper left corner: cohort competitor (*barco-ship*), target item (*barba-beard*), unrelated item (*genio-genie*), rhyme competitor (*tumba-grave*), and central picture question mark.

The stimuli[5] were normed for name and image agreement, familiarity and visual complexity across both languages and obtained from the On-line Resource for Psycholinguistic Studies (Szekely et al., 2004) and from the Snodgrass and Vanderwart's (1980) set of pictures (see Appendices 2 and 3 for more information). All selected items had two syllables and were initially stressed to control for the stress patterns of the languages under investigation (Domínguez Martínez & Cuetos Vega, 2018; Fudge, 1984; Guion, Harada, & Clark, 2004). Phonological overlap between the critical words and the competitor candidates was controlled by selecting competitors that shared at least two word-initial or word-final phonemes with the

[5] Out of the 292 pictures used, 33 were created by a professional graphic designer. These images were also controlled for name and image agreement, stress, frequency, and number of syllables. Prior to application in the study, all the visual stimuli were piloted (see Appendix 4 for more information).

target word. Moreover, all experimental stimuli were controlled for frequency in both languages. Finally, the auditory stimuli were recorded by a female native speaker of Castilian Spanish and a female native speaker of British English in a quiet room. The signal was standardised to 60 dB prior to adding 62 dB of white noise using PRAAT (Boersma & Weenink, 2017) to make word recognition more difficult (Botezatu et al., 2022).

We collected data from 30 participants by means of a dual set-up with an SMI RED 250[6] desktop mounted eye-tracker and the E-Prime 2.0 software (Psychology Software Tools Incorporated, 2012; Schneider, Schuman, & Zuccolutto, 2002) at the University of Essex, and 16 participants using a Tobii Pro Fusion 120 eye-tracker and the iMotions software at the ESSEXLab (University of Essex, UK). The data from Spanish-English bilinguals was collected using a portable Tobii Pro X3-120 eye-tracking device at the University of Murcia (Spain). The procedure was standardised across all participants, with pictures being pseudo-randomized within and between trials to ensure equal presentation of each item in every screen position. The order of English and Spanish eye-tracking tasks was also counterbalanced.

During the experimental session, participants were seated 60 cm from the screen monitor (1680x1050) and presented with a 9-point calibration. Subsequently, a trial preparation screen with a cross in the centre of the screen was presented for 2000 ms followed by 15 practice trials. Fourty experimental trials were designed for the Spanish task and 33 for the English task due to word selection constraints specified above. In each trial, the auditory stimulus was presented over headphones 200 ms after the onset of the visual array. Participants were instructed to use a mouse to select the picture that corresponded to the word they heard. To prevent potential L1 inhibition after L2 performance (Misra et al., 2012), bilinguals were tested

[6] Eye-tracking data collected at 250 Hz was downsampled to 120 Hz (see Data analysis section for more information).

in their L1 first, as per the approach used by Botezatu et al., (2022), before being tested in their L2.

3.3.2.2 Language Aptitude Tests

The participants' language aptitude was assessed using the LLAMA Language Aptitude tests, which were adapted by Meara (2005) from the MLAT tests (Carroll & Sapon, 1959). The LLAMA test is a computer-based battery of four subtests that measure different aspects of language aptitude, including vocabulary acquisition (LLAMA B), sound recognition (LLAMA D), sound-symbol correspondence (LLAMA E), and grammatical inferencing (LLAMA F). To analyse the data, the participants' score percentages from the four subtests were averaged and included as a covariate in the linear mixed-effects models (see Results section).

3.3.2.3 Flanker Task

Participants' inhibitory control and selective attention were assessed using the inhibition task developed by Barbara and Charles Eriksen (1974). The task consisted of three conditions, namely congruent, incongruent, and mixed, where five black chevrons (Font size 18, Courier New) appeared in the centre of the screen pointing either left or right. Participants were instructed to indicate the direction of the target chevron in the centre by pressing one of two keys on the keyboard. The task was administered on a computer screen using the E-Prime 2.0 software, and participants' accuracy and response times were recorded. Inhibitory control was assessed by measuring the interference scores by subtracting the mean reaction time (RT) for accurate congruent trials from the mean RT for accurate incongruent trials in the mixed condition as employed by Sanders and colleagues (2018).

3.3.2.4 Sociolinguistic and Personal Background Questionnaire (SPBQ)

General personal background and language use information was obtained through the sociolinguistic and personal background questionnaire (SPBQ) developed by Schmid and Dusseldorp (2010) (see Appendix 1). The questionnaire was administered online via the Moodle X platform. Following Schmid and Dusseldorp (2010), a Principal Component Analysis (PCA) with Varimax rotation (30) was conducted on the Likert scale questions related to participants' linguistic identification, language exposure, and language use. The use of PCA aimed to consolidate correlated elements from the SPBQ into a reduced set of variables. This enabled us to assess and incorporate these composite variables (i.e., L1 and L2 use) as covariates in our statistical analyses (Field, 2009) (see Table 5 below for more information).

Table 5. Summary of the predictor variables extracted from the PCA by group (Study 2).

Composite predictor variables	Items	Cronbach's α	Variance	KMO	Bartlett's test
L2 Spanish Language Use	English bilinguals' L2 receptive exposure and use	.914	37.67%	.5	<.001
L1 English Language Use	English bilinguals' L1 receptive exposure and use	.845	16.33%	.5	<.001
L1Spanish Language Use	Spanish bilinguals' L2 receptive exposure and use	.873	23.29%	.5	<.001
L2-English Language Use	Spanish bilinguals' L1 receptive exposure and use	.916	17.50%	.5	<.001

3.3.2.5 *Proficiency Tasks*

The participants' Spanish and English proficiencies were assessed through two tasks: a C-test (Grotjahn, 1987; Keijzer, 2007; Mehotcheva, 2010), and a self-rating task, the Can-Do scale (ALTE, 1998), which were obtained from the Language Attrition webpage (Schmid, https://languageattrition.org/resources-for-researchers/experiment-materials/c-test/) and administered online via the Moodle X platform.

For the C-test data analysis, participants' accuracy was measured, and the total percentage of accurate responses was calculated. This information was then compiled into a combined variable representing the total correct scores for each individual and language. The Can-Do scale responses were classified and averaged per main linguistic skill (listening, writing, speaking, and reading), and a total variable was calculated. The final compound variables were included as covariates in the linear mixed-effects models (see Table 6 for a summary of participants' language aptitude and proficiency scores).

Table 6. Language aptitude and language proficiency scores across groups (Study 2).

Variable	English sequential bilinguals			Spanish sequential bilinguals		
	M	SD	Range	M	SD	Range
L. Aptitude	49.37	12.25	22.5 – 78.75/ 100	45.1	10.73	13.33 - 63.33/1 00
Spanish C-test	54.02	6.54	43 - 65/66	63.59	2.51	56 - 66/66
English C-test	8.62	0.83	5.25 - 10/10	8.02	1.12	5.25 - 10/10
Spanish Can-Do	3.10	0.64	1.33 – 4.82/5	4.76	0.63	4.26 – 5/5

English Can-Do	4.77	0.23	4.16 - 5/5	4.09	0.71	2.73 - 5/5

3.4 Data analysis

The analyses conducted on the experimental trials from the visual world tasks focussed on the first 1000 ms of the task duration, starting from 200 ms after the visual display was presented. Reaction times were calculated from the onset of the auditory signal until the participants clicked on the target picture. Any reaction time data two standard deviations above the grand mean were excluded from further analyses (Sekerina, Campanelli & Van Dyke, 2016). Trials with track loss exceeding 25%, as well as blinks and saccades, were excluded from the analysis. Missing values resulting from equipment malfunctioning and track loss accounted for 9.76% of the data (data from 14 participants were excluded: 8 English-Spanish bilinguals, 6 Spanish-English bilinguals).

Reaction time data across groups were analysed by means of linear mixed-effects models (LMM, Baayen, Davidson & Bates, 2008) using the lme4 R package in R (Version 4.0.3; R Core Team, 2020). Accuracy rates were also calculated, and only correct responses were included in the analyses. Participants who selected the incorrect item in over 50% of the total number of trials per language were excluded from subsequent analyses (data from 11 participants were excluded: 5 English-Spanish bilinguals, 6 Spanish-English bilinguals).

In line with Godfroid's (2020) approach to preprocess eye-tracking data, data from 250 Hz eye-trackers were downsampled to 120 Hz for uniform analysis. Then, the data points were collapsed into time bins of 40 msec using the eyetrackingR R package (Version 0.2.0; Forbes et al., 2021). These aggregated measures were then used as a continuous independent variable in the generalised models described below. The dependent variable, which represented the odds of fixation to the rhyme or cohort competitor compared to fixations to everything else, was calculated by dividing the total number of fixations by the total number of non-fixations at an image and then taking the logarithm of the odds (logit) using the approach proposed by Barr (2008).

To investigate within-L1 and within-L2 lexical competition across languages, four sets of analyses were conducted on the eye-tracking data. Firstly, individual cohort and rhyme effects were calculated for each bilingual group and language to determine whether the bilinguals' competition dynamics were comparable to those observed in monolingual speakers, as well as to assess whether L1 and L2 lexical competition processes were comparable within groups. These analyses were performed using generalised linear mixed-effects models (GLMM, Baayen, Davidson & Bates, 2008) via a link function (logistic mixed-effects models) from the glmer function within the lme4 R package (Version 1.1.26; Bates, et al., 2015) (see Results section for more information on the analyses).

Secondly, we examined the time course of both L1 and L2 spoken word recognition between groups by analysing the participants' eye-movements as they shifted towards the two types of competitors under investigation before selecting the target word. For this analysis, we compared the cohort and rhyme competitor fixations between groups across time bins using the aforementioned generalised linear mixed-effects models via a link function. Thirdly, the total looking time to each phonological competitor was also calculated and compared between groups using linear mixed-effects models. To explore the relation between the individual differences in the linguistic and extralinguistic factors and how they could influence the bilinguals' competition dynamics, we included these measures as covariates in the models assessing total looking time. Lastly, to assess when the fixations to the cohort and rhyme competitors started to diverge between groups and the duration of such effects, we performed a series of bootstrapped cluster-based permutation analyses per fixations to each competitor between groups and per task via the eyetrackingR R package (Version 0.2.0; Forbes et al., 2021; Maris & Oostenveld, 2007).

3.5 Results

3.5.1 Accuracy rates and reaction times

The average reaction times recorded were: Spanish bilingual group (Spanish version: 1477.69 ms [SD = 455.37ms]; English version: 1902.8 ms [SD = 652.98 ms]); English bilingual group (Spanish version: 1654.74 ms [SD = 757.05 ms]; English version: 1609.71 ms [SD = 593.58 ms]); The Spanish bilingual group correctly identified 75 % of the target items on average in the Spanish version and 60% on average in the English version, while the English bilingual group correctly identified 70 % of the target items on average in the Spanish version and 80% on average in the English version.

Spanish bilinguals were faster in recognizing the correct Spanish target words compared to the English group (estimate = -0.10, SE = 0.05, $t(71) = 79.510$, $p < 0.05$). Interestingly, another linear mixed-effects model showed that the participants with lower proficiency in Spanish were also slower at recognising the target word (estimate = -0.05, SE = 0.02, $t(65) = -2.052$, $p < 0.05$). Regarding the English task, the Spanish bilinguals were slower in recognizing the correct English target words compared to the English group (estimate = 0.21, SE = 0.05, $t(91) = 3.742$, $p < 0.001$).

3.5.2 Within-L1 competition dynamics

To determine whether the experimental groups showed any cohort and/or rhyme effects, we performed a series of within groups analyses during the 200-1200 ms time window. Using generalised mixed-effects models, we measured whether participants were more likely to fixate on cohort or rhyme competitors than to the unrelated distractor. The models employed to evaluate this question incorporated a two-way interaction between time bin and area of interest (AOI, competitor versus unrelated) along with a quadratic term that was orthogonalized to mitigate collinearity (Godfroid, 2020). Additionally, random intercepts for participant and item were included in the models.

The results revealed that the Spanish bilinguals exhibited significant cohort effects (estimate = -0.42 SE = 0.15, $z(52724) = -2.853$, $p < 0.01$) and rhyme effects (estimate = -0.30 SE = 0.01, $z(52724) = -19.127$, $p < 0.001$) compared to fixations to unrelated items. Post-hoc analyses showed that Spanish bilinguals paid more attention to cohort than to rhyme competitors (estimate = -0.06 SE = 0.01, $z(52724) = -4.375$, $p < 0.001$).

The English bilingual also exhibited significant cohort effects (estimate = -0.53 SE = 0.07, $z(40150) = -6.881$, $p < 0.001$) and rhyme effects (estimate = -0.36 SE = 0.11, $z(40150) = -3.286$, $p < 0.01$). Similar to the Spanish group and consistent with evidence from monolingual speakers, English bilinguals were more likely to fixate on phonologically similar cohort competitors than on rhyme candidates (estimate = -0.10 SE = 0.01, $z(41094) = -7.291$, $p < 0.001$).

3.5.3 Within-L2 competition dynamics

To examine whether within-L1 and -L2 processes are comparable in the same bilingual individuals, we performed the same analyses during the L2 spoken word recognition tasks. Interestingly, Spanish bilinguals exhibited analogous cohort (estimate = -0.24 SE = 0.01, $z(28706) = -15.022$, $p < 0.001$) and rhyme effects (estimate = -0.19 SE = 0.01, $z(28706) = -11.906$, $p < 0.001$), with the cohort effect once again surpassing the rhyme effect (estimate = -0.04 SE = 0.01, $z(28296) = -2.998$, $p < 0.01$). Likewise, the English bilinguals replicated the cohort (estimate = -0.19 SE = 0.01, $z(28296) = -11.052$, $p < 0.001$) and rhyme effects (estimate

= -0.17 SE = 0.08, $z(28296) = -1.968$, $p < 0.05$) observed in the English version of the task, indicating comparable findings in both within-L2 and within-L1 competition processes.

3.5.4 Group comparison

After investigating how first and second language competition processes compare in the same bilingual speakers, we performed further analyses to examine how native speakers and L2 speakers of the target language (English or Spanish) would process the same stimuli during a visual world task.

For this set of analyses, we used separate generalised mixed-effects models to assess the participants' fixations across time for each competitor. We used a similar structure to the models reported above by incorporating a quadratic term two-way interaction (Time Bin x Group). The random-effects structure included random intercepts for participant and item and random slopes for group (Spanish vs English bilinguals) across items.

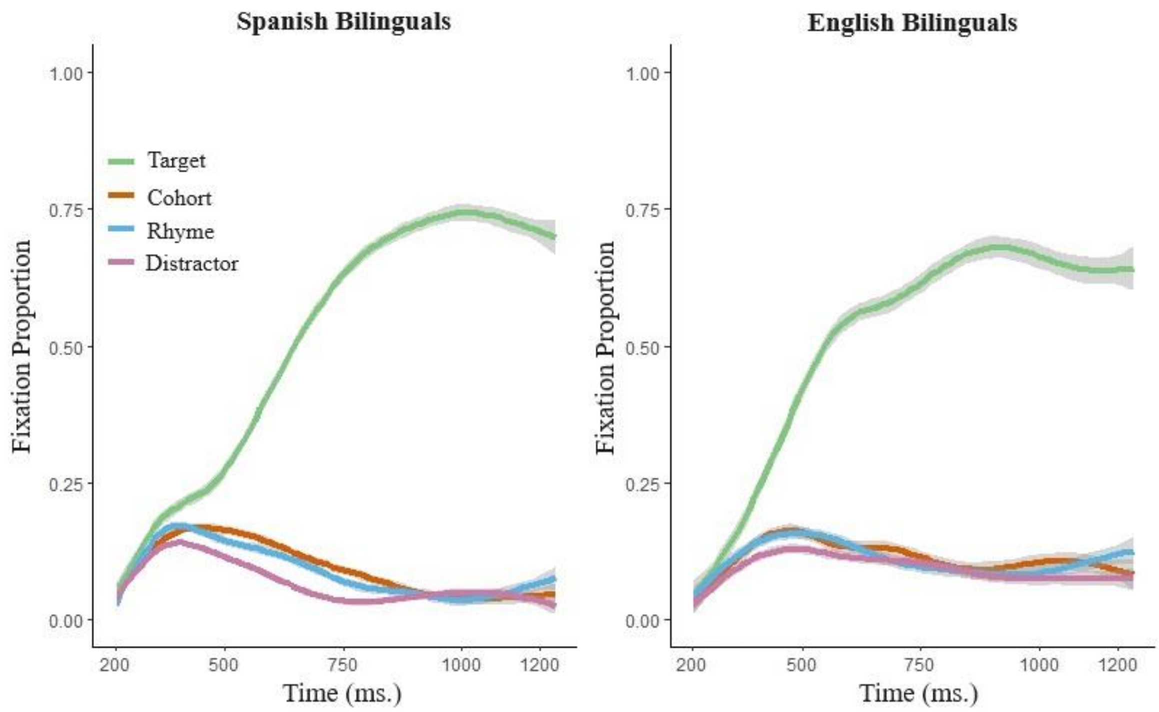

Figure 9. Average fixation proportions towards the Spanish lexical candidates across time. Comparison between the Spanish bilinguals and the English bilinguals.

3.5.4.1 Spanish task

Figure 9 presents the average proportion of fixations to the Spanish target words, cohort and rhyme phonological competitors, and the distractor items over time during the Spanish visual world task. The graph illustrates that both groups, exhibit high activation of both competitors early on, peaking around 400 ms before returning to baseline levels. Notably, the Spanish bilinguals (graph on the right) appear to fully and rapidly suppress both competitors compared to the English bilinguals, who fail to inhibit them before the first 1000 ms from the onset of the Spanish target spoken word. These findings align with the reaction time measures reported above.

The most striking result to emerge from this data is how both groups differ when resolving lexical competition: the Spanish bilinguals showed reduced likelihood of fixating on the cohort (estimate = -0.30 SE = 0.17, $z(42236) = -1.771$, $p < 0.05$) or rhyme competitors (estimate = -0.43 SE = 0.16, $z(42236) = -2.594$, $p < 0.01$) compared to the English bilingual group. To assess when the fixations to the cohort and rhyme competitors started to diverge between groups and the duration of such effects, we performed a bootstrapped cluster-based permutation analysis per fixations to each competitor between groups via the eyetrackingR R package (Version 0.2.0; Forbes et al., 2021; Maris & Oostenveld, 2007). Following previous analyses, we performed the test on the first 1000 ms from the onset of the target spoken word (200-1200 ms). The cluster-based permutation test on the rhyme competitors revealed a significant difference between the Spanish and English sequential bilinguals from the 400 to 600 ms post-onset of the spoken word ($p < 0.05$). However, no differences were found on the effect of the Spanish cohort competitors between groups ($p = 0.225$). Overall, in the Spanish task, native speakers of Spanish demonstrated faster and more accurate spoken word recognition compared to L2 Spanish speakers, who struggled to fully inhibit Spanish phonological competitors even after 1000 ms from the retrieval of the auditory signal.

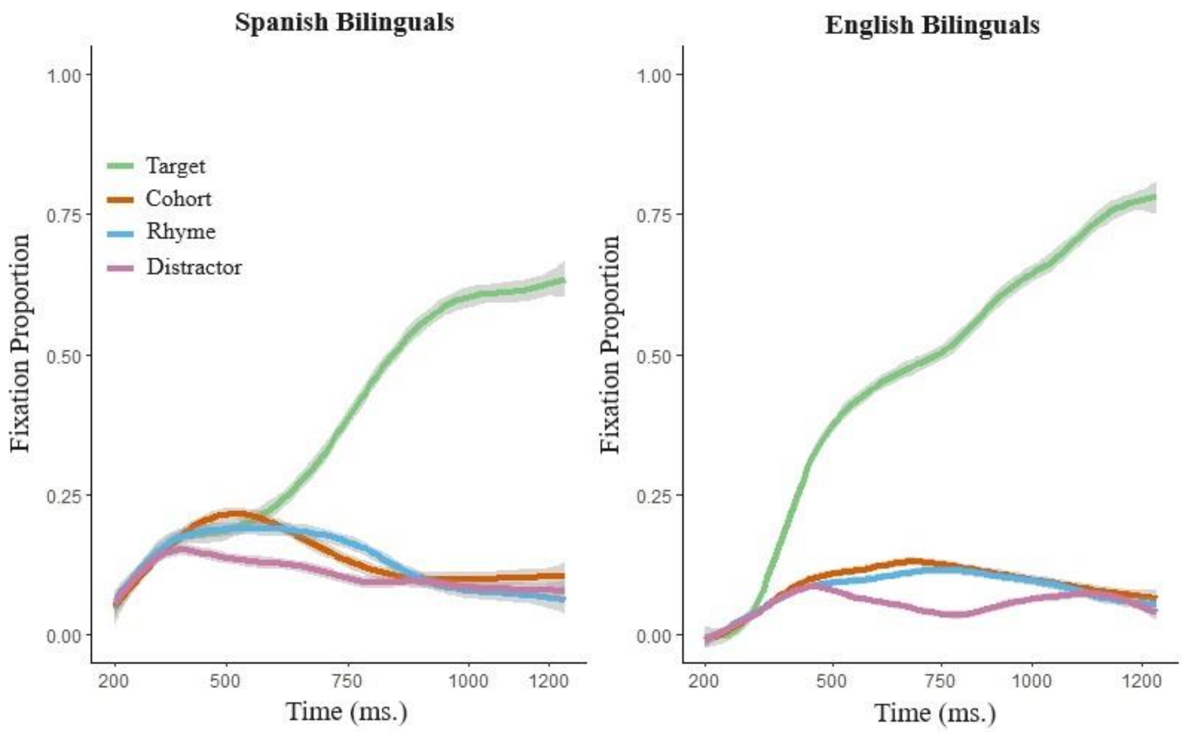

Figure 10. Average fixation proportions towards the English lexical candidates across time. Comparison between the Spanish bilinguals and the English bilinguals.

3.5.4.2 English task

Looking at Figure 10, it becomes evident that the Spanish bilinguals exhibit a higher activation rate of both competitors compared to the English bilinguals. In this case, the Spanish bilinguals seem to face more challenges in the lexical competition process compared to the English group. Specifically, the L1-Spanish group performs similarly to the English bilinguals during L2 spoken word recognition, as they do not fully suppress the competitors either. These findings align with the reaction time measures reported above. The Spanish bilinguals were more likely to look at both cohort (estimate = 0.31 SE = 0.12, $z(35420) = 2.670$, $p < 0.01$) and rhyme competitors (estimate = 0.44 SE = 0.14, $z(35420) = 3.186$, $p < 0.01$) when resolving L2 lexical competition.

Following the bootstrapped cluster-based permutation analyses performed on the Spanish competitors, we conducted a similar set of analyses on the English competitors. The cluster-based permutation test on the rhyme competitors revealed a significant difference between the Spanish and English sequential bilinguals from the 400 to 1100 ms post-onset of the spoken word ($p < 0.05$). However, no differences were found on the effect of the cohort competitors between groups ($p = 0.245$). To summarise, in the English visual world task, the L1-Spanish bilinguals did not inhibit the English competitors to the same extent as the L1-English bilinguals.

3.5.5 Individual differences

To examine to what extent the previous findings on lexical competition are modulated by the individual differences under investigation, a series of linear mixed-effects models was conducted on the overall fixation duration towards cohort and rhyme competitors in each task. These models incorporated the measures outlined in the Methods section, including interference scores from the Flanker task reflecting participants' interference effects in the mixed condition. Additionally, the models considered factors such as language aptitude, determined by averaging scores from the four LLAMA subtests, L1 and L2 use and exposure measured through PCA-derived composite variables, relevant descriptive information from bilingual experience (e.g., sex, age, age at onset of bilingualism, length of L2 school instruction, self-perceived linguistic dominance and level of education), and proficiency levels in both L1 and L2 gauged through administered proficiency tasks.

3.5.5.1 Spanish task

Three linguistic factors were found to influence the participants' looking behaviour towards the Spanish rhyme competitors. We found that English proficiency was marginally significant, as participants with higher proficiency in English paid less attention to the rhyme candidates in order to resolve the spoken word recognition task (estimate = -0.06, SE = 0.03, $t(73) = -1.974$, $p = 0.05$). The model also indicated that participants who had spent more time using the L2 at the time of testing look more to the rhyme competitors. Similarly, the participants who used more their L1 daily would look more to the rhyme competitor. To explain these results, we performed further linear mixed-effects models fitted on the experimental groups separately. We found that the amount of Spanish use played an important role for both groups, with Spanish bilinguals who used more Spanish daily looking more at the rhyme competitors (estimate = 0.07, SE = 0.02, $t(40) = 2.679$, $p < 0.05$; effect size of 0.85), while the English bilinguals who had spent more time using their L2 also looked more at the rhyme competitors (estimate = 0.25, SE = 0.07, $t(32) = 3.388$, $p < 0.01$; effect size of 1.50).

The participants' cognitive control skills, measured by the Flanker task, were also found to play role in both Spanish and English bilinguals' competition dynamics. We found that participants with better inhibitory control skills look less to the rhyme competitors (Spanish group: estimate = 0.06, SE = 0.02, $t(41) = 2.395$, $p < 0.05$; effect size of 0.76; English group: estimate = 0.13, SE = 0.05, $t(32) = 2.480$, $p < 0.05$; effect size of 1.10) (see Figure 11 below).

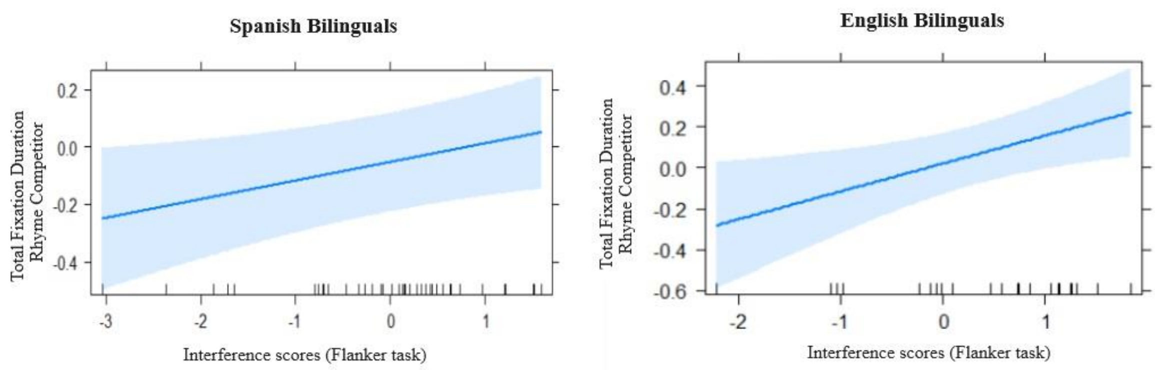

Figure 11. Interference scores from the Flanker task for the Spanish rhyme candidates across the Spanish and English bilingual groups.

Regarding the looks toward the cohort competitors, we found that those English bilinguals who had reported a higher use and exposure to their native language, would pay more attention to the cohort competitors to resolve L2 lexical competition (estimate = 0.31, SE = 0.14, $t(32) = 2.148$, $p < 0.05$). Analysis of the effect sizes for the main predictor indicated that English bilinguals' L1 use and exposure had an effect of 0.94. No other variables modulated the bilinguals' looks towards the Spanish phonological competitors.

3.5.5.2 English task

Only English proficiency was found to be a significant predictor of looking behaviour in the English task. Highly proficient bilinguals from both groups looked less at the English cohort (estimate = -0.10, SE = 0.04, $t(63) = -2.128$, $p < 0.05$; effect size = -0.52) and rhyme (estimate = -0.11, SE = 0.04, $t(63) = -2.489$, $p < 0.05$; effect size = -0.57).

3.6 Discussion

With the aim of further investigating how within-language competition takes place in bilinguals' first and second languages, what competition dynamics are employed to achieve word recognition and which external factors may modulate said mechanisms, the present study tested two groups of sequential bilingual speakers (L1-Spanish-English and L1-English-Spanish) across two within-L1 and within-L2 visual world tasks. First, we asked whether bilingual speakers would employ equivalent competition dynamics to the ones observed in monolingual speakers, as most studies on lexical competition in bilinguals have focussed on examining the well-established cohort effect. Second, we asked if these competition dynamics could also be observed during within-L2 competition in the same bilingual speakers, as this area has also remained understudied. Third, we explored whether L1 and L2 speakers of the same language (e.g., L1-Spanish bilinguals versus L2-Spanish bilinguals) would employ different mechanisms to resolve competition on the same stimuli. Finally, we assessed which individual difference measures included in the study would modulate the participants' competition dynamics.

3.6.1 Within-L1 and L2 lexical competition dynamics are equivalent in sequential bilinguals

The two bilingual groups under investigation exhibit analogous L1 competition mechanisms to the ones evidenced in monolingual speakers. Our findings revealed how participants presented a stronger cohort effect followed by a significant rhyme effect before selecting the spoken target word in both first languages (Allopenna et al., 1998; Desroches et al., 2006). As mentioned in the literature review, very few studies have investigated whether rhyme competitors play a role in the bilingual disambiguation process during within- or crosslinguistic lexical competition. The present findings on within-L1 competition support the assumption that bilingual spoken word recognition, especially the competition process, is more flexible that previously believed. Future work should also investigate its dynamicity in crosslinguistic competition studies, as little is still known about how bilinguals first and second languages interact in the mental lexicon.

Regarding our results on within-L2 competition, we found that sequential bilinguals appear to employ comparable competition dynamics to the ones observed during within-L1 competition. These findings accord with the significant L2 cohort and rhyme effects reported by Shin et al., (2015) on Korean-English early bilinguals. However, these results open up other lines of inquiry within the field of bilingualism research as the results reported in this study deviate from the L1 and L2 competition dynamics attested by previous studies on bilingual SWR where L2-immersed late-bilinguals (also named bilingual attriters) did not exhibit rhyme effects during L1 or L2 spoken word recognition (Bruggeman & Cutler, 2019; Soto & Schmid, 2023).

We argue that the differences found in our results could partially depend on the individual differences observed between the groups under study (L1-immersed sequential bilinguals vs L2-immersed late-bilinguals). Firstly, our participants had not been immersed in the L2 for long periods of time, which could influence the participants' mechanisms employed to resolve lexical competition by reducing the L1 competition effects due to the influence exerted by the parallel activation and crosslinguistic competition of both languages in addition to a prolonged exposure to the L2 and limited L1 use (Soto & Schmid, 2023). Secondly, the results reported by Shin and colleagues (2015) come from early bilinguals who migrated to the L2 environment before puberty, which could have inverted their linguistic dominance intensifying the influence of the L2 over the L1.Most of our participants were sequential bilinguals, who acquired the second language early in life but had not been exposed to the L2 to the same extent as to the participants in these studies, which could help explain the differences found in the lexical competition dynamics among these differing bilingual populations. Given these discrepancies, future studies on bilingual variability within the spoken word recognition process will need to be undertaken.

3.6.2 Spoken word recognition: L1 vs. L2 processing

Three main findings reported in the current investigation on the differences between L1 and L2 spoken word recognition processes among L1 and L2 speakers of the same target language (e.g., L1-Spanish, and L2-Spanish bilingual speakers) replicate the existing evidence on L2 spoken word recognition. It has been assumed that the process of recognising spoken words is a much more demanding task in the second language than in the first (Broersma & Cutler, 2011; Mercier et al., 2014; Titone et al., 2019; Sarret et al., 2022; Weber & Cutler, 2004) due to the parallel but not always accurate activation, and crosslinguistic influence of both languages in the bilingual's mental lexicon, which impede the full suppression of L2 competitor candidates during lexical competition. From the data observed in the current study, we can argue that the L2 speakers of Spanish and English under investigation encountered similar challenges during L2 spoken word recognition. Firstly, both groups of L2 speakers exhibited a higher activation rate of L2 competitors when compared to the native speakers. Figures 9 and 10 show clear evidence for this finding. Secondly, the native speakers of the target language under examination (Spanish or English) completely suppressed the L1 competitors before recognising the spoken target word, while the L2 speakers, conversely, did not inhibit them as quickly. Lastly, we also provided evidence of slower word recognition in the L2 than in the L1.

These findings corroborate the results reported by Sarret and colleagues (2022), who demonstrated that L2 learners of Spanish were not able to fully suppress the Spanish cohort competitor during within-L2 competition. The authors suggested this effect may relate to low levels of L2 proficiency, as they were less certain of which item should have been activated. The differences in levels of L2 proficiency (L2 bilingual speakers vs L2 learners) could help explain why our L2 speakers were able to suppress the L2 competitors later in the competition process (ca. 1500 ms after the onset of the spoken word), despite being slower than L1 speakers. However, this factor alone may not comprehensively explain the entire process. Perhaps the most interesting finding is how the bilinguals' variability in proficiency, inhibitory control, or language use, among other factors, regulated their competition dynamics during these L1 and L2 spoken word recognition tasks. We discuss these findings below.

3.6.3 Individual differences can regulate the lexical competition process

It has been suggested that bilingual speakers can resolve lexical competition more efficiently than monolingual speakers as parallel activation and crosslinguistic competition enhance the resolution parameters used during language processing (Blumenfeld & Marian, 2011; Green, 1998). Evidence from bilingual spoken word recognition reveals that inhibitory control aids bilinguals in suppressing word candidates during within-language and crosslinguistic competition (Blumenfeld & Marian, 2013; Mercier et al., 2014). However, recent studies seem to report contradictory findings (Botezatu et al., 2022). The present study offers new insights into whether the competition resolution mechanisms employed by bilingual speakers during spoken word recognition can be in fact regulated by inhibitory control.

According to BIA + (Dijkstra & van Heuven, 2002; van Heuven, Dijkstra, and Grainger, 1998) and BLINCS (Shook & Marian, 2013), cognitive control emerges later during word recognition to aid disambiguate lexical competition. Our results align with this argument as it was demonstrated that bilingual speakers with better inhibitory control skills (i.e., exhibiting lower interference scores in the Flanker task), were better able to suppress the rhyme competitors of the Spanish task than those who exhibited higher interference scores. These findings are consistent with the results reported by Mercier et al., (2014), as we found evidence of an improvement in both L1 and L2 within-language competition resolution dynamics via the bilinguals' inhibitory control mechanisms. Surprisingly, this inhibitory advantage was not revealed during the English version of the visual world task.

Previous studies have reported how highly proficient L2 bilinguals overcome lexical competition more efficiently than less proficient language users (Blumenfeld & Marian, 2007; 2013; Botezatu et al., 2022; Sarret et al., 2022). Our results are consistent with these findings as highly proficient L1-English and L2-English bilinguals attended less to both cohort and rhyme phonological competitors to successfully achieve word recognition during the English visual world task. In addition, during the Spanish task, the bilingual speakers with a lower proficiency in Spanish were slower at recognising the correct target words. This finding was consistent with Mercier et al., (2014) who did not find a relation between inhibitory control and language proficiency.

Related to language proficiency is the linguistic factor of language use and exposure. This linguistic measure has been linked to changes in competition dynamics during L1 development, as more exposure to the target language seems to speed up word recognition (Rigler et al., 2015; Sarret et al., 2022), as well as to changes in language processing in young bilinguals (Whitford & Titone, 2017). It has also been reported that high levels of L2 use can facilitate fixations to certain cross-linguistic competitors (Mercier et al., 2014). Our results revealed that more language use was related to more fixations to the rhyme or cohort competitors of that specific language. For example, we found that L1-Spanish bilinguals would fixate more on L1-rhyme competitors if participants had reported more L1 use and exposure than other participants with less use of Spanish. Similarly, L1-English bilinguals who recorded more time spent using their L1 or L2 (Spanish), would pay more attention to the English cohort competitors or the Spanish rhyme competitors, respectively.

To interpret these results, we posit that, as SWR is constrained by different cues (Scharenborg & Boves, 2010), Spanish native speakers, attuned to various lexical cues such as nominal endings, may be more inclined than English natives to fixate on the rhyme of a word. In Spanish, nominal endings, particularly those indicating gender, provide crucial lexical cues for word comprehension. Past research underscores the heightened sensitivity of Spanish natives to nominal endings, facilitating the processing of gender information in language comprehension (Caffarra & Barber, 2015; Hernández et al., 2004) and aiding in the disambiguation of spoken word recognition (Soto & Schmid, 2023). Conversely, native English speakers are less reliant on this aspect of the word, diminishing its significance as a cue for lexical access. This interpretation aligns with the observed influence of rhyme competition on L1-English bilinguals, especially those who extensively use Spanish, suggesting an impact from their L2.

However, it is important to note that this discussion extends beyond the scope of our current study. Further research should delve into the specific influence of Spanish grammatical gender cues on rhyme competition during spoken word recognition, exploring this intricate interplay in greater detail.

3.7 Conclusion

In conclusion, this study aimed to deepen our understanding of lexical competition dynamics in spoken word recognition among sequential bilinguals, focusing on both within-L1 and within-L2 competition processes. The results demonstrated that sequential bilinguals, regardless of their native language, exhibited analogous competition mechanisms within both L1 and L2 spoken word recognition processes. The observed patterns of competition, characterized by a robust cohort effect followed by a significant rhyme effect, mirrored those reported in the literature on monolingual speakers.

Notably, distinctive competition dynamics were observed in L2 speakers compared to native speakers, underscoring the challenges faced by L2 speakers in word recognition. Higher activation rates, delayed suppression of L2 competitors, and overall slower word recognition in the L2 were consistent with previous studies emphasizing the demanding nature of L2 spoken word recognition due to parallel activation and crosslinguistic influence.

Moreover, individual differences emerged as crucial factors influencing lexical competition resolution. Participants with better inhibitory control skills demonstrated enhanced rhyme competition resolution, suggesting a regulatory role of inhibitory control in spoken word recognition. Proficiency levels also impacted competition dynamics, with highly proficient bilinguals exhibiting more efficient resolution and reduced reliance on phonological competitors. Language use and exposure further influenced fixation patterns, underscoring the impact of exposure on competition dynamics during word recognition.

The present study contributes valuable insights into the nuanced processes of lexical competition in bilingual spoken word recognition. The findings shed light on the intricate interplay of individual differences such as proficiency, inhibitory control, and language use in shaping competition dynamics. Future research should continue exploring the specific influences of factors such as grammatical gender cues on rhyme competition and bilingual variability, expanding our understanding of the complexities within bilingual spoken word recognition processes.

4 Chapter 4: Study 3

4.1 Introduction

The recognition of spoken words may appear to be an effortless process; however, its transient and ambiguous nature makes listeners' endeavour of decoding speech a much more complex process than previously believed. Extensive research from the field of psycholinguistics has attempted to conceptualise this process for over 50 years, and although our understanding remains limited, some consensus has been reached. From a monolingual standpoint, most models on spoken word recognition (SWR) agree on two fundamental aspects: i) parallel activation - multiple candidates that partially match the incoming speech signal are activated simultaneously - and ii) parallel competition - activated candidates compete for recognition until one is finally selected (Cohort, Marslen-Wilson & Welsh, 1978; PARSYN, Luce et al., 2000; TRACE, McClelland & Elman, 1986; Shortlist, Norris, 1994).

Central to these two notions are the roles of acoustic-phonetic detail and the goodness of match between the unfolding auditory information and the stored lexical representations in the listener's mental lexicon. These components aid to spread or constrain the levels of activation and competition of the lexical hypotheses at play during the recognition process. For example, if the auditory signal matches many phonologically related neighbours (*cat* and *bat*, *cot*, *cast*, *can*), competition increases slowing down word recognition, while words with a small neighbourhood of competing candidates are recognised faster – *the neighbourhood density effect* (Luce, 1986; Luce & Pisoni, 1998; Magnuson et al., 2007). Also, phonologically similar candidates that overlap with the spoken word at the onset (also known as *cohort* competitors, *candle and candy*) are activated earlier and compete more strongly for recognition than those that match the auditory target at the rhyme (*rhyme* competitors, *candle and handle*). This so-called *cohort effect* can be attributed to the sequential nature of the speech signal, which favours incremental phonological activation from word onset (Allopenna et al., 1998; Desroches et al., 2009; Magnuson et al., 2003; Moss & Marslen-Wilson, 1993).

Beyond phonological similarity, competition in spoken word recognition is modulated by a variety of (language-related) factors. These include lexical frequency and lexical or contextual cues (Scharenborg & Boves, 2010), which can either facilitate or impede the competition process. Additionally, bilingual individuals navigate the intricate landscape of cross-linguistic activation and competition, a phenomenon inherently tied to the distinctive features of multilingual experience (e.g., varying degrees of age of acquisition, language proficiency or language use).

In the bilingual domain, competition is not only influenced by within-language competitors as in monolingual SWR. There is ample evidence demonstrating that bilinguals also temporally co-activate between-language competitors when processing a single language (e.g., Finkbeiner et al., 2004; Ju & Luce, 2004; Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999; Thierry & Wu, 2007). The pioneering studies led by Marian and colleagues, using a bilingual version of the Visual World Paradigm (VWP; Tanenhaus et al., 1995), laid the foundations for the study of cross-linguistic competition in the auditory domain. In these experiments, participants were instructed in their second language (L2) to pick up one of the four presented visual objects while their eye-movements were monitored. Specifically, the irrelevant L1 label for one object (e.g., *spichki*, Russian for *matches*) phonologically overlapped with the onset of the L2 target object (e.g., *spear*). This led bilinguals to focus more on the cross-linguistic L1 cohort competitor than on the L2 unrelated distractor objects, indicating its activation. Since then, a substantial body of research has employed various measures, including eye-tracking via the VWP and ERPs via the picture/spoken word matching paradigm (e.g., Desroches et al., 2022), to investigate the conditions under which these cross-linguistic interactions arise and their impact on bilingual auditory language comprehension across different levels of representation within the language system.

Cross-linguistic activation has been widely studied, particularly through the cognate facilitation effect (e.g., Costa, Caramazza & Sebastián-Gallés, 2000; Van Hell & Dijkstra, 2002). According to the BIA + model of visual word recognition (Dijkstra & Van Heuven, 2002), the form of a word activates orthographic cross-linguistic competitors, which in turn activates phonologically and semantically similar competitors, thereby enhancing language co-activation. Previous research in both word production and comprehension has demonstrated that cognate words benefit from a processing advantage over non-cognate words, resulting in a boost in parallel co-activation (e.g., Blumenfeld & Marian, 2007; Dijkstra, Grainger, & Van Heuven, 1999; Hoshino & Kroll, 2008).

While the temporal co-activation of L1 representations during L2 spoken word recognition is a well-documented phenomenon in auditory processing research (Blumenfeld & Marian, 2007; Sarrett et al., 2022), the impact of the second language during L1 SWR has not received as much attention, partly due to conflicting findings (Canseco-Gonzalez et al., 2010; but see Marian & Spivey, 2003b; Weber & Cutler, 2004). Previous studies have highlighted an asymmetry in the activation of the non-dominant language during L1 processing, compared to the robust L1 effects observed in L2 processing. For instance, evidence of L2 effects over the L1 emerged primarily when phonological overlap between the two languages was manipulated to resemble the L1 (e.g., Ju & Luce, 2004). However, recent evidence indicates that cross-linguistic interactions in spoken word recognition are bidirectional, influencing both L1 and L2 processing. This holds true even in monolingual environments and across multiple levels of representation (Bobb et al., 2020; Botezatu et al., 2022; FitzPatrick & Indefrey, 2010).

Models in the field of bilingual language processing, like the Bilingual Language Interaction Network for Comprehension of Speech Model (BLINCS; Shook & Marian, 2013), have previously suggested the presence of bidirectional cross-linguistic interactions in spoken word recognition. This model delves into the organisation of the bilingual lexicon in auditory comprehension by capturing the dynamicity of bilingual language processing across long- and short-term *features* (e.g., language proficiency and exposure) that impact the natural process of bilingual spoken word recognition. Particularly, BLINCS accounts for the co-activation of within- and between-language candidates (e.g., cohort and rhyme competitors and cognates) across a network of interconnected self-organising maps (SOMs) or levels of representation (i.e., phonological, phono-lexical, ortho-lexical and semantic) in a bidirectional manner, which allows for both bottom-up and top-down activation.

Evidence from the growing body of research in bilingual spoken word recognition aligns with the arguments put forth by BLINCS on cross-linguistic activation. Studies have demonstrated that lexical competitors can activate not only the phonological representations of the L2 via bottom-up phonological L1 input (e.g., an English-Spanish bilingual activating *casa* in the L2 when hearing *cast* in the L1) or via cognate status (e.g., Blumenfeld & Marian, 2007), but also L2 lexical or semantic information via top-down activation, even in the absence of overt L1-L2 phonological overlap (e.g., see Bobb et al., 2020; Desroches et al., 2022). However, the latter investigation of L2 activation and its potential influence during L1 processing remains relatively underexplored in the SWR area, along with the exploration of within-language competition in diverse bilingual communities (Sarrett et al., 2022). This gap exists primarily because most studies on bilingual SWR have predominantly focussed on cross-linguistic competition from a cohort perspective due to its strong competition effect (i.e., interlingual word onset competitors; Marian & Spivey, 2003a; 2003b; Sarrett et al., 2022).

4.1.1 Bilingual variability: a key factor in spoken word recognition.

In the monolingual auditory domain, extensive research has evidenced how listeners manage competition from a single language by examining not only competitors that overlap with the acoustic input at the onset of the word (cohort competitors), but also other candidates which present a degree of onset phonological mismatch (i.e., rhyme competitors) (Allopenna et al., 1998; Desroches et al., 2006; Magnuson et al., 2003; McQueen & Huettig, 2012; McQueen & Viebahn, 2007). By including a broader range of competitors, these studies have been able to demonstrate that, although lexical competition is strongly driven by the sequential speech input, other factors also play a role in the modulation of the listener's competition dynamics and competition resolution. For instance, the structure of the lexicon (e.g., increments in the size of the lexicon influencing the density of the competitive environment; see De Cara & Goswami, 2003; Botezatu et al., 2022).

From a bilingual perspective, a limited number of studies have explored the competition process employing a more extensive range of competitors. These investigations, however, have revealed disparities in within-language cohort and/or rhyme effects across diverse populations, including monolinguals (Botezatu et al., 2022), L2 learners (Sarrett et al., 2022), bilingual heritage speakers (Shin et al., 2015), as well as younger and older bilinguals (Ben-David et al., 2011) or L2-immersed late bilinguals (Bruggeman & Cutler, 2019; Soto & Schmid, 2023). These observations imply that bilingual variability may act as a potential mediating factor in bilingual lexical competition. However, as far as our current knowledge extends, no studies have to date investigated how the same L1 or L2 spoken word recognition process compares across various bilingual populations.

The suggested relevance of bilingual variability in SWR is consistent with the BLINCS model, which argues that the bilingual language system is inherently dynamic and interactive.

Moreover, the model posits that bilingual variability can be crucial, exerting diverse effects on language processing across different bilingual individuals. For example, it can be influenced not only by within- and between- language interactions or changes in the structure of the lexicon (such as increments in the vocabulary size affecting the density of the competitive environment), but also by features that modulate bilingual experience (Fricke, 2022; Kroll et al., 2022; Sarrett et al., 2022; Shook & Marian, 2013).

Several language-related factors have been observed to modulate lexical competition by influencing the strength of the connectivity patterns between lexical representations in the mental lexicon. For example, lexical representations from the dominant language are assumed to form strong connections in the mental lexicon across diverse levels of representation as proficiency increases during language development (e.g., Rigler et al., 2015). However, it has been argued that connections between lexical representations from the non-dominant language might not be as robust across levels due to a greater variability in language ability (Marian et al., 2008).

Similarly, previous studies employing form-priming have shown that highly proficient bilinguals exhibit activation of L2 items during L1 processing, whereas bilinguals with lower levels of L2 proficiency do not display the same pattern of interaction (Silverberg & Samuel, 2004). More sensitive measures, such as the VWP, have extended these findings. Higher L2 proficiency has been associated with elevated levels of L2 cross-linguistic activation and a faster competition resolution during L1 processing (Blumenfeld & Marian, 2013; Botezatu et al., 2022).

Age of acquisition has also been identified as a mediator during lexical competition in bilinguals. Canseco-Gonzalez and colleagues found that within- and between-language cohort effects were modulated by age of acquisition in a VWP study on the effects of the L2 during

L1 auditory processing (Canseco-Gonzalez et al., 2010). Specifically, only English-Spanish bilinguals who had acquired the L2 earlier in life activated between-language L2-Spanish representations (e.g., looks at *mustache* [*bigote* in Spanish], when hearing *beans*) during L1 spoken word recognition.

The linguistic environment and degree of language use are also two crucial factors modulating the bilingual's language system (Kroll et al., 2022). Extensive research in language attrition indicates that long-term immersion in an L2 context and frequent L2 use, combined with reduced L1 use, can impact various aspects of the bilingual's L1 processing (Schmid & Köpke, 2017). This includes reducing L1 access, even when the bilingual's L1 is well-entrenched (Goral et al., 2008; Malt et al., 2015; see Jarvis, 2019 for a review on lexical attrition), as well as potentially reversing linguistic dominance from the native language to the L2 (Bogulski et al., 2019; Marian et al., 2008). In the domain of bilingual auditory processing, Soto and Schmid (2023) recently investigated the L1 and L2 spoken word recognition processes of a group of L2-immersed Spanish-English late bilinguals (also known as bilingual attriters). They found that length of residence in the L2 context directly influenced the bilinguals' L1 competition dynamics during L1 SWR.

While these findings underscore the dynamic interplay of predictors influencing the bilingual language system, particularly in the realm of competition, two critical questions persist: first, how do diverse bilingual communities navigate and resolve lexical competition along the bilingual spectrum, leading to the observed discrepancies among these populations? And second, which of these predictors holds greater relevance in influencing the process in question? Addressing these questions promises a deeper understanding of the intricate process of lexical competition, one that embraces the full heterogeneity of the bilingual continuum.

4.1.2 The role of language-specific features during spoken word recognition.

Although the bilingual language system is open to cross-linguistic interactions during language processing in a non-selective manner, evidence from studies on speech comprehension indicate that listeners may employ various types of language-specific cues to modulate activation across all levels of representation, ranging from phonetic (e.g., Ju & Luce, 2004) to morphosyntactic cues (e.g., Lew-Williams & Fernald, 2007; 2010). In this vein, it has been proposed that gender marking is one of the many predictors (e.g., lexical frequency, neighbourhood size) that modulate the recognition of words. Therefore, in the following section we will focus on grammatical gender, particularly in Spanish, and its role as a morphosyntactic cue during spoken word recognition.

The Spanish language employs a grammatical gender system, which classifies nouns into masculine and feminine categories based on nominal suffixes (i.e., generally, -o for masculine, and -a for feminine) (Franceschina, 2005; Harris, 1991; Teschner & Russell, 1984). This gender-specific information is typically indicated at the word ending and extends to associated words like articles and adjectives for agreement. For instance, in Spanish, the definite article and adjective match the noun in gender and number (e.g., *la* (fem.sing) *casa* (fem.sing) *roja* (fem.sing) [*the red house*]).

In Spanish, as in many other gendered languages, grammatical gender has been shown to facilitate speech processing during sentence comprehension (e.g., Wicha et al., 2004), as well as in spoken word recognition (Morales et al., 2015). Particularly, grammatical gender acts as a morphosyntactic cue, assisting in lexical competition resolution during SWR. Substantial evidence indicates that grammatical gender can provide insight into the gender of an upcoming noun when prompted by a gender-marked prenominal determiner. When a listener hears the determiner “el”, used for masculine nouns, they will expect a masculine noun to follow, modulating the activation of potential lexical candidates by restricting cohort competitors that do not align with the gender of the target spoken word (e.g., hearing the masculine prenominal determiner "el" will constrain the activation of feminine nouns like "*casa*") (Dahan et al. 2000). Conversely, when the prenominal word does not convey gender information about the following noun, individuals require more time to process and identify the noun than when the prenominal word is gender-marked (Bates et al., 1996; Grosjean et al., 1994). This gender congruency effect has been evidenced across languages in monolingual (Lew-Williams & Fernald, 2007) and bilingual domains (Dussias et al. 2013; Lew-Williams & Fernald, 2010).

One noticeable difference between Spanish and other gendered languages is that gender in Spanish highly correlates with the formal features at the rhyme of the word (e.g., transparent endings). This extra layer of information can work as an additional cue to access gender from a form-based route (Corbett, 1991; Gollan & Frost, 2001). According to Gollan and Frost's two-route model (2001), gender can be retrieved as an abstract feature stored in the mental lexicon (i.e., the lexical route) and through the distributional cues localised at the rhyme of the noun (i.e., the form-based route). If the ending of the noun is informative of the gender category (e.g., *casa* [*house*] ending in -a informs of the feminine gender), both routes can be employed to retrieve the gender information. However, if the word ending is not informative (e.g., *barril* [*barrel*] ending in -l does not inform of a specific gender category), then grammatical gender is only accessible through the lexical route. Experimental evidence has shown that this ortho-lexical connection between transparent endings and their gender value can assist learners classifying nouns into gender classes (e.g., Pérez-Pereira, 1991), as well as processing gender information during language comprehension (Caffarra & Barber, 2015; Hernández et al., 2004). Given these findings, it has been proposed that Spanish native speakers are particularly sensitive to the ending of nouns and can exploit this phonologically transparent morphosyntactic cue at the word ending to facilitate the identification of words.

This argument is in line with recent evidence from the spoken word recognition area. Soto and Schmid (2023) found via the VWP that cues to grammatical gender localised at the rhyme of the bare noun in Spanish, may contribute to the resolution of lexical ambiguity during lexical competition. Spanish monolingual speakers exhibited a stronger rhyme effect (i.e., more attention to the rhyme competitor than to the unrelated distractors) than the English monolingual group when disambiguating the spoken word. The Spanish rhyme competitor did not only share the rhyme with the target spoken word but also its gender, which may have increased the activation of the rhyme competitor and therefore its competition with the target word. The authors suggest that the robust rhyme effects displayed by the Spanish monolinguals can be attributed to an interaction between the phonological input partially matching the rhyme competitor and the phonologically transparent nominal suffixes marked for gender, which according to previous research are used as a cue for lexical access.

According to the organisational framework of BLINCS, language-specific patterns of activation can potentially emerge within the language system at the phono-lexical and ortho-lexical SOMs (Shook & Marian, 2013). These levels of representation are separated but integrated networks where words that belong to the same language tend to cluster together (except cognate and false cognate words). Associated words (via phonological or orthographical overlap) are activated together and can interact bidirectionally from the phono-lexical level spreading activation to the ortho-lexical level or vice versa (McClelland et al., 2006). Given this, it is plausible that the generalised knowledge of grammatical gender reinforces the activation connection patterns between information at the phono-lexical and ortho-lexical levels, facilitating word recognition when a prenominal word is presented sequentially (e.g., Lew-Williams & Fernald, 2007), but slowing it down due to increased competition when the bare rhyme competitor and target nouns are displayed simultaneously (e.g., Soto & Schmid, 2023).

According to the Competition model (MacWhinney, 1987; 2004), the strength of this distributional cue to grammatical gender highly depends on its availability in the Spanish language, and on the reliability of the connection between the formal transparent endings (-o and -a) and the gender categories in the lexicon. In this vein, this grammatical gender cue appears to be a highly available and reliable cue, at least in the monolingual domain (e.g., 96% of the nouns ending in -a are feminine, while 99% of the nouns ending in -o are masculine; Harris, 1991). It has been suggested that the weight of formal cues can also be influenced by other factors such as other known languages, their dominance, or their language use (Caffarra et al., 2017; Montrul, 2008; Scheutz & Eberhard, 2004; Soto & Schmid, 2023).

For example, Caffarra and colleagues (2017) investigated early bilinguals of Spanish (gendered language) and Basque (non-gendered language) and reported via ERP measures that early Spanish-Basque bilinguals immersed in an L1-dominant context exhibit sensitivity to transparent nouns in a similar manner to Spanish monolinguals. However, Soto and Schmid (2023) reported very different findings in a group of L2-immersed Spanish-English late bilinguals or bilingual attriters (mean age of arrival (AoA) = 24 years old) with reduced L1 use. This group of Spanish native speakers exhibited significantly diminished rhyme effects compared to those observed in the Spanish monolinguals during an eye-tracking visual world task. The discrepancies between Spanish monolingual and bilingual speakers were attributed to the influence of their L2 (English), a non-gendered language where cues at the end of words play a less significant role in lexical access and competition resolution, over a possibly attrited-L1 system (see Dussias & Sagarra, 2007, for similar findings on the influence of the L2 on the L1 in reading processing). Highly proficient L2 bilinguals who were immersed in the L2-dominant environment for longer exhibited the most pronounced shifts in looking patterns. Their behaviour mirrored that of English monolinguals, as they tended to prioritise cohort information over the rhyme information to a greater extent than their L1 monolingual counterparts, who exhibited a stronger competition effect from the rhyme candidates. In this vein, other studies focussed on L1 change have indicated that gender may be a vulnerable feature to the effects of an L2 (but see Bergmann et al., 2015). For instance, studies on heritage speakers have reported asymmetries i) in L1 gender marking influenced by age at onset of bilingualism (Montrul et al., 2008), ii) in the manner of categorising gender nouns based on formal cues due to language proficiency (Polinsky, 2008), and iii) in the employment of anticipatory gender effects via gender-marked prenominal determiners during a code-switching task (Valdés Kroff et al., 2017). Thus, gender seems to be a vulnerable feature among heritage speakers.

Overall, the revised studies suggest that grammatical gender serves as a morphosyntactic cue during spoken word recognition facilitating competition resolution. Specifically, Spanish native speakers immersed in an L1-dominant context seem to take advantage of the gender information embedded at the end of prenominal and nominal words via phonologically transparent suffixes in real-time processing. Discrepancies in the usage of this cue have been observed in diverse L2-immersed Spanish-English bilinguals, suggesting the permeability of the L1 to L2 effects. Further research should investigate whether these language-specific cues employed by Spanish monolinguals to disambiguate the spoken word recognition process are also observed in other bilingual populations with different degrees of bilingual experience (e.g., heritage speakers).

4.2 The Study

This study aims to delve into the lexical competition dynamics of three distinct Spanish-English bilingual communities: heritage speakers (i.e., bilingual speakers who grow up in a bilingual home with a minority language in addition to the majority language spoken by the society in which they reside), L2-immersed late-bilingual speakers (i.e., bilingual speakers who have resided in an L2 dominant environment since adulthood for an extended period of time – also known as bilingual attriters), and sequential bilinguals in an L1-dominant environment (i.e., bilingual speakers who acquired both languages sequentially without immersive experiences in the L2). Employing an eye-tracking visual world task, we seek to shed light on to the intricate interplay of language-related factors - including language-specific predictors such as distributional cues to grammatical gender - and L2-to-L1 interactions that influence the bilingual competition process. Our focus is on understanding the role of bilingual variability during competition resolution in the native language as a function of language experience. This exploration promises valuable insights into the fundamental mechanisms governing bilingual language processing along the continuum.

Given the limited exploration of within-language competition in the domain of bilingual word recognition, the current study aims to examine the within-L1 competition dynamics of the bilinguals under investigation. We do this by comparing their fixation patterns to phonologically similar L1 candidates, including both cohort and rhyme competitors, throughout the time course of spoken word recognition. Our primary focus lies on L1 spoken word recognition, an area necessitating further investigation, particularly in light of the influence of the L2 on the L1 process. By contrasting the competition dynamics of different bilingual populations within the same L1 spoken word recognition framework and the same L2, we aim to discern any distinct patterns in how the L2 shapes the L1 across the spectrum of bilingual variability.

Unlike prior research on speech comprehension which traditionally examined language-related factors in isolation, this study takes a comprehensive approach. We seek to uncover how a range of crucial predictors collectively influence the bilingual language system during spoken word recognition, particularly the competition process. These include the impact of distinct linguistic environments (L1 vs L2 contexts), degrees of L1 and L2 proficiency, dominance, frequency of exposure to both languages, age of L2 acquisition, and language aptitude, among others. Through this systematic examination of how these multifaceted factors and linguistic interactions interrelate with lexical competition dynamics, our study endeavours to offer a holistic understanding of the intricate mechanisms that drive within-language competition in bilinguals.

In the context of investigating how different Spanish-English bilingual populations employ their competition dynamics to recognize spoken words in their native language, we also take into consideration the observed word-final cues to grammatical gender that appear to influence L1 processing in Spanish monolinguals. This phenomenon has been substantiated through studies on grammatical gender, illustrating that the gender-marked suffixes in adjacent prenominal words expedite the recognition of the subsequent noun. These findings are in alignment with research on spoken word recognition using the VWP where it has been noted that Spanish monolinguals display stronger rhyme effects when disambiguating a spoken word, given its shared gender with the target spoken word, which increases competition (Soto & Schmid, 2023). However, variations were evidenced by the authors in how this cue is employed by other native speakers of Spanish. For example, Spanish bilinguals immersed in an L2 environment where the majority language does not carry grammatical gender displayed minimal competition from L1 rhyme candidates during L1 spoken word recognition, suggesting that this bilingual population was not as influenced by this distributional gender cue as their L1 monolingual counterparts. The question that remains is whether other bilingual populations with different degrees of age of L1/L2 acquisition, L1 and/or L2 proficiency and exposure to name a few will display variations in how they use this gender cue to recognise spoken words (e.g., heritage speakers who were immersed in the L2 environment since childhood). By taking the influence of this grammatical cue into account, we will be able to discern how it is employed by the three diverse groups, which in turn will provide us with a clearer understanding of how bilingual variability influences the spoken word recognition process.

In agreement with the Competition model and the previously reviewed findings on L1- and L2-immersed bilingual speakers, we should expect that both heritage and late bilingual (attriter) groups, who have spent an extensive length of time in an L2-dominant context, might display differences during L1 processing due to transfer from the second language when compared to the bilinguals immersed in the L1-dominant context. In the Competition model, MacWhinney (2019) proposes that as time passes cues become much more dependent on their reliability than on their availability. Additionally, in order to strengthen a cue (and make it more reliable), one must frequently use it. In other words, if the connection between the gender information in the mental lexicon and the distributional cue at the rhyme of the word is strong due to continuous use, then competition at the rhyme should be significant, as it is in the case with Spanish monolinguals. However, in the case of a bilingual's language system whose L1 is not well-entrenched (e.g., due to L1 attrition or incomplete acquisition), a decrease in the degree of competition between the rhyme and the target word could indicate the weakening of cue reliability, and therefore, the reduced maintenance of that cue in the language system.

The Competition model accounts for this weakening of cue strength in the L1 by means of L2 transfer. As the L2 becomes the majority dominant language that bilinguals are exposed to on a daily basis, L2 patterns can be transferred or merged into the L1, particularly if the L2 form is a more general pattern of the one presented in the L1. Notably, these predictions have also been supported by previous findings in areas where the L1 and L2 presented different patterns (e.g., attachment preferences in English and Spanish; Dussias & Sagarra, 2007), or even when the two languages are clearly distinct (e.g., typologically like English and Chinese; Malt et al., 2015). In this vein, while the two languages under investigation, Spanish and English, do not present similar L1 and L2 grammatical gender patterns (Spanish has a grammatical gender, while English does not), several effects of L2-English on L1-Spanish gender processing have been accounted for in previous studies on L2-immersed late bilinguals (also named bilingual attriters) and heritage speakers (Montrul et al., 2008; Soto & Schmid, 2023; Valdés Kroff et al., 2017).

4.3 Methods

4.3.1 Participants

Data were collected from 123 Spanish-English bilinguals (89 female), of which 20 were Spanish-English heritage bilinguals (i.e., bilinguals who were born or emigrated very early in life to the L2 environment; early age of arrival), 40 were Spanish-English sequential bilinguals and 63 were Spanish-English late bilinguals (i.e., bilinguals who emigrated to the L2 environment as adults; late age of arrival). The sequential bilinguals under investigation were living in Murcia (Spain) at the time of testing, while the late bilinguals and heritage speakers' populations were living in the East of England and London (UK) areas at the time of testing.

The heritage speakers (HS) under investigation were diverse in terms of linguistic proficiency, dominance, and age at onset of bilingualism. Of all the Spanish heritage speakers, 14 acquired English from birth, while 6 started before the age of 12 (range = 0-11 years). Five HSs reported equal dominance in both languages, 13 stated that were more dominant in English and 2 in Spanish.

Although all Spanish sequential bilinguals started to acquire English before the age of 12 (32 Spanish sequential bilinguals started to learn English before the age of 6, while 8 participants began between the ages of 6 and 11), there were no bilingual participants from this group that acquired English from birth (range = 2-11 years). Lastly, 32 sequential bilinguals reported being more dominant in Spanish than in English, while 8 were equally dominant in both languages. Similarly, most of the Spanish late bilinguals (i.e., attriters) acquired English before puberty (range = 3-16 years), with 6 participants that reported starting to learn English between 12 and 16. In terms of dominance, 21 late bilinguals were more dominant in Spanish, 17 participants were equally dominant in both languages and 3 considered themselves as more dominant in English (see Table 7 for more information on the participants' characteristics including age, age at onset of bilingualism (AoO), age of arrival (AoA), length of residence (LoR), length of L1 and L2 instruction (L2Inst and L2Inst, respectively), and dominance).

All participants reported normal or corrected-to-normal vision and hearing and were paid for their participation in the study.

Table 7. Participant characteristics by group (Study 3).

Variable	Late Bilinguals			Heritage Speakers			Sequential bilinguals		
	M	SD	Range	M	SD	Range	M	SD	Range
Age	28.2	8.76	19 - 51	26.76	9.53	18 - 57	21.79	3.89	18 - 33
AoO (English)	6.63	3.48	3 - 16	3.36	4.12	0 - 11	5.24	2.18	2 - 11
AoA	24	6.32	17 - 43	3.36	4	0 - 11	__		
LoR	5	6	2 - 32	__			__		
L2Inst (English)	11.44	5.42	2 - 20	13.5	2.53	7 - 16	14.38	3	6 - 21
L1Inst (Spanish)	__			3.36	4.33	0 - 16	__		
Dominance	3 English 17 Both 21 Spanish			13 English 5 Both 2 Spanish			0 English 8 Both 32 Spanish		
Education Level	10 PhD Degree 27 Master's Degree 23 Bachelor's Degree 3 Voc. Training			__ 8 Master's Degree 9 Bachelor's Degree 3 Voc. Training			1 PhD Degree 1 Master's Degree 36 Bachelor's Degree 2 Voc. Training		

4.3.2 Materials

Participants completed one visual world paradigm task (VWP; Tanenhaus et al., 1995) to assess the L1 spoken word recognition process across groups. Participants also performed the Flanker task to examine cognitive control (Eriksen, 1974), as well as the LLAMA test (Meara, 2005) to measure language aptitude. Additionally, participants were asked to fill out an online sociolinguistic and personal background questionnaire (SPBQ), Spanish and English proficiency C-tests, and proficiency self-rating Can-Do scale tasks. The order of tasks administered was counterbalanced across all participant groups. The experimental session took approximately 1 hour.

4.3.2.1 Visual World Paradigm Task

4.3.2.1.1 Design

A visual world task in Spanish was used to examine the participants' within-L1 competition process in real time. The task involved a total of 55 trials, consisting of 15 practice trials and 40 experimental trials. In this version of the task, each trial simultaneously presented 4 black-and-white line-drawings: target, cohort competitor, rhyme competitor and a distractor item, along with a spoken word that matches the target (see Figure 12 below). Participants were instructed to select the response option that best matched the presented auditory stimulus. To minimize random selection and ensure active engagement, a question mark sign was introduced at the centre of the screen. Participants were encouraged to choose the question mark response option when they were not able to identify the target referent or when the auditory target did not match any of the visual items displayed during 5 practice trials (Botezatu et al., 2022). Finally, the presentation of pictures was pseudo-randomized within and between trials, guaranteeing an equal representation of each item in all screen positions.

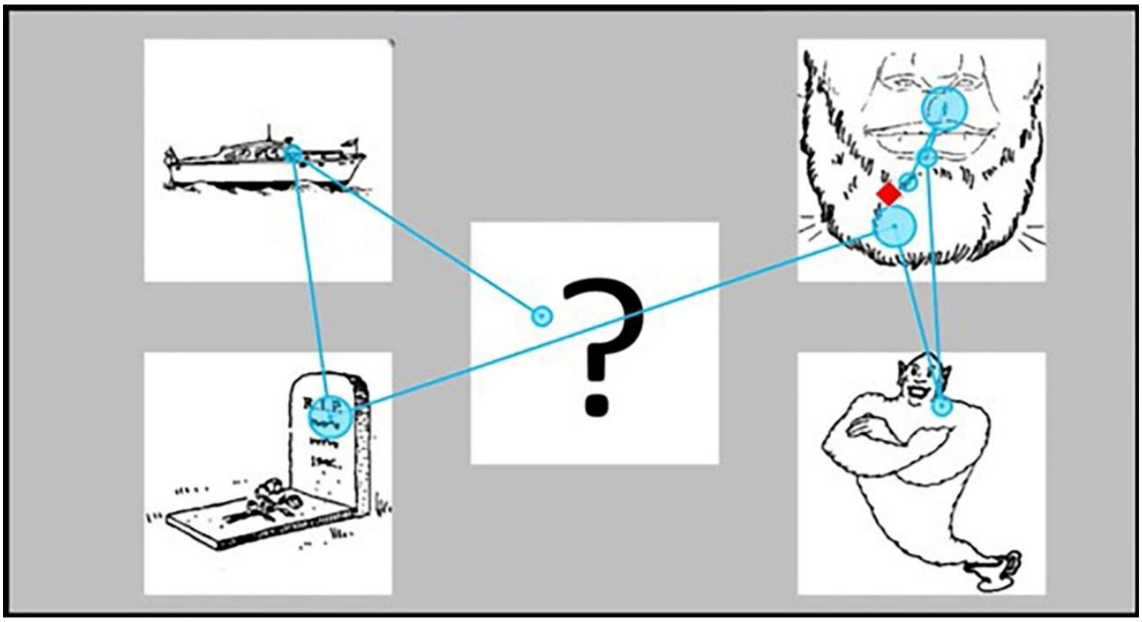

Figure 12. Scan Path Data View. Sample experimental trial of VWP from Soto and Schmid (2023) with items from Snodgrass and Vanderwart´s (1980) dataset. Clockwise order of components from upper left corner: cohort competitor (*barco-ship*), target item (*barba-beard*), unrelated item (*genio-genie*), rhyme competitor (*tumba-grave*), and central picture question mark.

4.3.2.1.2 Stimuli

Stimulus[7] selection was based on two sets of pictures: the On-line Resource for Psycholinguistic Studies from Szekely and colleagues (2004) work and the Snodgrass and Vanderwart (1980) corpus (see Appendices 2 and 3 for more information). These items were carefully chosen to control for name and image agreement, familiarity, visual complexity and lexical frequency in the language under investigation. Additionally, the selected words were disyllabic, with stress on the initial syllable (Domínguez Martínez & Cuetos Vega, 2018; Fudge, 1984; Guion et al., 2004). Critical words and competitor candidates' phonological

[7] Out of the 292 pictures used, 33 were created by a professional graphic designer. These images were also controlled for name and image agreement, stress, frequency, and number of syllables. Prior to application in the study, all the visual stimuli were piloted (see Appendix 4 for more information).

similarity was controlled by selecting cohort and rhyme competitors that shared an overlap in the first or last two phonemes with the target word (e.g., target-cohort: *cuna-cubo* [crib-block]; target-rhyme: *lazo-pozo* [bow-well]).

To design the auditory stimuli, all spoken words were recorded by a female native speaker of Castilian Spanish, and then standardised to a 60dB intensity level. Using PRAAT software (Boersma & Weenink, 2017), white noise at 62dB was incorporated to the recordings to make the word recognition task more demanding (Botezatu et al., 2022).

4.3.2.1.3 Eye-tracking methods

Data from all 3 groups of participants were collected using three different eye-tracking devices due to the participants' location at the time of testing. For the sequential bilinguals residing in Spain, their eye-movements were recorded using a portable Tobii Pro X3-120 eye-tracking device at the University of Murcia (Spain). The data collected from the heritage speakers originated from two separate populations: one living in Essex and the other in London (UK). For the population in Essex, data collection employed a Tobii Pro Fusion 250 [8]eye-tracker, in conjunction with the iMotions software at ESSEXLab (University of Essex, UK). Data from the population in London was collected using a 1000 EyeLink portable eye-tracker from SR Research. As for the late bilingual group, it also comprised two distinct populations - one also living in Essex and another in London. For the participants in Essex, a dual set-up was used, combining an SMI RED 250 desktop-mounted eye-tracker and the E-Prime 2.0 software (Schneider et al., 2002), both provided by the University of Essex. Meanwhile, the data collection from the population residing in London was carried out using the 1000 EyeLink eye-tracker previously mentioned.

[8] Eye-tracking data collected at 250 Hz was downsampled to 120 Hz (see Data analysis section for more information).

4.3.2.1.4 Procedure

The following procedure was standardised across all participants. At the beginning of the visual world task, participants were seated at a distance of 60 cm from the screen monitor, which maintained a consistent resolution of 1680x1050 across all experimental set-ups. Prior to the experiment, instructions were provided, and participants were presented with a standard 9-point calibration. Each trial began with a 2000 ms presentation of a trial preparation screen, featuring a central cross, followed by an array of pictures. During each trial, the auditory stimulus was presented to participants through headphones, 200 ms after the visual array appeared on the screen. Participants were then required to click on the picture referent for the word they had heard, which signalled the end of the trial.

4.3.2.2 Flanker Task

A computerised version of the task was administered using E-Prime 2.0. The non-linguistic inhibition test developed by Barbara and Charles Ericksen (1974) was employed to evaluate participants' inhibitory control and selective attention. The task consisted of 3 types of trials: congruent, incongruent, and mixed. All 3 conditions contained 5 black chevrons (Font size 18, Courier New) in the middle of the screen pointing to the left or right. Participants were required to indicate the direction of the target chevron, presented in the middle, by pressing designated keys on the keyboard. In the congruent block, the target chevron was surrounded on both sides by two nontarget chevrons, all pointing in the same direction as the target. In the incongruent block, the distractor chevrons pointed in the opposite direction to the target. Lastly, in the mixed block, randomised trials from both congruent and incongruent conditions were presented.

Participants' accuracy, response times and interference scores were obtained to measure participants' inhibitory control. Consistent with Sanders and colleagues' (2018) approach to analyse the Flanker task, the interference scores were computed by subtracting the mean reaction time (RT) for correct congruent trials from the mean RT for correct incongruent trials in the mixed condition and added as a covariate in subsequent analyses (see Data analysis section).

4.3.2.3 Aptitude Test

The LLAMA Language Aptitude tests designed by Meara (2005) based on the MLAT tests developed by Carroll and Sapon (1959) were used to assess participants' language aptitude. This computerised battery of subtests (LLAMA B, D, E and F) evaluates 4 components: vocabulary learning, sound recognition, sound-symbol correspondence, and grammatical inferencing. The collected data was analysed by calculating the participants' average score percentage from the four subtests. This variable was added as a covariate in the linear mixed-effects models (see Data analysis section).

4.3.2.4 Sociolinguistic and Personal Background Questionnaire (SPBQ)

Information regarding participants' general personal background and language use was collected using the sociolinguistic and personal background questionnaire (SPBQ) designed by Schmid and Dusseldorp (2010) (see Appendix 1). The questionnaire was administered via the Moodle X platform. Following Schmid's and Dusseldorp (2010) approach, a Principal Component Analysis (PCA) with Varimax rotation (30) was performed on the Likert scale questions pertaining to participants' linguistic identification, language exposure, and language use. The purpose of employing PCA was to group related items from the SPBQ into fewer variables, allowing us to measure and utilise these composite variables (e.g., L1 or L2 use) as covariates in our statistical analyses (Field, 2009) (for additional details, refer to Table 8 below).

Table 8. Summary of the predictor variables extracted from the PCA (Study 3).

Composite predictor variables	Items	Cronbach's α	Variance	KMO	Bartlett's test
Spanish Language Use	L1 receptive exposure and use	.914	35.54%	.5	<.001
English Language Use	L2 receptive exposure and use	.845	19.19%	.5	<.001

4.3.2.5 Proficiency Tasks

The participants' proficiency in both Spanish and English was evaluated using two tasks: a C-test (Grotjahn, 1987; Keijzer, 2007; Mehotcheva, 2010), and a self-rating task known as the Can-Do scale (ALTE, 1998). Both versions of the two proficiency tasks were accessed from the Language Attrition webpage (Schmid, https://languageattrition.org/resources-for-researchers/experiment-materials/c-test/) and administered through the Moodle X platform.

To analyse the data, the participants' correct responses from the C-test were aggregated and computed into a total variable of correct scores per individual and language (C-test-SPA and C-test-ENG). For the Can-Do scale data, participants' responses were categorized and averaged based on the main linguistic skills (listening, writing, speaking, and reading) per language. Subsequently, a total variable was computed for each test version (CANDO_ENG and CANDO_SPA) (refer to Table 9 for a summary of participants' language aptitude and proficiency scores). Both variables were also included as covariates in the statistical analyses.

Table 9. Language aptitude and language proficiency scores across groups (Study 3).

Variable	Late Bilinguals			Heritage Speakers			Sequential bilinguals		
	M	SD	Range	M	SD	Range	M	SD	Range
L. Aptitude	50.69	11.79	22.5 - 75/100	48.66	14.56	17.5 – 72.5/100	45.1	10.73	13.33 - 63.33/100
Spanish C-test	62.6	3.38	45 - 66/66	58.33	7.25	42 - 66/66	63.59	2.51	56 - 66/66
English C-test	8.2	1.02	5.5 - 9.75/10	8.84	1.14	5.25 - 10/10	8.02	1.12	5.25 - 10/10
Spanish Can-Do	4.75	0.5	4.09 - 5/5	4.05	0.58	3.1 - 5/5	4.76	0.63	4.26 – 5/5
English Can-Do	4.36	0.69	2.5 - 5/5	4.85	0.19	4.39 – 5/5	4.09	0.71	2.73 - 5/5

4.4 Data analysis

All analyses conducted on the experimental trials from the visual world task focussed on the initial 1000 ms after the onset of the spoken utterance, starting 200 ms following the presentation of the visual array. Reaction times were also calculated from the onset of the auditory signal until the participants selected the target picture.

Reaction times exceeding two standard deviations above the grand mean were excluded. Additionally, blinks, saccades and trials with track loss exceeding 25% were excluded from the analyses. Missing values resulting from equipment malfunctioning and track loss accounted for 9% of the data (data from 16 participants were excluded: 10 Spanish-English L2-immersed late bilinguals (attriters) and 6 Spanish-English L1-immersed sequential bilinguals). The analyses only considered correct responses, and accuracy rates were calculated accordingly.

Reaction time data from all groups were subjected to analysis using linear mixed-effects models (LMM, Baayen et al., 2008) through the lme4 R package in R (Version 4.0.3; R Core Team, 2020). Participants were excluded if they selected a non-target item in over half of the experimental trials during the visual world task (data from 9 participants were excluded: 3 Spanish-English L2-immersed late bilinguals (attriters) and 6 Spanish-English L1-immersed sequential bilinguals).

To analyse the time course of L1 spoken word recognition across groups, we followed Godfroid's (2020) approach and collapsed the eye-tracking data points into time bins of 40 ms using the eyetrackingR R package (Version 0.2.0; Forbes et al., 2021). The aggregated measure was included as a continuous independent variable in the generalised analyses described below. To calculate the dependent variable for those analyses, we followed Barr's (2008) approach. We divided the total number of fixations to an image by the total number of non-fixations at the other images, and then we logged the odds, which gave the dependent variable – the log odds of fixating on one of the competitors versus the fixations to the rest of visual items.

To assess the within-L1 competition process in the three bilingual groups under investigation, we conducted three types of analyses on the eye-tracking data gathered from the visual world task. First, we analysed the participants' fixations to the competitor items under investigation across time until the participants recognised the target word. This analysis was performed, first, within-groups, to assess the cohort and rhyme effects of each bilingual population. The competitor effects were measured by calculating whether bilinguals were more likely to fixate on the cohort or rhyme competitor than on the unrelated items as the speech signal unfolded. Then, we performed the analysis between-groups, to determine whether the bilinguals' competition dynamics differed across competitors and groups. The statistical models were generalised linear mixed-effects models (GLMM, Baayen et al., 2008) via a link function (logistic mixed-effects models) from the glmer function within the lme4 R package. The structure of the between- and within-group models accounted for a two-way interaction (Time Bin x Group for the between group analyses; Time Bin x Area of Interest (AOI) for the within-group analyses) with a quadratic term, which was orthogonalized to remove collinearity (Godfroid, 2020).

In another set of analyses, we examined what linguistic and extralinguistic factors influenced the bilinguals' total looking time (duration of fixations) to each phonological competitor via linear mixed-effects models (LMM, Baayen, Davidson & Bates, 2008) within the lme4 R package. The external variables included in the models encompassed the following factors: sex, gender, age, level of education, L1 and L2 proficiency, L1 and L2 use and exposure, self-perceived linguistic dominance, language aptitude, age of arrival to the L2 dominant immersion context (AoA), age at onset of bilingualism (AaO), length of residence (LoR), length of L1 and L2 school instruction (L2Ins), and interference scores from the Flanker task. All the random-effects and fixed- effects structures across GLMM and LMM models were determined by a forward selection approach (Barr et al., 2013).

Finally, we were also interested in assessing the point in time at which the fixations to the competitors started to diverge across groups and the duration of such discrepancies. Therefore, we performed a bootstrapped cluster-based permutation analysis per total fixations to each individual competitor across groups via the eyetrackingR R package (Version 0.2.0; Forbes et al., 2021; Maris & Oostenveld, 2007).

4.5 Results

4.5.1 Accuracy rates and reaction times

The average reaction times and accuracy rates recorded from the L1 visual world task per bilingual group were as follows: Spanish heritage speakers (M = 1682.21; SD = 531.19) with 80% accuracy rate; Spanish sequential bilingual speakers (M = 1460.67; SD = 434.35) with 75% accuracy rate; Spanish late bilinguals (M = 1462; SD = 547.31) with 90% accuracy rate. The Spanish heritage speakers were significantly slower than the other two groups (estimate = 0.16, SE = 0.05, $t(137) = 2.948$, $p < 0.01$). The Spanish sequential-bilinguals and the Spanish late bilingual-attriters did not differ in their reaction times (estimate = -0.02, SE = 0.04, $t(121) = -0.481$, $p = 0.631$).

4.5.2 Within-L1 lexical competition

Before presenting these results, in Figure 13 below, we illustrate the temporal evolution of fixation proportions on the Spanish candidates during the visual world task.

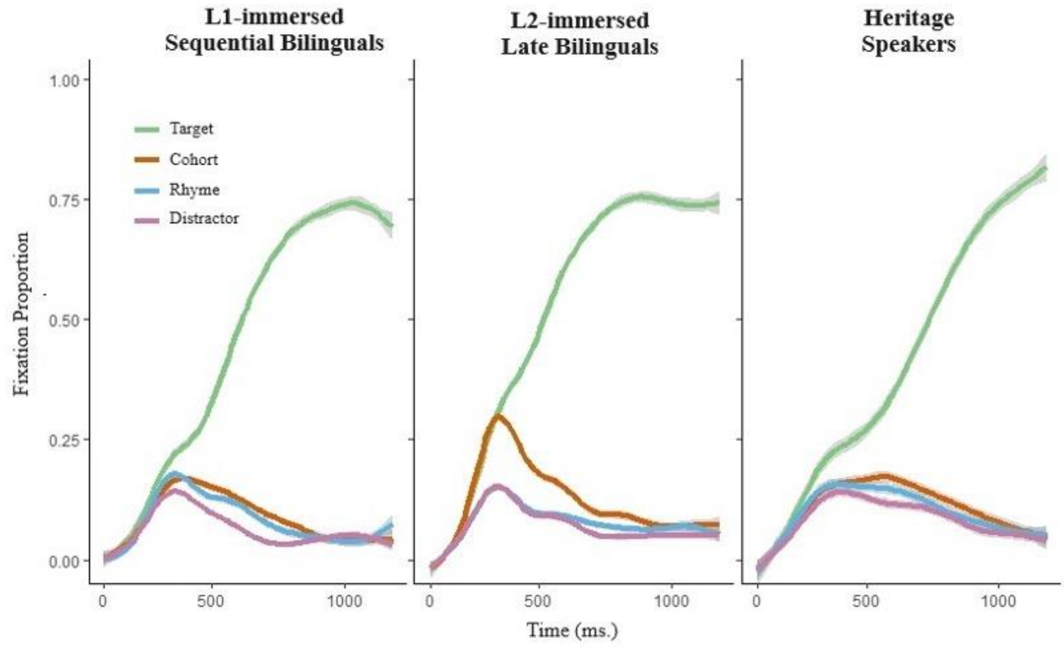

Figure 13. Average fixation proportions towards the Spanish lexical candidates across time. Comparison between L1-immersed sequential bilinguals, L2-immersed late bilinguals (i.e., bilingual attriters) and heritage speakers.

The three groups display distinct activation patterns. Sequential bilinguals initially show high activation levels for both competitors, peaking around 400 ms before returning to baseline levels. Late bilinguals exhibit a robust cohort effect, while a weaker rhyme effect emerges around 600 ms, followed by the suppression of both competitors. Heritage speakers maintain a consistent cohort effect, with the rhyme effect intermittently present, occurring from 600 to 800 ms. All three groups eventually achieve full suppression of both competitors, with Spanish sequential bilinguals demonstrating the quickest suppression.

4.5.2.1 Within-group analyses

The three Spanish-English bilingual populations revealed both cohort and rhyme effects via a series of GLMM models, which included random intercepts for participant and item (model structure explained in Data Analysis section). These models were performed on the first four

200 ms intervals from the onset of the spoken word (200-1000 ms) to capture these effects in greater detail.

The cohort effect (i.e., more looks to the cohort competitor than to the distractor item) displayed by the Spanish heritage speaker group started in the 200-400 ms interval (estimate = -0.19 SE = 0.02, $z(19692) = -8.772$, $p < 0.001$), and remained significant until the 1000 ms. Additionally, this group's rhyme effect (i.e., more looks to the rhyme competitor than to the distractor item) appeared in the 200-600 ms intervals (estimate = 0.20 SE = 0.03, $z(\text{inf}) = 6.050$, $p < 0.001$), and then again at the 800-1000 ms interval (estimate = 0.23 SE = 0.06, $z(\text{inf}) = 3.440$, $p < 0.01$).

Both cohort and rhyme effects displayed by the Spanish sequential bilingual group started in the 200-400 ms interval and remained significant until 1000 ms (cohort effect, estimate = -0.19 SE = 0.02, $z(19692) = -8.772$, $p < 0.001$; rhyme effect, estimate = 0.20 SE = 0.03, $z(\text{inf}) = 6.050$, $p < 0.001$).

Similarly, the Spanish late bilingual group exhibited a cohort effect across the 200-1000 ms intervals (estimate = -0.60 SE = 0.01, $z(36156) = -39.386$, $p < 0.001$). The rhyme effect displayed by the late bilinguals started at the 600-800 ms interval (estimate = 0.18 SE = 0.03, $z(\text{inf}) = 5.082$, $p < 0.001$). All three bilingual groups paid more attention to the visual cohort competitors than to the rhyme visual items.

4.5.2.2 Between-group analyses

After examining the cohort and rhyme effects by group, we compared the competition dynamics of the three bilingual groups by analysing their odds of looking at each competitor across time. The GLMM models employed in this set of analyses followed the model structure described in the Data Analysis section, but the random-effects structure included random intercepts for participant and item and random slopes for group across items.

According to the GLMM model employed to assess the odds of looking at the rhyme competitors across groups, the Spanish heritage speakers are more likely to look at the rhyme competitor than any other bilingual group (estimate = 0.41 SE = 0.16, $z(82772) = 2.454$, $p < 0.05$). This model accounted for 53% of the variance. In addition, the GLMM model assessing the participants' odds of looking at the cohort competitor across time, which accounted for 54% of the variance, showed that both Spanish late bilinguals and heritage speakers are more likely to look at the cohort competitor than the sequential bilinguals (estimate = 0.41 SE = 0.16, $z(83584) = 2.496$, $p < 0.05$).

These analyses examined the differences across groups in odds of looking at each competitor, however, the reported GLMM models cannot inform us of the duration of such discrepancies. Therefore, we conducted a series of bootstrapped cluster-based permutation analyses for the total fixations on each competitor across the three groups. Following previous analyses, we performed the tests on the first 1000 ms from the onset of the target spoken word (200-1200 ms). The cluster-based permutation test on the rhyme competitors revealed a significant difference between the Spanish heritage speakers and the Spanish sequential bilinguals from the 900 to 1200 ms post-onset of the spoken word ($p < 0.01$), as well as between the Spanish heritage speakers and the Spanish late bilinguals ($p < 0.01$) from the 300 to 1000 ms. Finally, the Spanish sequential bilinguals and the Spanish late bilinguals diverged in their looks towards the rhyme competitors from the 300 to the 800 ms ($p < 0.01$), and from the 1000 to the 1200 ms of the task ($p < 0.05$) (see Figure 14 below for more information).

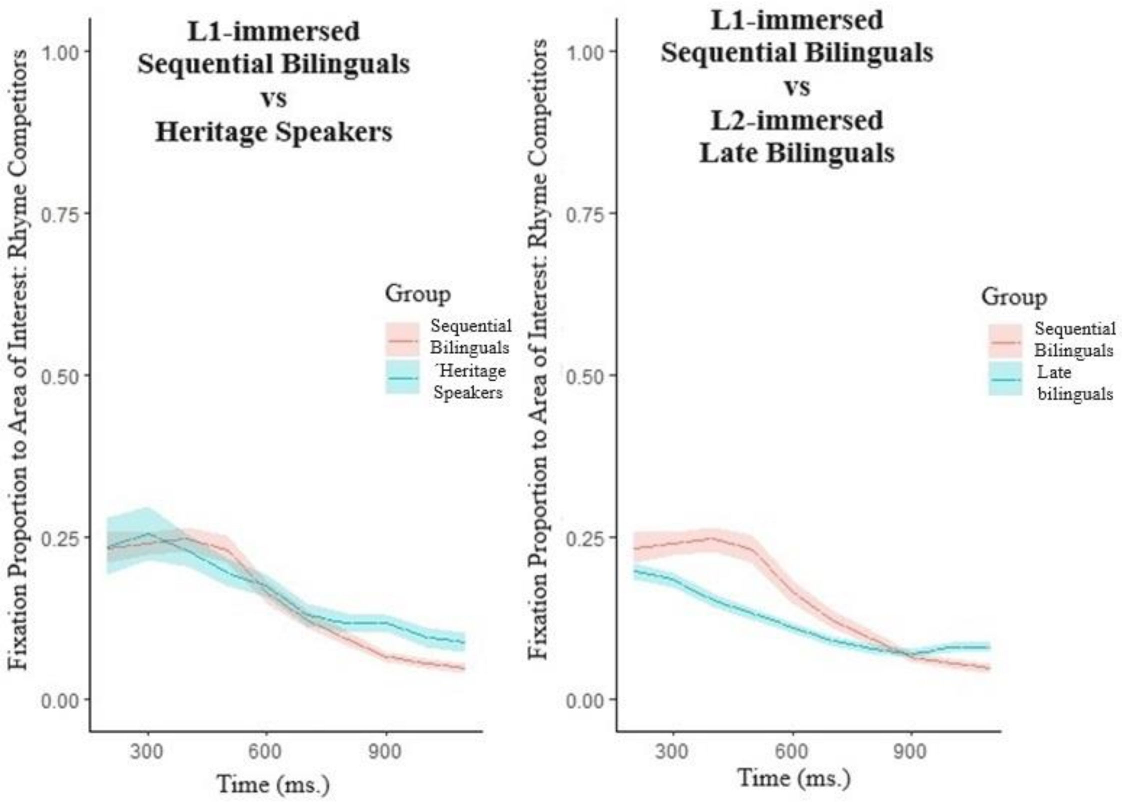

Figure 14. Average fixation proportions towards the rhyme competitors across time. L1-immersed sequential bilinguals vs Heritage Speakers and L1-immersed sequential bilinguals vs L2-immersed late bilinguals (i.e., bilingual attriters).

Additionally, the cluster-based permutation test on the cohort competitors revealed that the Spanish heritage speakers and the Spanish sequential bilinguals' fixations to the cohort competitor were not significantly different ($p = 0.283$). The Spanish late bilinguals and heritage speakers differed in looks to the cohort competitor from the 200 ms to 500 ms ($p < 0.05$), while the Spanish sequential bilinguals differ in looks to the cohort competitor from the Spanish late bilinguals from the 200 to 400 ms ($p < 0.05$).

4.5.2.3 Individual differences

Lastly, with the aim of examining to what extent the bilinguals' competition dynamics are modulated by different external factors, we performed a series of linear mixed-effects models on the total duration of the fixations to the cohort and rhyme competitors. These models included the recorded measures described in the Methods section, encompassing i) the interference scores from the Flanker task, which measured the participants' interference effect during the mixed condition, ii) their language aptitude, which was calculated by averaging the participants' scores from the four LLAMA subtests, iii) their L1 and L2 use and exposure, which were measured through composite variables from the PCA, iv) relevant descriptive information from their bilingual experience such as sex, age, age at onset of bilingualism, length of residence for those living in an L2 context, length of L1 and L2 school instruction, self-perceived linguistic dominance and level of education, and v) their levels of L1 and L2 proficiency, which were calculated via the two administered proficiency tasks.

In this set of LMM analyses, we replicated the results we described in the previous section from the GLMM models, as heritage speakers (estimate = 0.26, SE = 0.13, $t(100) = 2.024$, $p < 0.05$), and late bilinguals (estimate = 0.21, SE = 0.09, $t(90) = 2.221$, $p < 0.05$) were reported to look more to the cohort competitors than the sequential bilinguals. Similarly, we found that heritage speakers look more to the rhyme competitors than sequential bilinguals (estimate = 0.25, SE = 0.09, $t(61) = 2.620$, $p < 0.05$). This LMM model also indicated that L2 proficiency plays a role in the modulation of lexical competition as highly proficient bilinguals looked less to the rhyme competitors than those with lower levels of English proficiency (estimate = -0.05, SE = 0.02, $t(118) = -2.516$, $p < 0.05$). This factor was particularly relevant for the late bilinguals as high L2 proficiency was linked to fewer looks at the rhyme competitors (estimate = -0.06, SE = 0.03, $t(60) = -2.122$, $p < 0.05$), as well as increased looks to the cohort competitors (estimate = 0.10, SE = 0.05, $t(60) = 2.053$, $p < 0.05$).

In relation to the predictors measuring time (i.e., length of residence, age of L2 onset and length of L2 school instruction), we found that the late bilingual speakers who had spent more time immersed in the L2 context presented fewer looks to the rhyme competitors (estimate = -0.05, SE = 0.02, $t(68) = -2.047$, $p < 0.05$), and more looks to the cohort competitors (estimate = 0.12, SE = 0.04, $t(62) = 2.603$, $p < 0.05$). Similarly, the heritage speakers who were older at their onset of bilingualism (AoO) look more to the rhyme competitors than those who were younger when they were first exposed to English (estimate = 0.12, SE = 0.05, $t(18) = 2.483$, $p < 0.05$). We found that length of L2 school instruction modulated the heritage speakers' rhyme looks in the same manner (estimate = -0.14, SE = 0.06, $t(18) = -2.229$, $p < 0.05$), however, this predictor correlated very highly with AoO, and therefore was not included in the model as AoO is more theoretically relevant.

Finally, two additional predictors influenced the sequential bilingual speakers: L1 use and exposure and the interference effect from the Flanker task. We found that sequential bilinguals who reported to use their L1 more often look more to both cohort (estimate = 0.08, SE = 0.03, $t(39) = 2.189$, $p < 0.05$) and the rhyme competitors (estimate = 0.07, SE = 0.03, $t(39) = 2.577$, $p < 0.05$). In addition, those sequential bilingual participants with better inhibitory control skills (i.e., participants who showed less interference from the Flanker task) look less to the rhyme competitors (estimate = 0.08, SE = 0.03, $t(39) = 2.172$, $p < 0.05$).

4.5.3 Summary of results

The three bilingual populations under investigation exhibited a number of differences in the manner they resolved the competition process, particularly regarding the rhyme competitor. Although the heritage speaker group was more likely to look at the rhyme candidates when compared to the other two groups, the sequential bilingual group exhibited a more consistent rhyme effect than the heritage speakers, who displayed an intermittent rhyme effect, and the late bilingual group, who showed a delayed rhyme effect.

The sequential bilingual speakers were also the fastest group to fully suppress both competitors as well as to recognise the target spoken word. These findings are supported not only by the reaction time data, but also by the bootstrapped cluster-based permutation analyses, indicating that the only point in time the late bilinguals and heritage speakers were more likely to look at the rhyme than the sequential bilinguals was at the end of the first 1000 ms on the visual world task when the sequential bilinguals had already inhibited the rhyme candidates (see Figure 14 above).

In relation to the external factors that played a role in the resolution of lexical competition, we found that, overall, L2 proficiency modulated the bilinguals' competition dynamics as those participants with higher levels of English proficiency were less likely to look at the rhyme competitor. This predictor was particularly relevant for the bilinguals immersed in an L2 context, as those heritage speakers who started to learn English earlier in life, together with those highly L2 proficient late bilinguals were less likely to look at the rhyme candidates. Finally, the sequential bilinguals who were more exposed to and used more the target language on a daily basis were more likely to fixate on both competitors, while those sequential bilinguals who reported better inhibitory skills were less likely to fixate on the L1 rhyme competitor.

4.6 Discussion

The present study showed that bilingual variability impacts the competition resolution dynamics during L1 spoken word recognition by exploring how three distinct Spanish-English bilingual populations disambiguate the process of within-L1 lexical competition. Employing the eye-tracking Visual World Paradigm, this research sought a comprehensive understanding of how various factors, including factors related to the bilinguals' experience (e.g., language proficiency and exposure), language-specific factors like the distributional cue to gender retrieval observed in the Spanish language, as well as the influence of the L2 exerted on the L1, shape the L1 competition process across the bilingual spectrum. In the following section, we will discuss these findings in relation to theoretical accounts on the dynamicity of the bilingual language system and the permeability of the native language.

4.6.1 Bilingual variability modulates L1 competition dynamics via grammatical gender and the L2

The study revealed notable distinctions among the three groups of bilingual speakers in how they navigate competition resolution within their L1 competition dynamics. Although all three groups exhibited robust cohort effects, demonstrating a preference for the cohort competitor over the rhyme or unrelated items, the primary inter-group disparity centred on their rhyme competition effects -specifically, the looks towards the rhyme competitor as opposed to the unrelated items.

Among the three groups, sequential bilingual speakers immersed in an L1-dominant environment exhibited the most pronounced rhyme effects, surpassing the two groups of L2-immersed bilingual speakers (i.e., attriters and heritage speakers) who presented more delayed levels of rhyme activation and a weaker competition. These results align with prior studies which have noted a parallel increase in rhyme competition effects among Spanish monolingual speakers during visual world tasks (Soto & Schmid, 2023). These robust levels of rhyme competition have been attributed to two factors: phonological similarity, which activates competitors that partially overlap with the spoken word at the rhyme, and the transparent gender-marked nominal endings that serve as a morphosyntactic cue to access gender in Spanish.

It is well-stablished that as the speech input unfolds, a broad range of competitors that match the acoustic signal to some extent are activated (Allopenna et al., 1998; Shook & Marian, 2013). However, the levels of activation differ between cohort and rhyme competitors due to the sequential nature of the competition process, weakening the activation of candidates that overlap with the target word at the rhyme. Therefore, the high levels of rhyme activation and competition observed in both monolingual and L1-immersed bilingual Spanish natives during spoken word recognition cannot be explained solely by their phonological similarity with the target spoken words.

Previous studies have highlighted that Spanish native speakers have a heightened sensitivity to transparent noun endings during L1 processing (Caffarra & Barber, 2015; Caffarra et al., 2017; Hernández et al., 2004). This sensitivity has been linked to the role that nominal suffixes have in Spanish as they can act as a cue to access gender information in the mental lexicon through the form-based route (Corbett, 1991; Gollan & Frost, 2001). As reviewed in the theoretical background, most Spanish nouns ending in -a are feminine, while most nouns ending in -o are masculine. This formal distinction is informative of the gender category stored in the mental lexicon and can aid the speaker in gender retrieval. In addition, extensive evidence suggests that grammatical gender facilitates language processing during spoken word recognition. By providing gender information of the forthcoming noun via gender-marked prenominal determiners (e.g., *la casa* [the house]), grammatical gender constrains the activation of the competing candidates to nouns that agree in gender with the prenominal word. Notably, when a noun is presented in isolation or is followed by a prenominal determiner that is uninformative of gender, more time is needed to recognise the target word (i.e., *the gender congruency effect*).

Based on these findings, Soto and Schmid (2023) proposed that grammatical gender can act as a facilitatory cue when presented sequentially, such as in the case of a determiner-noun sequence in spoken word recognition (e.g., Lew-Williams & Fernald, 2007). However, when a bare spoken target item is displayed simultaneously with a rhyme competitor, as in this version of the VWP, the phonological transparent ending of the rhyme candidate, which matches the gender of the target word, is expected to intensify the competition between the rhyme and the target, leading to an increase of the rhyme effect until the word is recognised. Our current findings regarding rhyme effects in Spanish sequential bilinguals provide additional support for this argument. We demonstrate that the increased rhyme competition in Spanish monolinguals due to transparent gender cues localised at the end of the word can also be observed in Spanish bilinguals residing in an L1-dominant environment.

Turning our attention to the L2-immersed Spanish-English bilingual groups, we also observed significant differences in how both heritage and late bilingual speakers (i.e., bilingual attriters) manage L1 lexical competition. Spanish late bilinguals displayed delayed activation and a reduction in rhyme competition, beginning around 600 ms, when compared to the Spanish sequential bilingual group. On the other hand, heritage speakers exhibited an irregular rhyme effect, starting at approximately 400 ms as in the case of the sequential bilinguals, but disappearing for 200 ms, only to reappear at 800 ms (see Figure 13 for more information). Notably, the sequential bilinguals not only showed a stronger rhyme competition effect, but also inhibited both competitors faster than any other bilingual group before the first 1000 ms of the visual world task. This, taken together with their faster reaction times compared to the other two groups, indicates a more efficient disambiguation of the competition process by the sequential bilinguals under investigation.

A main difference between these two groups and the sequential bilinguals we discussed previously is that these bilingual speakers had been potentially influenced for a long time by the majority language of the L2 context where they resided at the time of testing. The influence of English, a second language which lacks grammatical gender, might have contributed to the discrepancies found in the way they employed their L1 competition dynamics, particularly regarding the rhyme competitors, to disambiguate the target spoken word.

The Competition model accounts for the L2 interactions that can take place during L1 processing when bilinguals are mainly exposed to a context where the L2 is the dominant language. Distributional cues, like the formal cue to grammatical gender under investigation, become more dependent on cue reliability as time passes. To reinforce the strength of a cue and therefore its reliability, MacWhinney (2019) proposes that the key is frequent L1 use and exposure. From a psycholinguistic view, we understand this process of L1 maintenance as the strengthening of the connections between the gender information at the mental lexicon and the distributional cue localised at the word ending. The more we use a cue, the stronger the connection between that formal cue and its lexical representation will become, facilitating its maintenance against the interactions from the L2 that weaken those connections through continuous exposure to the L2. Based on this theoretical account, the heritage and late bilinguals are more at risk to the weakening of these connections (i.e., the decrease of cue reliability) than sequential bilinguals immersed in the L1 context, which explains why the L2-immersed bilingual groups display more erratic and weaker rhyme effects (i.e., less rhyme competition) than the sequential bilingual group as well as a slower suppression of both cohort and rhyme competitors.

The previous theoretical arguments help us understand the differences we found among L1- and L2-immersed bilingual speakers in resolving lexical competition in the native language.

Yet, one question that remains is how the influence of a non-gendered second language like English weakens the connections of a functional cue in a gendered language such as Spanish. Two hypotheses are considered. First, the Competition model posits that L1 changes arise from continuous competition between L1 and L2 patterns. According to this view, gender cues and their connections with the language system should not be susceptible to L2 transfer since Spanish and English do not share competing gender patterns. However, it is worth noting that English, while mostly non-gendered, does possess a pronominal gender system based on semantics (Corbett, 1991). Certain nouns and pronouns are gendered as masculine or feminine according to biological sex (e.g., *bull*/*cow*, *man*/*woman*). This suggests that English speakers may form connections between gendered abstract lexical representations and corresponding gender categories in the mental lexicon to retrieve gender information (i.e., the lexical route, Gollan & Frost, 2001). If so, L2 transfer might facilitate these connections through abstract lexical representations, potentially diminishing connections to the form-based route of gender retrieval (i.e., reducing sensitivity to cues at word endings). It is important to note that this hypothesis cannot be conclusively confirmed with the data from this study, and further research is necessary to explore this question.

Another hypothesis we consider pertains to the distinct L1 competition dynamics observed in Spanish and English monolinguals during spoken word recognition. Soto and Schmid (2023) proposed that while Spanish monolinguals exhibit strong levels of rhyme competition influenced by the Spanish grammatical gender cue, English monolinguals do not prioritise rhyme candidates as they do not rely as heavily on rhyme-based information, favouring cohort competitors instead. This suggests that Spanish native speakers demonstrate a *preference* or sensitivity for attending to rhyme candidates, while English monolinguals engage in a more generalized form of competition resolution, favouring cohort competitors over rhyme candidates. This preference aligns with the notion that English places less emphasis on information localized at the end of the word compared to Spanish. This assumption is in line with how L2 patterns may transfer to the L1 through a broader L2 form (MacWhinney, 2019). Nevertheless, further research is needed to confirm the hypothesised cohort preference in speakers of languages with unmarked suffixes (e.g., languages like English without grammatical gender), as there is currently limited study on this matter.

Previous studies from the bilingual research literature on Spanish-English heritage speakers and L2 immersed late bilinguals (also named attriters) have indicated how English, as a second language, can impact various aspects of L1-Spanish processing, even in the absence of direct L1-L2 competition (e.g., Dussias & Sagarra, 2007; Montrul et al., 2008; Soto & Schmid, 2023; Valdés Kroff et al., 2017). Consistently with the BLINCS model (Shook & Marian, 2013), these studies suggest that bilingual variability together with factors like age of acquisition, proficiency, and the immersion context play pivotal roles in shaping observed variations in L1 processing, reflecting the adaptable nature of the bilingual language system to various linguistic interactions. We argue that the changes we observe in the native language in this study align with the significant influence exerted by the second language on L1 processing. This influence stems not only from variations in bilinguals' sensitivity to gender-marked distributional cues but also from their differing abilities to suppress competitors. Importantly, we emphasise that this influence cannot be solely attributed to L2 interactions. It is essential to adopt a comprehensive perspective, one that considers individual measures and their nuanced contributions to the observed disparities in L1 processing among bilingual speakers.

4.6.2 The role of language-related predictors as mediators of L1 competition

In the previous section, we highlighted the influence exerted by the L2 on the variations observed when different bilingual populations disambiguated the L1 competition process during spoken word recognition. Specifically, the three bilingual groups exhibited diverse competition dynamics towards the rhyme competitor, an effect we attributed to the participants' varying sensitivity to the grammatical gender cue located at the rhyme of the word. Previous studies have demonstrated that bilingual variability and its associated language-related factors (e.g., dominance, proficiency, language use) can moderate the competition dynamics during SWR (e.g., Bruggeman & Cutler 2019; Sarrett et al., 2022; Shin et al. 2015). Having established that different bilingual communities regulate L1 competition differently, we now delve into the role that various linguistic and non-linguistic measures of bilingual experience play in shaping the competition process in the L1.

Language proficiency has been identified as one of the most pervasive factors to modulate bilingual language processing. Specifically, in the domain of bilingual spoken word recognition, second language proficiency appears to exert a critical influence on the activation and resolution of L1 competition due to its role in modulating the bidirectional linguistic interactions within the language system (e.g., Blumenfeld & Marian, 2013; Botezatu et al., 2022; Marian et al., 2008). Previous research has indicated that highly proficient L2 bilinguals exhibit higher activation rates and more efficient competition resolution than their less proficient counterparts. Our findings demonstrate that bilinguals with higher levels of L2 proficiency report a weaker rhyme competition effect in the native language across groups, even in an L1-dominant context. For bilinguals in an L2-dominant environment, this factor holds significant importance.

Heritage speakers who started to learn English at an earlier age, alongside highly L2 proficient late bilinguals (i.e., attriters), who had also spent an extended period in the L2 environment, displayed a reduced tendency to direct their attention towards rhyme candidates when disambiguating the target spoken word (i.e., reduced rhyme competition). Considering these findings, L2 proficiency, together with context of language use, predict the bilinguals' sensitivity to the rhyme competitor during L1 spoken word recognition. Furthermore, we found that L2 proficiency and length of residence in the L2 environment were also relevant for the late bilingual speakers' modulation of the cohort competitor. Highly proficient L2 bilinguals who had extensive experience in the L2 context presented increased competition from the cohort competitor. The exhibited interchange where more L2 experience (i.e., L2 proficiency, length of residence in the L2, and early age at onset of bilingualism) appears to influence the bilinguals' L1 competition dynamics in a greater manner, corroborates our earlier interpretation on the influence of the L2 on bilinguals' within-L1 competition process.

We posit that as L2 proficiency advances in certain bilinguals, particularly in L2-immersed bilingual speakers (i.e., the attriters and heritage speakers under investigation), the connections between the lexical representations and the transparent formal cue to gender in the native language begin to weaken. This enables more pronounced L2-to-L1 interactions, exerting a stronger influence on L1 processing over time. This explanation clarifies why highly proficient bilingual speakers of L2-English, specifically those residing in an L2 context, exhibited reduced sensitivity to rhyme competitors when identifying the target spoken word.

It is crucial to note that our version of the VWP task did not involve any overt crosslinguistic competitors, and the participants performed the task entirely in Spanish. Therefore, assuming that the high levels of L2 proficiency reported in this study activated a broader range of L2 competitors, these findings provide support for the activation and interaction of L2 representations during L1 processing, even in the absence of overt phonologically matching L1-L2 competitors, aligning with the findings of Bobb and colleagues (2020).

Age at onset of bilingualism, particularly among heritage speakers, appears to interact significantly with the bilinguals' L1 competition dynamics. According to Montrul and Polinski (2019), extreme differences emerge in the native language of adult bilinguals who emigrated to an L2 context in childhood or were born in one, as in the case of heritage speakers, when compared to the L1 of late bilinguals who emigrated during adulthood. The younger the child was when they emigrated to the L2 context, combined with intense amounts of L2 exposure and fewer opportunities for the native language to develop as the dominant language, the more pronounced are the observed changes in the L1 (e.g., Flores, 2015; Polinski, 2006). Heritage speakers who acquired their heritage language first, experiencing a period of monolingualism, tend to be more proficient in that language than heritage speakers who acquired both languages simultaneously in the L2-dominant environment (e.g., Montrul, 2008).

Our results align with previous findings from the heritage language literature regarding the role of age of immigration; heritage speakers born in the L2 context or who emigrated very early in life exhibited an increased weakening of the rhyme competition effects when compared to heritage speakers exposed to the L2 later in life (around the age of 7 years old). Additionally, differences were also found between both L2-immersed heritage and late bilingual (attriter) groups in the way they manage the L1 competition process. While the late bilingual group presented a delayed activation of the rhyme competitor, which did not affect their ability to disambiguate the spoken target word as quickly as the L1-immersed bilingual speakers, the heritage speakers showed an erratic rhyme effect across the visual world task as well as a slower recognition of the spoken target word. Differences in L1 processing are anticipated between these two bilingual groups due to greater variability in L1 proficiency, age at onset of bilingualism, L1 literacy or L1 input and use among other factors, which heritage speakers tend to exhibit, impeding them from attaining native-like abilities in their L1 (Bolger & Zapata, 2011; Montrul et al., 2008; Montrul, 2016). In general, heritage speakers do not receive the same quantity and quality of L1 input during childhood as sequential bilinguals or L2-immersed late bilingual speakers who resided in an L1-dominant context during the period of language development. This difference in exposure to the L1 input is deeply interrelated with the age at which children are firstly exposed to the L2, and consequently, the context in which this trade-off of L1 and L2 social interactions occurs, facilitating a switch in linguistic dominance at the expense of their L1.

Notably, first language use and exposure did not appear to play a substantial role in regulating the competition dynamics of the bilinguals immersed in an L2-dominant environment, contrary to the Competition model (MacWhinney, 2019). Conversely, this factor was crucial for the bilinguals residing in the L1 environment, as we found that the sequential bilinguals who used the L1 more often presented stronger competition from both cohort and rhyme competitors. This is a surprising effect, given that the L1-immersed bilinguals under investigation were expected to be more exposed to the L1 than any other bilingual group. It has been suggested that bilinguals with a well-entrenched L1 form stronger connections among lexical representations from the dominant L1 in the mental lexicon (MacWhinney, 2019; Marian et al., 2008). Hence, a more frequent exposure to the dominant language might help explain the observed strengthened connections among the L1 lexical representations exhibited by the sequential bilinguals (e.g., heightened sensitivity to the distributional cue) through the increase in activation levels of both competitors. Furthermore, studies on heritage speakers have indicated that the quality of the input is as important as the quantity of the input (e.g., the richness of the vocabulary the bilingual is exposed to) (Montrul & Polinski, 2019). The quality of the input varies considerably in heritage communities, as the input they are exposed to tends to be a more restricted version than the variety that they would encounter in their L1 context (e.g., it has been proposed that many heritage children are influenced by the L1 proficiency of their parents, who might have become bilingual attriters, decreasing the quality of the input their children are exposed to). Given this, and assuming that the input the L1-immersed bilinguals are exposed to is of a better quality than the one in communities of heritage speakers or L2-immersed late bilingual speakers (also known as bilingual attriters), due to more frequent and more proficient social interactions in an L1-dominant context, we wonder whether the effect observed on the amount of L1 use in L1-immersed sequential bilinguals might not only be linked to the quantity of L1 use, which should be extensive in an L1 context, but also to the quality of the L1 input they are exposed to.

While the sequential bilinguals under investigation exhibited strong cohort and rhyme levels of activation, they were also able to fully suppress both competitors more swiftly than the other two bilingual groups. An efficient control mechanism is essential to manage the activation of multiple candidates (within-and between-language representations) and subsequent competition during bilingual spoken word recognition (Green, 1998). Previous studies investigating the modulatory role of inhibitory control have indicated that competition resolution can be particularly influenced by the individual's inhibitory control skills (e.g., Blumenfeld & Marian, 2011; 2013; Mercier et al., 2014; but see Botezatu et al., 2022). For example, Blumenfeld and Marian (2011) found that bilinguals who exhibit better non-linguistic inhibitory control are more efficient at resolving within-L1 cohort competition. Our results extend these findings to within-L1 rhyme competition in bilinguals, as we found that the sequential bilinguals who showed less interference from the non-linguistic Flanker task (i.e., better inhibition skills), also presented fewer fixations to the rhyme competitor during the visual world task.

4.7 Conclusion

In this investigation, we delved into the intricate dynamics of bilingual spoken word recognition, scrutinising the impact of various factors on the competition process within the native language. Our study encompassed three distinct bilingual populations—sequential bilinguals, late bilinguals or attriters, and heritage speakers—each exhibiting unique patterns in handling rhyme competitors and resolving lexical competition. These distinctions were rooted in their differential sensitivity to grammatical gender cues, a phenomenon deeply influenced by interactions from their second language.

Crucially, our findings underscore the pivotal role of bilingual variability as a chief modulator of L1 spoken word recognition. Sequential bilinguals, entrenched in an L1 environment, showcased robust connections between lexical representations and distributional cues, resulting in heightened rhyme competition and the swift application of efficient competition resolution mechanisms. However, even within this group, heightened L2 proficiency wielded influence, highlighting the permeability of the L1 even in L1-dominant contexts.

Late bilinguals, navigating an L2 milieu, deviated markedly from sequential bilinguals. They displayed attenuated sensitivity to transparent nominal cues, evident in delayed rhyme competition, alongside heightened cohort competition. We propose that extensive L2 influence, characterized by high levels of L2 proficiency and prolonged residence in the L2 context, potentially modified the late bilinguals' L1 processing mechanisms. Rather than relying on form-based routes, these bilinguals could have strengthened connections between lexical representations and abstract gender information, a process potentially reinforced by the influence of the L2. While these shifts in L1 competition dynamics did not markedly impact word recognition accuracy, reaction times were marginally delayed, and competition disambiguation was less efficient compared to sequential bilinguals.

The competition dynamics of heritage speakers, marked by inconsistent rhyme effects and slower recognition, present a unique case. These patterns cannot either be exclusively attributed to second language effects. Instead, they arise from a confluence of factors, including age at onset of bilingualism. Notably, heritage speakers who were introduced to English later exhibited more robust connections between nominal cues and gender information, underscoring the impact of early language exposure on L1 competence.

In conclusion, our investigation delves into the rich tapestry of factors influencing the L1 competition process in bilingual spoken word recognition. Through the analysis of individual measures and consideration of the diverse effects that can influence the permeable bilingual language system, we have corroborated the dynamic nature of bilingual spoken word recognition. This study not only expands our understanding of bilingual language processing in diverse linguistic contexts but also underscores the astonishing adaptability of the language system in the face of multifaceted bilingual experiences. As we navigate the complex spectrum of bilingual development, we hope these findings serve as a basis for future research.

5 Chapter 5: General Discussion

To better understand bilingual spoken word recognition and the role that bilingual variability and diverse linguistic and non-linguistic factors play in modulating its competition process in both first and second languages, the present project investigated how the process of spoken word recognition (SWR) at the word level varies across diverse monolingual and bilingual populations. Three studies examined the within-L1 and within-L2 competition strategies, including both cohort and rhyme competition effects, employed by different bilingual communities with varied levels of bilingual experience via the Visual World Paradigm. In Study 1, the competition dynamics of L2-immersed Spanish-English late-bilinguals (i.e., bilingual attriters) were compared to the strategies employed by Spanish monolinguals during L1 SWR and English monolinguals during L2 SWR. Building upon the findings from Study 1, Study 2 explored the discrepancies in the management of the competition process between L1-immersed L1-Spanish and L1-English sequential bilinguals during SWR across both languages. Finally, Study 3 further investigated how different degrees of bilingual experience influence the spoken word recognition process in the bilinguals' native language by assessing whether the competition dynamics employed to disambiguate the L1 competition process vary across the bilingual development spectrum.

5.1 Summary of the findings

5.1.1 Study 1

Study 1 delved into bilingual spoken word recognition in the context of first language attrition, investigating the competition dynamics employed by L2-immersed Spanish-English late bilinguals (i.e., bilingual attriters) when navigating within-L1 and within-L2 lexical competition. The results revealed that the bilinguals' L1 competition dynamics differed from those exhibited by the Spanish monolingual control group, specifically in relation to rhyme competition effects. Analogous to the English monolinguals under investigation, Spanish bilinguals demonstrated delayed activation and weaker rhyme competition during L1 SWR, diverging from the patterns observed in Spanish monolinguals. These findings were examined in relation to the Spanish grammatical gender and its gender cues localised at the rhyme of the word.

As discussed in Studies 1 and 3, in Spanish, grammatical gender information can be retrieved through transparent nominal suffixes (i.e., nouns ending in -o tend to be masculine, whereas nouns ending in -a tend to be feminine; Corbett, 1991). These canonical gender-marked cues have been demonstrated to aid gender processing during language comprehension (e.g., Caffarra & Barber, 2015; Hernández et al., 2004), and facilitate the disambiguation of lexical competition when encoded in the article preceding the target noun (e.g., *la* [f.] *casa* [f.] – *the house;* Dussias et al., 2013; Lew-Williams & Fernald, 2007). In light of these findings, a heightened sensitivity among Spanish natives to word endings has been suggested (see Caffarra & Barber, 2015).

Study 1 not only supports this hypothesised language-specific sensitivity of Spanish monolinguals to transparent endings, but also extends previous research on the role of grammatical gender during SWR. Specifically, this study introduces a novel dimension by exploring rhyme competition effects in Spanish monolinguals using bare nouns in a visual world task. The results indicate that the information from the rhyme competitor was retained for longer by the Spanish monolingual group than by the late bilinguals, implying a reliance on the rhyme for competition resolution. In contrast, English monolinguals quickly inhibited the rhyme competitor. These findings suggest that the increased rhyme competition observed in the Spanish control group may be attributed to the intricate interplay between phonological similarity and gender overlap at the rhyme of both target and rhyme items. This effect becomes apparent when examining the relationship between the rhyme competitor and the spoken target word during the visual world task of Spanish monolinguals but not in that of L2-immersed Spanish bilinguals (i.e., bilingual attriters).

A crucial observation was the variation in L1 competition dynamics employed by bilingual and monolingual Spanish speakers during L1 SWR. As mentioned earlier, L2-immersed Spanish bilinguals relied less on the information from the rhyme competitors when disambiguating the competition process in their L1. This shift in looking patterns was attributed to the prolonged influence exerted by the L2, as highly L2-proficient bilinguals who had resided in the L2-dominant environment for longer were more likely to resemble the competition resolution strategies of English monolinguals (i.e., more robust cohort competitor effects). These findings align with theoretical accounts of first language attrition (e.g., the Competition Model), wherein prolonged transfer from the L2 in an L2-dominant context can impact how L1 distributional cues (e.g., grammatical gender cues) operate during L1 processing.

Study 1 also investigated the bilinguals' competition dynamics during the L2 SWR process and compared the performance of both English-speaking groups (English monolinguals and Spanish-English bilinguals). The results showed that the bilingual group, particularly highly L2-proficient bilinguals, rapidly inhibited both English competitors without exhibiting strong cohort or rhyme effects. That is, highly proficient bilinguals did not seem to rely on either competitor to resolve the temporal ambiguity caused by the acoustic information during within-L2 competition. These results align with previous literature, supporting the role of L2 proficiency in facilitating competition resolution during L2 SWR by efficiently suppressing competitor effects (e.g., Sarrett et al., 2022).

Finally, beyond length of residence and second language proficiency, language aptitude emerges as another language-related factor that appears to play a role in modulating the Spanish natives' competition dynamics. Spanish-speakers from both groups with higher levels of language aptitude, specifically those individuals who exhibited higher scores in the sound-symbol association subtest from the LLAMA task, were more likely to fixate on the cohort competitor. These results were explained in relation to the sequential nature of the SWR process and how individuals with better skills at identifying speech sounds would promptly activate competitors that matched the target's onset.

5.1.2 Study 2

Expanding on the findings of Study 1, which revealed disparities in the resolution of lexical competition during L1 spoken word recognition (SWR) between monolingual and L2-immersed bilingual speakers (i.e., bilingual attriters), Study 2 delves deeper into these processes of within-L1 and within-L2 competition in other bilingual populations. This exploration specifically targets sequential bilingual populations—individuals who sequentially acquired both languages without immersive experiences in the second language. Employing the methodology from Study 1, Study 2 examines the competition dynamics employed by Spanish-English and English-Spanish bilingual speakers in spoken word recognition through visual world tasks. The study also investigates external factors that may influence these strategies across the two bilingual groups under investigation.

Previous studies have indicated that bilingual speakers may employ the same fundamental competition strategies to resolve the SWR process than monolingual speakers. In other words, strong cohort effects and significant, but weaker rhyme effects (Allopenna et al., 1998). However, most studies on bilingual spoken word recognition have only examined cohort competition effects (e.g., Blumenfeld & Marian, 2011; Botezatu et al., 2022; Sarret et al., 2022). The current results extend these findings as it was revealed that both sequential bilingual groups exhibited cohort and rhyme competition patterns of within-L1 competition dynamics comparable to the ones reported on monolingual speakers from the SWR literature.

As discussed in Study 2, previous research has found certain discrepancies in the way bilingual communities with diverse levels of linguistic experience employ L1 and L2 competition resolution strategies to disambiguate the process of spoken word recognition when compared to monolingual speakers of those languages. For example, Shin and colleagues demonstrated that Korean-English bilinguals immersed in an L2-dominant context since childhood presented similar competition dynamics in their L2 to the ones observed in English monolinguals. Conversely, recent studies on L2-immersed bilinguals who emigrated to the L2 context as adults have reported greater variability between monolinguals and L2-immersed bilinguals' competition dynamics (e.g., Bruggeman & Cutler, 2019).

To better understand how the process of lexical competition differs across bilinguals' first and second languages, Study 2 investigated whether the observed patterns of within-L1 competition dynamics are also employed during within-L2 competition by the same bilingual speakers as well as how these two processes (i.e., L1 vs L2 spoken word recognition) differ across bilingual groups (e.g., L1 vs L2 English speakers). The results demonstrated that the sequential bilinguals under investigation, regardless of their native language, employ similar underlying competition mechanisms to disambiguate both L1 and L2 spoken word recognition processes (i.e., stronger competition from cohort competitors than from rhyme competitors before disambiguating the competition process by selecting the target word). Notably, Study 2 replicated the robustness of the cohort and rhyme effects reported during within-L2 competition by Shin and colleagues (2015) but deviated from Bruggeman and Cutler's (2019) findings on within-language competition. Given these findings, it was argued that the differences in competition resolution found across studies could be attributed to the impact of individual differences across bilingual populations.

Regarding how both L1 and L2 spoken word recognition processes differ across L1 and L2 speakers of the same language, Study 2 evidenced that L2 speakers of both Spanish and English faced greater challenges in spoken word recognition compared to native speakers, as evidenced by higher activation rates and delayed suppression of L2 competitors and overall slower word recognition in the L2. Results align with previous studies highlighting the demanding nature of L2 spoken word recognition due to parallel activation and crosslinguistic influence (e.g., Broersma & Cutler, 2011; Mercier et al., 2014; Sarret et al., 2022; Titone et al., 2019).

Finally, three external factors influenced the L1 and L2 competition dynamics during spoken word recognition. Bilinguals with better inhibitory control skills demonstrated enhanced rhyme competition resolution in Spanish, suggesting a regulatory role of inhibitory control in spoken word recognition. In addition, proficiency levels influenced competition dynamics, with highly proficient bilinguals exhibiting more efficient resolution and reduced reliance on phonological competitors. Language use and exposure was also linked to the participants' fixation patterns, with more language use correlating with increased fixations to specific phonological competitors, emphasizing the impact of exposure on competition dynamics during word recognition.

5.1.3 Study 3

Studies 1 and 2 demonstrated that, despite employing similar fundamental mechanisms for competition resolution, diverse monolingual and bilingual communities disambiguate lexical competition in a distinct manner depending on their linguistic experience and other language and non-language-related factors. The findings reported in the previous studies offer valuable insights into the complex landscape of bilingual spoken word recognition. However, further research is needed to explore how the variability evidenced across the bilingual development spectrum influences bilingual spoken word recognition. Considering this, Study 3 investigated the influence exerted by diverse degrees of bilingual experience on the resolution of within-L1 competition during L1 spoken word recognition in bilinguals. In this study, three distinct Spanish-English bilingual populations were examined – the L2-immersed late-bilinguals (i.e., bilingual attriters) from Study 1, the L1-immersed sequential bilinguals from Study 2, and a group of heritage Spanish speakers – through a visual world task in their first language. This study aimed to explore how a range of factors, including factors associated with bilinguals' experience, language-specific predictors such as the Spanish grammatical gender cue observed in Study 1, and the impact of the L2 on the L1, contribute to modulating competition resolution in the L1 across the bilingual development spectrum. The findings were discussed in relation to Spanish grammatical gender as well as theoretical perspectives concerning the dynamic nature of the bilingual language system.

Study 3 revealed significant differences among the three bilingual populations under investigation when resolving within-L1 competition. Specifically, the three bilingual groups exhibited unique dynamics when handling rhyme competitors during the visual world task, which were attributed to their differential sensitivity to the Spanish grammatical gender cue located at the rhyme of the word. Notably, the sequential bilinguals, residing in an L1 context at the time of testing, mirror the robust rhyme effects observed in Spanish monolinguals from Study 1. In contrast, the two L2-immersed bilingual groups exhibit weaker rhyme competition, yet all bilingual populations showcase a more pronounced cohort effect compared to rhyme effects, aligning with the patterns observed in Studies 1 and 2. These inter-group differences emphasise the importance of bilingual variability in shaping L1 SWR.

Expanding upon the findings from Study 1, which linked heightened rhyme competition in Spanish monolinguals to the presence of grammatical gender cues at the rhyme of Spanish nouns, Study 3 further underscores the impact of grammatical gender on intensifying rhyme competition. This influence is observed in sequential bilinguals residing in an L1-dominant environment. Notably, this group of bilingual speakers exhibited superior performance in competition resolution compared to both L2-immersed bilingual groups, showcasing a faster ability to suppress both L1 competitors before selecting the target word. These results underscore the substantial influence of the L2 on L1 processing, particularly in bilinguals with prolonged exposure to the L2.

In this vein, L2-immersed late bilinguals (i.e., bilingual attriters) and heritage speakers displayed distinctive competition dynamics, marked by attenuated sensitivity to transparent nominal cues, resulting in delayed and inconsistent rhyme competition effects. Following the Competition model, it was suggested that as L2 proficiency increases in an L2-dominant context, connections between lexical representations and transparent formal cues in the L1 weaken, allowing greater L2-to-L1 influence.

L2 proficiency was not the only L2-related factor that played a crucial role in predicting reduced sensitivity to rhyme competitors in the bilinguals' L1 across groups. Age at onset of bilingualism, especially among heritage speakers, interacts significantly with L1 competition dynamics. Those heritage speakers exposed to the L2-dominant context earlier in life exhibited weakened rhyme effects. Differences in reaction times between L2-immersed heritage and late-bilingual (i.e., attriter) groups suggests that longer L1 exposure during childhood, as a function of age of immigration, enhances L1 proficiency, affecting L1 competition resolution.

Contrary to expectations, the frequency of L1 use and exposure did not substantially regulate L1 competition in the L2-dominant environment. However, in the L1-dominant setting, sequential bilinguals, despite extensive L1 exposure, exhibited stronger L1 competition, potentially influenced by higher-quality L1 input. Additionally, efficient inhibitory control mechanisms were crucial for competition resolution, as seen in sequential bilinguals with better inhibition skills showing less interference in rhyme competition during the visual world task. Overall, this study underscores the dynamic nature of bilingual spoken word recognition, emphasizing the nuanced influence of factors such as L2 proficiency, age at onset of bilingualism, and inhibitory control on competition resolution within the intricate bilingual language system.

5.2 Does the general influence of the second language suggest L1 attrition or adaptability?

Throughout this research project, I have substantiated the impact of bilingual variability on the competition process within the native language during bilingual spoken word recognition. In Study 1, our investigation into L1 spoken word recognition in the context of first language attrition unveiled distinctions between Spanish monolinguals and L2-immersed Spanish-English late bilinguals (i.e., bilingual attriters) in their competition resolution strategies. This divergence primarily arises from the influence that the L2 exerts on the L1. During a visual world task, Spanish monolinguals exhibited robust rhyme competition effects attributed to transparent gender cues located at the end of Spanish nouns. Conversely, the late bilingual (attriter) group, particularly highly proficient bilingual speakers immersed in the L2-dominant context for an extended period, demonstrated competition dynamics more aligned with their second language.

To further explore the effects of bilingual variability in the spoken word recognition process, we investigated how the observed findings from late bilingual-attriters in Study 1 would differ across the bilingual development spectrum. Therefore, in Study 3, we compared the results obtained from the late bilingual attriter group in Study 1 to two other L1-Spanish bilingual communities with diverse degrees of bilingual experience. Three bilingual populations – L1-immersed sequential bilinguals, L2-immersed late bilinguals or attriters and heritage speakers – exhibited distinct L1 competition dynamics, particularly in their management of rhyme competitors to resolve lexical competition. The discrepancies found among groups were ascribed to the participants' varying sensitivity to the distributional cues to grammatical gender, positioned at the end of Spanish words. Crucially, these variations in the utilisation of gender cues seem to be influenced by interactions from the second language. This influence is revealed through a combination of linguistic factors (i.e., second language proficiency, length of residence, age at onset of bilingualism and first language use) and non-linguistic cognitive factors (inhibitory control skills). A key question that remains is whether the disparities observed among these bilingual populations result from the interactive nature of the dynamic bilingual language system or if they may be attributed to L1 attrition.

The bilingual language system has long been recognised as a dynamic network where both languages interact bidirectionally across all levels of representation (Kroll et al., 2014). Thanks to the extensive research on parallel activation and cross-linguistic competition in the spoken word recognition area, models on bilingual language processing such as the BLINCS model account for this view arguing that the architecture of the language system is inherently dynamic, with bilingual variability being a crucial predictor of the modulations that occur in the bilingual system in the short or long term (Shook & Marian, 2013). From an L1 attrition perspective and in agreement with the definition provided by Schmid & Köpke (2017), any change that takes place in the native language as a consequence of the cross-linguistic activation or potential interactions from the L2 in the bilingual language system (with or without L1 disuse) can be subsumed under the general label of attrition, particularly when a pre-existing L1 pattern or mechanism is modified as a result of the influence exerted by a second language, impacting its processing. Conversely, some researchers argue that because the language system is intrinsically malleable due to the multiple factors that can influence bilinguals' language processing, changes can emerge in the language system without being solely attributed to weakening (e.g., due to language attrition), but rather to its inherent plasticity (Dussias et al., 2019).

Looking at the three groups of bilingual speakers from Study 3, our findings align with the relevance of bilingual variability as a key modulator of the L1 spoken word recognition process. The sequential bilinguals residing in an L1-environment, with a well-entrenched native language, displayed strong connections between the lexical representations and the distributional cues, resulting in high levels of rhyme competition and the application of the fastest and most efficient competition resolution mechanisms. While this group demonstrated reliable sensitivity to the distributional gender cues, higher levels of L2 proficiency appeared to influence rhyme competition levels, underscoring the permeability of the L1 even in L1-dominant contexts.

The late bilingual speakers (also named attriters), immersed in an L2 context, diverged significantly from the group of sequential bilinguals. They displayed a weaker sensitivity to the transparent nominal cues, evident in delayed rhyme competition. Moreover, this group also exhibited stronger cohort competition compared to any other bilingual group. These discrepancies in their L1 competition dynamics did not significantly impact their ability to recognise words during the visual world task, as they demonstrated high accuracy rates in the eye-tracking task. However, they showed slightly slower reaction times compared to the sequential bilinguals, as well as a less efficient disambiguation of the competition process. The sequential bilingual group was able to efficiently resolve competition around 800 ms, while the other two groups of L2-immersed bilinguals experienced cohort and rhyme effects until the

1000 ms mark. The changes observed in this group of bilinguals have been ascribed to the extensive influence of the L2 and the bidirectional interactions that take place in the dynamic linguistic system by both accounts (Dussias et al., 2019; MacWhinney, 2019; Schmid & Kökpe, 2017). The question remains: how do we distinguish between a process of language attrition and the changes that occur as a result of the permeability of the bilingual linguistic system?

According to the account proposed by Dussias and colleagues (2019), to demonstrate that changes in the L1 of L2-immersed bilinguals are not a consequence of L1 attrition, one must reveal the permeability of the linguistic system without showing effects of the weakening of L1 processing, such as the gradual loss of sensitivity. For example, in a study on attachment preferences carried out by Dussias and Sagarra (2007), a group of L1 Spanish-L2 English bilinguals immersed for an extended period of time in an L2 context employed attachment preferences associated with the L2 when reading in the native language, in contrast to a group of L1-immersed bilinguals. Although the L2-immersed bilinguals (i.e., bilingual attriters) adopted the L2 processing mechanisms, their reading times and comprehension in the L1 were not affected by this modification, which the authors attributed to the high adaptability of the linguistic system to diverse contexts of language use and the influence of the L2 on the L1.

According to this interpretation, the results from the late-bilingual speakers under investigation should not be assumed as a clear-cut example of L1 attrition, but a result of the malleability of the language system to the vast influence of the L2 in an L2-dominant context, akin to Dussias and Sagarra's (2007) findings. The present results suggest that both groups easily identified the target spoken words despite the differences reported in their management of the competition process. Hence, the reported reduced sensitivity to the distributional L1 cues to access gender did not appear to significantly weaken the spoken word recognition process of the late bilinguals' native language, corroborating the adaptability of the L1 to the influence of the L2 in the bilingual language system.

According to Schmid and Köpke (2017), and contrary to the restrictive view of attrition as a permanently irreversible phenomenon, the impact of L1 attrition in the bilingual language system can manifest at any stage of development throughout the bilingual continuum, without a clear way of establishing whether the observed changes will lead to permanent restructuring or transient effects due to the influence of the L2 on the L1. If the process of L1 attrition is understood as a consequence of the influence exerted by extensive L2 exposure on the permeable L1, which may lead to modifications of pre-existing L1 patterns, we can attribute some of the discrepancies observed in the late bilingual group to this process.

For example, the differences found in how late (i.e., attriter) and sequential bilinguals manage the L1 competition process could also be attributed to the weakened distributional L1 cues, as the L2-immersed late bilinguals exhibit a less efficient competition resolution mechanism. According to the Competition model, lower L1 frequency and extensive influence from the L2 could have impacted the reliability of the cue in the bilinguals' language system, leading to a reduction in the cue's strength. While we cannot account for the weakening of cue reliability among the late bilinguals due to lower levels of L1 use, as this factor did not provide conclusive results for either the late bilingual or heritage speaker groups (see Opitz, 2019, for a review on variables in L1 attrition), we can consider how the robust influence of the L2 can impact the L1 in an L2-dominant context where the permeable L1 is more at risk of being modified than in an L1-dominant context. MacWhinney (2019) proposes that as bilinguals become more exposed to the L2 on a frequent basis, the interactions from the L2 can impact the L1 via partial mergers. These mergers have been observed in some areas, such as syntactic structure (e.g., Dussias & Sagarra, 2007) or the lexicon (Malt et al., 2015). Considering this, it is equally plausible that the L1 competition dynamics of the late bilinguals could have been extensively modified when compared to the dynamics of the sequential bilinguals, as a consequence of the impact of the L2 on the L1 via the permeability of the native language or the process of L1 attrition.

If we recall from Study 3, highly English-proficient sequential bilinguals displayed weaker competition towards the rhyme competitor, which we attribute to the influence of the L2. However, they did not exhibit the levels of inhibition towards the rhyme competitors presented by the late-bilingual speakers. We propose that the levels of competition variation reported by the late-bilingual speakers could be attributed to extensive influence from the L2, via high levels of L2 proficiency and extensive length of residence in the L2 context, on a *disentrenched* native language. This could have led to the hypothesised lack of sensitivity to the distributional cues that aid the retrieval of gender information through the transparent nominal suffixes. As English lacks grammatical gender or transparent gender cues localised at the rhyme of the noun, its influence could have altered the way in which late bilinguals rely on the rhyme of the word to access gender information, without deteriorating their native language as reported through the average reaction times and accuracy rates. We suggest that instead of using the form-based route to access gender information through the phonologically transparent nominal suffixes, which would have increased their L1 rhyme competition as in the case of the sequential bilinguals, the late bilinguals could have displayed a more robust use of the lexical route via the strengthening of the connections between the lexical representations and the abstract gender information. This strengthening of the connections to access gender through the lexical route could have been reinforced by the influence of the L2, as even though English is not a functional gendered language, it may need to employ this lexical route to access the gender of certain words (e.g., certain animals such as *cow* and *bull*).

Turning to the heritage speakers' L1 competition dynamics and their effortful competition resolution during the visual world task, we argue that their inconsistent rhyme effects combined with their slow recognition of the target spoken words, when compared to the other two bilingual groups, cannot be solely attributed to the effects of the second language on the first. As previously discussed in Study 3, heritage speakers often present variable linguistic abilities in their native language due to several language-related factors, including age at onset of bilingualism. Those heritage speakers who were not exposed to English until the age of 7 were more likely to pay attention to the rhyme competitor before recognising the target word. According to previous research, sequential bilingual children are more likely to exhibit higher linguistic abilities in their heritage language, which in this study could be translated to stronger L1 connections between the nominal cues and the gender information at the mental lexicon via a stronger rhyme competition. In agreement with the Competition model, the heritage speakers under investigation were more at risk of exhibiting a deterioration of the L1 gender cues, as it has been previously observed in other studies investigating gender marking in this bilingual group (e.g., Montrul et al., 2008; Polinski, 2008).

In summary, addressing the initial question posed at the outset of this section - whether the observed discrepancies in the studied bilinguals, particularly the L2-immersed late bilinguals (also known as attriters), primarily reflect the dynamic, interactive nature of the bilingual language system or could also be attributed to first language attrition - depends on our interpretation of attrition itself. Understanding whether these shifts constitute attrition or adaptation hinges on our interpretation of attrition itself. If we narrowly define language attrition as the gradual deterioration of L1 functions, then the observed changes may not align precisely with this definition. However, if we conceive of attrition more broadly as a dynamic process wherein the L1 undergoes frequent modifications, irrespective of the degree of adaptation to the language system, then the current findings represent a complex interplay between language attrition, the permeability of the L1, and the adaptability of the language system to extensive L2 influence. This nuanced perspective sheds light on the intricate mechanisms underlying bilingual language processing, emphasising the importance of considering both attrition and adaptability of the architecture of the language system as complementary forces shaping the bilingual experience.

5.3 The Spoken Word Recognition process and bilingual variability

Across the three studies presented, a remarkable consistency emerges: bilingual speakers, regardless of their level of bilingual experience, consistently demonstrated similar cohort effects when resolving competition during L1 and L2 spoken word recognition, revealing a shared tendency among bilinguals to direct more attention towards cohort competitors in comparison to rhyme or unrelated candidates. The observed bias in bilingual speakers aligns with theoretical models of monolingual spoken word recognition (e.g., Marslen-Wilson, 1987; McClelland & Elman, 1986), which predict that cohort competitors are activated earlier and more strongly than rhyme competitors due to the linear nature of the spoken word recognition process. This consistent cohort effect has been extensively reported in the literature across monolingual and bilingual populations alike (Allopenna et al., 1998; Blumenfeld & Marian, 2011; Marian & Spivey, 2003a), suggesting that both monolingual and bilingual speakers employ similar mechanisms to resolve within-language competition during auditory word comprehension.

The findings provided in this research project extend this argument. The pervasive cohort effect manifested across the populations under investigation underscores the universality of the underlying mechanisms of activation and competition utilised by both monolingual and bilingual speakers during the competition resolution process. Participants consistently exhibited a robust cohort effect followed by a weaker rhyme effect, regardless of their native language (Spanish or English), their linguistic experience (monolingual or bilingual speakers) or the language in which they performed the task (L1 or L2). However, Studies 1, 2 and 3 aimed to explore not only the presence of these mechanisms during L1 and L2 spoken word recognition in bilinguals, but also the varying degrees of activation and competition witnessed across the bilingual development spectrum by investigating a wider competitor set, namely rhyme competitors.

Having established the consistent cohort effects, let us now delve into the relatively unexplored realm of rhyme competition in bilingual spoken word recognition. As discussed in Studies 2 and 3, very few studies have investigated rhyme competition in bilinguals when compared to the extensive research on cohort competition. While evidence from cohort studies has revealed differences between bilinguals and monolinguals in resolving within-L1 competition due to the influence exerted by parallel co-activation (Marian & Spivey, 2003a), and linguistic and non-linguistic factors such as L2 proficiency (Blumenfeld & Marian, 2013; Botezatu et al., 2022), cognitive control (Blumenfeld & Marian, 2011; Mercier et al., 2014) or age of acquisition (Canseco-Gonzalez et al., 2010), the role of rhyme competitors in the bilingual competition process remains inconclusive (e.g., Ben-David et al., 2011; but see Bruggeman & Cutler, 2019; Shin et al., 2015).

To better understand the role that rhyme competitors play in this process, the present research project employed a version of the visual world paradigm that included not only competitors matching the onset of the target word, but also candidates that overlapped at the rhyme. By investigating rhyme competition effects and how these candidates impact competition resolution during the spoken word recognition process in diverse bilingual speakers, the studies presented here demonstrate that the extent and intensity of rhyme activation and competition appear to be dynamic factors influenced by the intricate interplay of linguistic experiences, language-specific characteristics, and individual differences within each bilingual population.

As revealed across the three studies, bilingual populations exhibited distinct L1 competition resolution dynamics, indicating differences in their management of rhyme competitors with Spanish monolingual speakers (Study 1) and across the bilingual continuum (i.e., the spectrum of bilingual experiences under investigation) (Study 3). Previous studies have shown that monolingual and bilingual native speakers of Spanish, who are dominant in their L1, demonstrate a characteristic sensitivity to gender-marked transparent word endings during L1 processing (Caffarra & Barber, 2015; Caffarra et al., 2017). This sensitivity was replicated in Study 1 during a visual world task in Spanish where Spanish monolinguals exhibited stronger rhyme competition than their L2-immersed late bilingual (i.e., attriter) counterparts when disambiguating the competition process. Notably, Study 3 revealed that only L1-immersed Spanish sequential-bilinguals presented a robust rhyme effect when compared to two other bilingual groups of L2-immersed Spanish bilingual speakers (late-bilinguals or attriters and heritage speakers).

The reported differences across speakers were attributed to differences in bilingual experience and the diverse effects of a non-gendered L2 on the bilinguals' linguistic system. By investigating the impact of rhyme competition across diverse groups of bilingual speakers, an inverse relationship between the influence of L2-English and the rhyme competition effect in L1-Spanish was demonstrated. As the results reported across studies indicate, the intensity of these L2 effects on the bilinguals' L1 competition dynamics was mainly characterised by the linguistic environment they were immersed in – as L1-immersed bilinguals were more likely to exhibit strong rhyme effects in Spanish than L2-immersed bilingual populations – and the participants' levels of L2 exposure – those L2-immersed late bilinguals (i.e., attriters) who resided for longer in the L2-dominant context, as well as those heritage speakers who were in contact with the English language from a younger age, exhibited less L1 rhyme competition. Additionally, L2 proficiency was another factor that consistently modulated the bilinguals' competition dynamics across studies. Throughout the research project, highly proficient English-speaking bilinguals were less prone to fixate on the rhyme competitors and, in some cases, were more prone to look at the cohort competitors (e.g., late bilingual speakers in Study 1).

By considering *bilingualism* as a multifaceted community that includes a wide range of populations with complex bilingual experiences, we have been able to capture the nuanced effects of these experiences on bilingual spoken word recognition (e.g., via discrepancies in L1 competition resolution dynamics across bilingual populations). This approach enhances our understanding of how bilingual variability can be leveraged to better comprehend the dynamic bilingual linguistic system and its processes.

As reviewed in Chapter 1, treating bilingualism as a continuous measure - a spectrum or continuum of bilingual experiences – enables us to identify predictors that influence bilingual individuals to different extents, such as age of acquisition, linguistic environment, L1 and L2 proficiency, or linguistic exposure. In turn, these predictors can provide valuable information helping position bilingual individuals along this continuum. For instance, regarding current linguistic environment and language exposure, both L2-immersed bilingual groups under investigation would be closer to each other on the continuum, as they were more influenced by L2 effects than the L1-immersed sequential bilinguals. However, when considering the first language, due to similar ages of L2 acquisition and linguistic context during the developmental stages of the L1, the L1-immersed sequential bilinguals and L2-immersed late bilinguals (also known as attriters) would appear closer on the spectrum as both groups would have been exposed to the L1 for longer during childhood, possibly influencing their ability to recognise words (i.e., both groups present better accuracy scores than the heritage speakers).

This complex, multidimensional bilingual continuum cannot be fully accounted for by the results of a single research project. Nevertheless, future research should embrace this complexity, treating bilingual individuals as part of a heterogeneous continuum rather than a homogeneous community (e.g., de Bruin, 2019; Voits, de Luca, & Abutalebi, 2022). By adopting this perspective, we can gain a more nuanced view of how bilingual variability truly affects spoken word recognition and further our understanding of the bilingual linguistic system and its dynamic architecture.

In essence, while the core SWR mechanisms remain constant, the nuanced manifestation of rhyme competition reflects unique linguistic patterns that characterise the adaptability of the bilingual linguistic system across populations. The question now is how these varying L1 rhyme effects align with previous theoretical accounts of SWR?

From a spoken word recognition framework, these results align with the arguments posed by the BLINCS model (Shook & Marian, 2013) on the interactivity of the bilingual SWR process. First, the interactive architecture of this model accounts for the consistent rhyme competition effects observed in L1-immersed Spanish native speakers, which were attributed to the speakers' sensitivity to the grammatical gender cues in Spanish. As discussed previously, the model was developed as a network of interconnected SOMs, which interact bidirectionally, spreading information across the four levels of representation (i.e., phonological, phono-lexical, ortho-lexical and semantic). Given this, not only words that are phonologically similar may be co-activated, but also words that are semantically or orthographically associated can become active. For example, according to the model's simulation with Spanish and English stimuli, the phono-lexical representation of *arena* "sand" activates the Spanish candidates *ballena* "whale" and *playa* "beach". Following the model's proposed interactive activation mechanism, both rhyme competitors overlap phonetically, orthographically, or semantically to some extent with the Spanish target word. What's more, the co-activated candidates selected by the model simulation also share the grammatical gender with the target word. This connection between word endings and the Spanish grammatical gender has been previously observed in the research literature.

Spanish grammatical gender is strongly associated with transparent nominal suffixes, as these are informative of the gender of the noun. According to Harris (1991), 96% of Spanish nouns ending in -a are of feminine gender, and 99% of Spanish nouns ending in -o are of masculine gender. This morphosyntactic cue has been shown to facilitate competition resolution during spoken word recognition when predicted by a gender-marked prenominal determiner (e.g., *la* (fem.sing) *casa* (fem.sing) "the house"; Dahan et al. 2000; Gussow et al., 2019). Additionally, Spanish nominal endings have been reported to aid speakers in gender processing (Gollan & Frost, 2001; Hernández et al., 2004; Pérez-Pereira, 1991). How can BLINCS account for this link between the Spanish grammatical gender cue localised at the end of the word and the spoken word recognition process?

If we recall the model's organisational framework, the phono-lexical and ortho-lexical levels of representation are semi-integrated networks where each language is separated by clusters of words. By clustering words as a function of linguistic proximity, BLINCS can account for language-specific localised patterns of activation (e.g., transparent grammatical gender cues). For example, phono-lexical representations belonging to one cluster are directly mapped onto the orthographic map of that same cluster, strengthening the within-language connection across levels in a bidirectional manner. Building upon this argument, a phono-lexical representation like *sopa* "soup" could be clustered around other feminine gender-marked items like *ropa* “clothes” or *tumba* “grave” due to their phonological and/or orthographical association at the rhyme, which can act as a cue to access gender (see Figure 14 in Shook & Marian, 2013 for more examples). According to the authors, the continuous activation of the overlapping patterns will “teach” the learning mechanism implemented in BLINCS about this ongoing association of word endings, strengthening its activation across levels. For example, by modulating the activation of rhyme competitors due to the interplay of overlapping phonological and gender-marked information that seems to influence lexical access in dominant L1-Spanish monolingual and bilingual speakers during spoken word recognition. The present findings support this theoretical argumentation, suggesting that grammatical gender cues in Spanish can be employed as a cue for lexical access and gender processing, influencing the rhyme activation patterns during the spoken word recognition process by means of reinforcing the gender-marked information located at the Spanish nominal suffixes across the phono-lexical and ortho-lexical levels of representation.

The observed discrepancies in rhyme competition between L1- and L2-immersed Spanish native speakers, which were attributed to the participants’ varying sensitivity to grammatical gender cues due to the effects of the L2, can also be explained through BLINCS’ interactive architecture. As discussed previously, BLINCS posits that the mechanisms of speech comprehension are subject to the influence of multilingual experience (both long- and short-term factors) due to the dynamic nature of the bilingual linguistic system. In addition, BLINCS’ interactive organisation successfully predicts bidirectional cross-linguistic interactions across levels of representation, including the co-activation of within and between-language cohort and rhyme competitors.

As reviewed in Study 3, extensive evidence from the bilingual spoken word recognition area has demonstrated how the bilingual language system can be influenced by parallel activation and cross-linguistic competition effects, particularly from a focus on cohort competitors, from the language not in use. The present findings corroborate the impact that L2-related factors can have on the activation and competition of L1 patterns in the bilinguals' linguistic system and account for the modulatory role of bilingual variability in SWR via the exploration of a wide competitor set across the bilingual development spectrum. Moreover, the observed variability in competition resolution and strong influence of L2 effects on L1 competition dynamics across the bilingual development spectrum reported throughout this research project strongly support not only the plasticity of the bilinguals' linguistic system, but also the dynamicity of the spoken word recognition process, as we also found how language-specific features like Spanish natives' sensitivity to gender-marked nominal suffixes can modulate their activation of rhyme competitors across the bilingual continuum.

5.4 Limitations and suggestions for future research

The present research project explored the intricate competition dynamics of bilingual spoken word recognition across the bilingual development spectrum, shedding light on the impact of various linguistic and non-linguistic factors from a holistic approach. Building upon the findings from the three conducted studies, several avenues for future research are proposed to deepen our understanding of the nuanced interplay between bilingualism and the process of spoken word recognition:

First, the sensitivity observed in L1-immersed Spanish native speakers to nominal endings prompts further exploration into what language-specific mechanisms influence this process (e.g., Kapnoula et al., 2024). Future research could investigate whether listeners develop competition resolution preferences based on their native language, as exemplified by the heightened sensitivity to rhyme competition in Spanish natives due to relevant morphosyntactic cues localised at the end of Spanish words (e.g., grammatical gender).

Additionally, the influence of diverse L2 experiences (e.g., immersion in an L2 dominant environment, age of L2 acquisition, language use or language proficiency) on L1 spoken word recognition across bilingual populations offers a promising avenue for research. Understanding how specific features of the L1 can be influenced by the L2, even in the absence of direct L1-L2 competition, provides valuable insights. Further research should delve into the mechanisms underlying spoken word recognition in bilinguals and the principles governing this process for a better understanding of this research field. Furthermore, longitudinal studies should be conducted in the future to track the development of bilingual spoken word recognition over time to explore how changes in language proficiency, exposure and the use of both languages contribute to the evolution of, for example, competition dynamics across the bilingual continuum. This could provide insights into the long-term adaptability of the bilingual language system.

Overall, this research project sheds light on various theoretical and empirical aspects within the domain of bilingual spoken word recognition and suggests promising avenues for future investigation. Nevertheless, the findings are subject to certain limitations that demand careful consideration and attention.

As reported in Study 1, Spanish monolingual speakers exhibited slower reaction times and lower accuracy in identifying the target word during the visual world task in Spanish compared to their bilingual counterparts. While Spanish bilinguals correctly identified an average 90% of the target items, Spanish monolinguals reported an average accuracy of 70%.

To account for these findings, a follow-up experiment manipulating the presence of background noise was conducted on 15 of the Spanish monolinguals under investigation. The decision to investigate background noise as a possible factor impacting overall accuracy and response speed was based on previous literature on the effects of speech distortion in auditory language processing. Previous studies using the VWP have reported that in poor listening conditions where the speech signal becomes less reliable, participants may be less certain of the spoken target word that has been heard. As exemplified by McQueen and Huettig (2011), during a visual world task with presence of noise, a participant is presented with a visual array including the pictures of a *beaker* (target), a *beetle* (cohort competitor) and a *speaker* (rhyme competitor). When listening to the spoken target word *beaker*, the participant might be less certain that they have heard *beaker*, weakening support for the competition of *beetle*, but increasing it for the competition of *speaker* as the participant may be less certain that they have not heard the rhyme candidate. McQueen and Huettig (2011) tested this prediction by manipulating the presence or absence of noise in a VWP study with Dutch listeners. In the baseline condition with absence of noise, the participants' performance aligned with previous studies (e.g., Allopenna et al., 1998) by looking more at cohort competitors (e.g., looking at a picture of a *crocodile*, "*krokodil*", as they heard "*krokus*"), than at rhyme competitors (e.g., looking at a picture of a *hammer* "*hamer*" while they heard "*kamer*"). Conversely, when presented with intermittent AM radio noises, the strength of this tendency varied. While participants exhibited stronger cohort than rhyme effects, the tendency to look at the cohort competitor was weaker, exhibiting in turn a stronger rhyme competition than in the baseline condition.

Given these findings, it could be argued that the background noise employed in the visual world tasks in this research project could have impacted the participants' confidence on the spoken word they had heard, influencing their accuracy scores and competition resolution strategies (i.e., cohort and rhyme effects). However, the findings reported in this research project challenge this notion.

Firstly, the visual world experiments conducted in this project employed auditory stimuli that was standardised to an intensity level of 60 dB and merged with white noise (62 dB), resulting in a speech-to-noise-ratio of -2 dB. This approach, standardised by Botezatu and colleagues (2022), aimed to slightly challenge word recognition without encountering comprehension difficulties, as demonstrated during the piloting of the experimental tasks (see Appendix 4 for more information on the pilot study).

Regarding results from the follow-up experiment previously mentioned, Spanish monolinguals in the quiet condition exhibited similar cohort and rhyme effects to those reported in the presence of background noise. While accuracy rates improved considerably (92%), reaction times were comparable to those recorded in the noisy condition. These results suggest that Spanish monolingual participants were more certain of the critical word being heard in the quiet condition, however, the current findings do not support the idea that background noise influenced the participants' competition dynamics (i.e., the looks to the cohort and rhyme competitors).

Considering the findings reported from the Spanish bilingual and English monolingual speakers in Study 1, who consistently exhibited robust cohort effects and significantly weaker rhyme effects, it is less likely that background noise influenced the competition dynamics of the participants under study. If that were the case, the three populations in Study 1 would demonstrate a fixation tendency to competitors similar to McQueen and Huettig's (2011) report in the noise condition, with comparable accuracy rates to Spanish monolinguals. However, Spanish bilinguals and English monolinguals' accuracy scores during the visual world task in their respective L1s reached an average 90% correct answers, far outscoring the Spanish monolingual group.

Nevertheless, a link between Spanish monolinguals' accuracy rates and the experimental condition with the presence of background noise seems evident. A similar finding was reported in Study 3, where L1-Spanish sequential bilinguals exhibited the fastest reaction times when recognising spoken words in the visual world task in their L1, but the lowest accuracy rates among the three groups (i.e., 75% accuracy compared to 80% and 90% for heritage speakers and L2-immersed late bilinguals or bilingual attriters, respectively). A clear explanation for the behaviour observed in Spanish monolinguals from Study 1 and Spanish sequential bilinguals from Study 3 cannot be provided with the data reported in this research project. Further investigation is needed to understand the observed discrepancies in accuracy rates, particularly for monolingual and sequential bilingual Spanish speakers.

5.5 Conclusion

This research project embarked on a comprehensive exploration of bilingual spoken word recognition, scrutinising the intricacies of competition dynamics within both the first and second languages across diverse monolingual and bilingual populations. The three studies undertaken collectively provide key perspectives into the nuanced landscape of lexical competition resolution in bilingual spoken word recognition.

In Study 1, the investigation into L2-immersed Spanish-English late bilinguals (also known as bilingual attriters) revealed distinct L1 competition dynamics from the ones observed in Spanish monolinguals marked by the influence of first language attrition. The observed shifts in competition mechanisms aligned more closely with their second language, indicating a complex interplay between L1 and L2 influences. This study significantly contributes to our understanding of how prolonged exposure to an L2-dominant environment, among other factors, can impact the delicate balance of the mechanisms of SWR in the first language. Additionally, Study 1 extended previous findings on the role of grammatical gender during SWR as it demonstrated how Spanish monolinguals exhibit a language-specific sensitivity to nominal endings via the investigation of bare nouns in the VWP.

Study 2 explored lexical competition dynamics among sequential bilinguals, uncovering similar competition mechanisms within both L1 and L2 spoken word recognition processes via the investigation of cohort and rhyme competition effects. The findings emphasised the challenges faced by L2 speakers during L2 SWR, highlighting the influence of individual differences in inhibitory control, proficiency levels, and language use on competition dynamics. This study enriches our comprehension of the intricate interplay of factors shaping within-L1 and within-L2 competition in L1-dominant environments.

In Study 3, the focus shifted to the influence of diverse degrees of bilingual experience on within-L1 competition. The three distinct bilingual populations—sequential bilinguals, L2-immersed late bilinguals (i.e., attriters), and heritage speakers—exhibited unique patterns in handling rhyme competitors, showcasing the substantial impact of bilingual variability on L1 spoken word recognition. This study contributes to the growing body of literature on the adaptability of the bilingual language system in response to varied linguistic experiences.

Collectively, the findings from these studies underscore the dynamic nature of bilingual spoken word recognition, revealing the influences of diverse bilingual experiences across the bilingual continuum on competition resolution mechanisms. The variations observed in competition dynamics across diverse bilingual populations emphasise the need for a comprehensive understanding of the bilingual language system. The research presented here not only expands our knowledge of bilingual language processing but also provides a foundation for future investigations into the complexities of bilingual development in the field of spoken word recognition.

6 Appendices

6.1 Appendix 1: Sociolinguistic and Personal Background Questionnaire (SPBQ).

A. Version of the questionnaire for L2-immersed Spanish-English late bilinguals (i.e., bilingual attriters).

1. Please, write your name and surname

2. What is your date of birth?

3. What is your gender?

4. Where were you born? Please give the name of the village/town/city and country.

5. What is (are) your mother tongue?

6. What is the highest level of education you have completed?

7. If you have done a university degree, in which year are you?

8. If you have done a university degree, what degree have you studied?

9. What do you do for a living?

10. When did you come to the UK?

11. Have you ever lived in another country, other than the UK and your country of birth?

12. If you've indicated that you have lived in another country, please say here which country that was.

13. What language(s) did you acquire before starting school?

14. If you marked "other", please specify the language(s) here.

15. Did you attend any English classes before coming to the UK?

16. What language or languages did you learn professionally or at school?

17. What language or languages did you learn outside of an educational environment?

18. Have you ever been back to your home country since leaving for the UK?

19. In general, how would you rate your English language proficiency before you came to the UK?

20. In general, how would you rate your English language proficiency at present?

21. In general, how would you rate your Spanish language proficiency before you came to the UK?

22. In general, how would you rate your Spanish language proficiency at present?

23. How often do you speak Spanish?

24. Do you consider it important to maintain your Spanish?

25. In general, do you have more Spanish-or English-speaking friends in the UK?

26. Do you feel more at home with British or with your home culture?

27. Are you in frequent contact with relatives and friends from your country?

28. Do you ever watch Spanish television programmes?

29. Do you ever read Spanish newspapers, books or magazines?

30. Do you feel more comfortable speaking Spanish or English?

31. Could you, please, indicate to what extent you use Spanish in the domains provided? You may simply tick the box below:

1. All the time
2. Frequently
3. Sometimes
4. Rarely
5. Very rarely

	1	2	3	4	5
With relatives					
With friends					
To pets					
At work					

32. Could you, please, indicate to what extent you use English in the domains provided? You may simply tick the box below:

1. All the time
2. Frequently
3. Sometimes
4. Rarely
5. Very rarely

	1	2	3	4	5
With relatives					
With friends					
To pets					
At work					

33. Could you, please, indicate to what extent you use Spanish in the domains provided? You may simply tick the box below:

1. All the time (daily)
2. Very frequently (once/twice a week)
3. Frequently (once/twice a month)
4. Rarely (once/twice a year)
5. Very rarely-Never

		1	2	3	4	5
I watch Spanish and/or English-speaking tv programmes/series/films/youtube-channels/etc in Spanish (including any online platform -i.e., Netflix-).	◉	○	○	○	○	○
I watch Spanish and/or English-speaking tv programmes/series/films/youtube-channels/etc in English with Spanish subtitles (including any online platform -e.g. Netflix-).	◉	○	○	○	○	○
I listen to Spanish-speaking radio programmes/songs/podcasts/audiobooks/etc.	◉	○	○	○	○	○
I read newspapers/books/magazines/webpages/etc in Spanish.	◉	○	○	○	○	○
I access webpages/social media sites/etc in Spanish.	◉	○	○	○	○	○
I write essays/articles/letters/emails/WhatsApp texts/messages/in my social media/etc in Spanish (including any written action, for example, your shopping list).	◉	○	○	○	○	○

34. Could you, please, indicate to what extent you use English in the domains provided? You may simply tick the box below:

1. All the time (daily)
2. Very frequently (once/twice a week)
3. Frequently (once/twice a month)
4. Rarely (once/twice a year)

5. Very rarely-Never

	1	2	3	4	5
I watch Spanish and/or English-speaking tv programmes/series/films/youtube-channels/etc in English (including any online platform -e.g. Netflix-).					
I listen to English-speaking radio programmes/songs/podcasts/audiobooks/etc.					
I read newspapers/books/magazines/etc in English.					
I access webpages/social media sites/etc in English.					
I write essays/articles/letters/emails/WhatsApp texts/messages/in my social media/etc in English (including any written action, for example, your shopping list).					

35. You have come to the end of this questionnaire. Is there anything you would like to add?

This can be anything from language-related comments to remarks about the questionnaire.

B. Version of the questionnaire for L1-immersed sequential bilinguals.

1. Please, write your name and surname

2. What is your date of birth?

3. What is your gender?

4. Where were you born? Please give the name of the village/town/city and country.

5. What is (are) your mother tongue?

6. What is the highest level of education you have completed?

7. If you have done a university degree, in which year are you?

8. If you have done a university degree, what degree have you studied?

9. What do you do for a living?

10. Have you ever lived in another country, other than your country of birth?

11. If you've indicated that you have lived in another country, please, say here which country that was, and for how long.

12. What language(s) did you acquire before starting school?

13. If you marked "other", please specify the language(s) here and for how long.

14. What language or languages did you learn professionally or at school? How old were you when you started to learn that language(s)? How long did you study that language(s) for?

15. What language or languages did you learn outside of an educational environment? (If any) How old were you when you started to learn that language(s)? For how long?

16. In general, how would you rate your English language proficiency at present?

17. In general, how would you rate your Spanish language proficiency at present?

18. Do you feel more comfortable speaking Spanish or English?

19. Could you elaborate on your answer: why do you feel more comfortable speaking either Spanish or English or why you do not have any preferences?

20. Could you, please, indicate to what extent you use Spanish in the domains provided? You may simply tick the box below:

1. All the time
2. Frequently
3. Sometimes
4. Rarely
5. Very rarely

		1	2	3	4	5
With relatives	◉	○	○	○	○	○
With friends	◉	○	○	○	○	○
To pets	◉	○	○	○	○	○
At work	◉	○	○	○	○	○

21. Could you, please, indicate to what extent you use English in the domains provided? You may simply tick the box below:

1. All the time
2. Frequently
3. Sometimes
4. Rarely
5. Very rarely

		1	2	3	4	5
With relatives	◉	○	○	○	○	○
With friends	◉	○	○	○	○	○
To pets	◉	○	○	○	○	○
At work	◉	○	○	○	○	○

22. Could you, please, indicate to what extent you use Spanish in the domains provided? You may simply tick the box below:

1. All the time (daily)
2. Very frequently (once/twice a week)
3. Frequently (once/twice a month)
4. Rarely (once/twice a year)
5. Very rarely-Never

	1	2	3	4	5
I watch Spanish and/or English-speaking tv programmes/series/films/youtube-channels/etc in Spanish (including any online platform -i.e., Netflix-).					
I watch Spanish and/or English-speaking tv programmes/series/films/youtube-channels/etc in English with Spanish subtitles (including any online platform -e.g. Netflix-).					
I listen to Spanish-speaking radio programmes/songs/podcasts/audiobooks/etc.					
I read newspapers/books/magazines/webpages/etc in Spanish.					
I access webpages/social media sites/etc in Spanish.					
I write essays/articles/letters/emails/WhatsApp texts/messages/in my social media/etc in Spanish (including any written action, for example, your shopping list).					

23. Could you, please, indicate to what extent you use English in the domains provided? You may simply tick the box below:

1. All the time (daily)
2. Very frequently (once/twice a week)
3. Frequently (once/twice a month)
4. Rarely (once/twice a year)
5. Very rarely-Never

	1	2	3	4	5
I watch Spanish and/or English-speaking tv programmes/series/films/youtube-channels/etc in English (including any online platform -e.g. Netflix-).					
I listen to English-speaking radio programmes/songs/podcasts/audiobooks/etc.					
I read newspapers/books/magazines/etc in English.					
I access webpages/social media sites/etc in English.					
I write essays/articles/letters/emails/WhatsApp texts/messages/in my social media/etc in English (including any written action, for example, your shopping list).					

24. You have come to the end of this questionnaire. Is there anything you would like to add? This can be anything from language-related comments to remarks about the questionnaire.

C. Version of the questionnaire for Heritage Speakers of Spanish.

1. Please, write your name and surname

2. What is your date of birth?

3. What is your gender?

4. Where were you born? Please give the name of the village/town/city and country.

5. Have you ever lived in a country other than the UK?

6. If you've indicated that you have lived in another country, please, state here which country that was, and for how long (years).

7. What is (are) your mother tongue?

8. What is the highest level of education you have completed?

9. If you have done a university degree, in which year are you?

10. If you have done a university degree, what degree have you studied?

11. What do you do for a living?

12. What language(s) did you acquire before starting school?

13. If you marked "other", please specify the language(s) here and for how long you learnt those languages (years).

14. If you think about your language environment when you were a child (this means the languages you have been exposed to since you were little), what languages would it be? Please, write down a sentence or two for each language explaining how the exposure to that language in your life was.

15. What language or languages did you learn professionally or at school?

16. Following the earlier questions, please, list all the languages you can speak and understand including English, in order of fluency. Please, also answer the following questions for each language as follows:

1. Language: English - Where did you learn it? : at home / at school - At what age did you learn it?: from birth - Were there any periods in your life when you did not use this language? Indicate duration in months/years: NA

17. In general, how would you rate your English language proficiency at present?

18. In general, how would you rate your Spanish language proficiency at present?

19. Do you feel more comfortable speaking Spanish or English?

20. Could you elaborate on your answer: why do you feel more comfortable speaking either Spanish or English or why you do not have any preferences?

21. Please indicate which language(s) you most frequently heard or used in the following life stages, both inside and outside the home.

1. All English
2. Mostly English

3. Half English – Half Spanish

4. Mostly Spanish

5. Only Spanish

	1	2	3	4	5
Infancy					
Preschool age					
Primary school age					
High school age					
Adulthood					

22. Please indicate which language(s) you generally use when speaking to the following people:

1. All English

2. Mostly English

3. Half English – Half Spanish

4. Mostly Spanish

5. Only Spanish

	1	2	3	4	5
Parents					
Siblings					
Grandparents					
Other relatives					
Partner					
Roomate(s)					
Neighbours					
Friends					
With colleagues at work					
With colleagues at university					
To pets					

23. Please indicate which language(s) you generally use when speaking to the following people:

1. All English

2. Mostly English

3. Half English – Half Spanish

4. Mostly Spanish

5. Only Spanish

		1	2	3	4	5
Home	◉	○	○	○	○	○
School	◉	○	○	○	○	○
Work	◉	○	○	○	○	○
Social activities (e.g. hanging out with friends, movies)	◉	○	○	○	○	○
Religious activities	◉	○	○	○	○	○
Extracurricular activities (e.g. hobbies, sports, volunteering, gaming)	◉	○	○	○	○	○
Shopping/Restaurants/Other commercial services	◉	○	○	○	○	○
Health care services/Government/Public offices/Banks	◉	○	○	○	○	○

24. Please indicate which language(s) you generally use in the following situations:

1. All English

2. Mostly English

3. Half English – Half Spanish

4. Mostly Spanish

5. Only Spanish

		1	2	3	4	5
Reading	◉	○	○	○	○	○
Emailing	◉	○	○	○	○	○
Texting	◉	○	○	○	○	○
Social Media (e.g. Twitter, Instagram, etc)	◉	○	○	○	○	○
Writing shopping lists, notes, etc.	◉	○	○	○	○	○
Watching TV/listening to radio	◉	○	○	○	○	○
Watching movies	◉	○	○	○	○	○
Browsing on the Internet	◉	○	○	○	○	○
Praying	◉	○	○	○	○	○

25. Some people switch between the languages they know within a single conversation (i.e. while speaking in one language they may use sentences or words from the other language).

This is known as "language-switching". Please indicate how often you engage in language-switching.

1. All the time
2. Frequently
3. Sometimes
4. Rarely
5. Very rarely-Never

		1	2	3	4	5
With parents and family	●	○	○	○	○	○
With friends	●	○	○	○	○	○
On social media (e.g. Twitter, Instagram, etc)	●	○	○	○	○	○

26. Could you, please, indicate to what extent you use English in the domains provided? You may simply tick the box below:

1. All the time (daily)
2. Very frequently (once/twice a week)
3. Frequently (once/twice a month)
4. Rarely (once/twice a year)
5. Very rarely-Never

		1	2	3	4	5
I watch Spanish and/or English-speaking tv programmes/series/films/youtube-channels/etc in English (including any online platform -e.g. Netflix-).	●	○	○	○	○	○
I listen to English-speaking radio programmes/songs/podcasts/audiobooks/etc.	●	○	○	○	○	○
I read newspapers/books/magazines/etc in English.	●	○	○	○	○	○
I access webpages/social media sites/etc in English.	●	○	○	○	○	○
I write essays/articles/letters/emails/WhatsApp texts/messages/in my social media/etc in English (including any written action, for example, your shopping list).	●	○	○	○	○	○

27. Could you, please, indicate to what extent you use Spanish in the domains provided? You may simply tick the box below:

1. All the time (daily)
2. Very frequently (once/twice a week)
3. Frequently (once/twice a month)
4. Rarely (once/twice a year)
5. Very rarely-Never

	1	2	3	4	5
I watch Spanish and/or English-speaking tv programmes/series/films/youtube-channels/etc in Spanish (including any online platform -i.e., Netflix-).					
I watch Spanish and/or English-speaking tv programmes/series/films/youtube-channels/etc in English with Spanish subtitles (including any online platform -e.g. Netflix-).					
I listen to Spanish-speaking radio programmes/songs/podcasts/audiobooks/etc.					
I read newspapers/books/magazines/webpages/etc in Spanish.					
I access webpages/social media sites/etc in Spanish.					
I write essays/articles/letters/emails/WhatsApp texts/messages/in my social media/etc in Spanish (including any written action, for example, your shopping list).					

28. You have come to the end of this questionnaire. Is there anything you would like to add? This can be anything from language-related comments to remarks about the questionnaire.

6.2 Appendix 2. Experimental item lists from the visual world tasks in Spanish and English.

Table A. Experimental items used in the visual world task in Spanish.

Target item	Cohort competitor	Rhyme competitor	Unrelated item

Paja (Hay)	Pavo (Peacock)	Hoja (Leaf)	Reina (Queen)
Barba (Beard)	Barco (Boat)	Tumba (Grave)	Genio (Genie)
Rama (Branch)	Ramo (Bouquet)	Cama (Bed)	Bolso (Purse)
Tabla (Wood)	Taza (Cup)	Jaula (Cage)	Pierna (Leg)
Beso (Kiss)	Vela (Candle)	Hueso (Bone)	Libro (Book)
Novia (Bride)	Nota (Musical note)	Lluvia (Rain)	Cuadro (Picture)
Bota (Boot)	Bola (Ball)	Gota (Drop)	Cisne (Swan)
Lata (Can)	Labios (Lips)	Puerta (Fence)	Hongo (Mushroom)
Perro (Dog)	Pera (Pear)	Gorro (Hat)	Hilo (Thread)
Puente (Bridge)	Puerta (Door)	Guante (Glove)	Bolsa (Bag)
Burro (Donkey)	Bucle (Loop)	Carro (Wagon)	Percha (Hanger)
Pato (Duck)	Pata (Paw)	Gato (Jack)	Olla (Pot)
Rana (Frog)	Radio (Radio)	Luna (Moon)	Ducha (Shower)
Gancho (Hook)	Ganso (Goose)	Corcho (Cork)	Búho (Owl)
Casa (House)	Cabra (Goat)	Rosa (Rose)	Yunque (Anvil)
Cuna (Crib)	Cubo (Block)	Trona (Highchair)	Bomba (Bomb)

Placa (Badge)	Playa (Beach)	Vaca (Cow)	Pistola (Gun)
Rayo (Lightning)	Raya (Ray)	Tallo (Stem)	Vino (Wine)
Humo (Smoke)	Hucha (Piggybank)	Termo (Thermos)	Pulpo (Octopus)
Regla (Ruler)	Remo (Oar)	Jungla (Jungle)	Bruja (Witch)
Llave (Key)	Llama (Llama)	Nube (Cloud)	Tipi (Tepee)
Garra (Claw)	Gafas (Glasses)	Sierra (Saw)	Concha (Shell)
Copa (Wineglass)	Coma (Comma)	Capa (Cape)	Pinzas (Tweezers)
Lobo (Wolf)	Loro (Parrot)	Globo (Balloon)	Roca (Rock)
Pecho (Chest)	Pelo (Hair)	Techo (Roof)	Tigre (Tiger)
Mapa (Map)	Mazo (Hammer)	Arpa (Harp)	Mosca (Fly)
Arma (Gun)	Árbol (Tree)	Goma (Rubber)	Piña (Pinecone)
Cuerda (Rope)	Cuernos (Antlers)	Hada (Fairy)	Cactus (Cactus)
Ancla (Anchor)	Anca (Frog leg)	Chancla (Flip flop)	Casco (Helmet)
Moño (Bow)	Lápiz (Pencil)	Pozo (Well)	Peine (Comb)
Metro (Subway)	Media (Stocking)	Potro (Foal)	Tanque (Tank)
Mono (Monkey)	Moto (Motorcycle)	Cono (Ice cream cone)	Nudo (Knot)

Planta (Plant)	Plancha (Iron)	Llanta (Tire)	Morsa (Walrus)
Pala (Shovel)	Palo (Stick)	Ala (Wing)	Coche (Car)
Peso (Weight)	Pesca (Fishing)	Queso (Cheese)	Alce (Moose)
Clavo (Nail)	Clase (Class)	Pavo (Turkey)	Mujer (Woman)
Lima (Lime)	Libra (Pound)	Pluma (Feather)	Dedo (Finger)
Vaso (Glass)	Baño (Toilet)	Oso (Bear)	Huevo (Egg)
Niña (Girl)	Niño (Boy)	Piña (Pineapple)	Ojo (Eye)
Tronco (Log)	Trono (Throne)	Banco (Bench)	Piano (Piano)

Table B. Experimental items used in the visual world task in English.

Target item	Cohort competitor	Rhyme competitor	Unrelated item
Barrel	Barrow	Camel	Necklace
Apron	Acorn	Onion	Palm tree
Button	Bucket	Onion	Present
Candle	Cannon	Needle	Bathtub
Monkey	Money	Donkey	Tweezers
Medal	Meadow	Bottle	Drawer

Iron	Eyebrow	Wagon	Dentist
Hammer	Hammock	Pitcher	Dustpan
Hanger	Handcuffs	Burger	Hippo
Rooster	Ruler	Toaster	Trumpet
Lemon	Lettuce	Bacon	Rocket
Letter	Leopard	Lobster	Cookie
Lightning	Lightbulb	Earring	Mushroom
Lion	Lighthouse	Dragon	Closet
Lighter	Light switch	Beaver	Ashtray
Magnet	Magpie	Helmet	Thermos
Mirror	Mixer	Anchor	Table
Lipstick	Lizard	Music	Cowboy
Carrot	Carriage	Parrot	Ladle
Teapot	Tepee	Robot	Ladder
Jacket	Jack-knife	Rabbit	Pizza
Paper	Paintbrush	Diaper	Ostrich
Pencil	Penguin	Apple	Toilet
Pillow	Pillar	Arrow	Windmill

Pumpkin	Puzzle	Dolphin	Airplane
Rainbow	Raincoat	Window	Glasses
Razor	Raincoat	Tractor	Panda
Radish	Racket	Jellyfish	Mailbox
Tire	Tiger	Dresser	Pirate
Toothbrush	Toothpaste	Paintbrush	Curtain
Turtle	Turkey	Whistle	Eagle
Wallet	Waffle	Biscuit	Trophy
Butter	Bucket	Waiter	Package

6.3 Appendix 3. Extra information about picture stimuli from the VWP.

As mentioned in Chapters 2, 3 and 4, the pictures selected for the visual world experimental tasks in this research project were primarily chosen from Szekely and colleagues' (2004) online corpus from the International Picture Naming Project (IPNP), which includes Snodgrass and Vanderwart's (1980) picture database. The majority of the picture stimuli sets were selected from this database because they have been normed across seven languages for name agreement, familiarity, visual complexity, length in syllables, and word frequency.

Additionally, 33 pictures were created by a professional graphic designer and subsequently normed for name reliability in both Spanish and English. This was done with a group of 20

Spanish monolingual speakers (estimate = -0.01, SE = 0.01, $t(19) = -1.476$, $p = 0.15$) and a group of 20 English monolingual speakers (estimate = 0.009, SE = 0.01, $t(19) = 1.049$, $p = 0.30$). All selected items were controlled for word frequency, orthographic and phonological neighbourhood density and cognateness across both languages (see Table 10 for more information).

Table 10. Statistical analyses on controlled linguistic factors for picture stimuli across languages.

Linguistic Factors	*Language*	Linear *Models*				
		Estimate	Std. Error	*t* value	Df	*p* value
Word Frequency	English	-0.05	0.04	-1.227	132	0.22
	Spanish	0.46	0.39	1.156	160	0.24
Orthographic Neighbourhood Density	English	0.02	0.06	0.378	129	0.70
	Spanish	-0.06	0.08	-0.804	160	0.42
Phonological Neighbourhood Density	English	0.06	0.14	0.482	129	0.63
	Spanish	-0.05	0.10	-0.508	160	0.61
Cognateness	English	-0.02	0.08	-0.238	132	0.81
	Spanish	-0.06	0.05	-1.458	160	0.14

6.4 Appendix 4. Pilot Study.

To avoid issues with the name reliability of the stimuli from the visual world tasks as well as to account for potential lexical variations among speakers of the same language (e.g., Castilian Spanish vs Latin American Spanish and British English vs American English), 10 native speakers of Spanish and 10 native speakers of English were asked to name the selected line drawings. One target item was incorrectly identified due to difference in meaning between Latin American Spanish and Castilian Spanish (i.e., *bolsa* means *purse* or *plastic bag* depending on the region), leading to the exclusion of one experimental trial from the Spanish visual world task. No differences were reported by the English native speakers in the English task.

To address the potential complexity of the task due to added background noise in the audio stimuli (to make word recognition more challenging as noted by Botezatu et al, 2022), both experimental visual world tasks were piloted with 30 Spanish and/or English speakers living in the UK or Spain at the time of testing. These piloting sessions, each consisting of 10 participants, were organised for all three studies to ensure the experiment's functionality across populations and eye-tracking devices. Ethical approval was obtained, and participants were compensated for their contribution.

During the piloting sessions, participants followed the same experimental procedure intended for the actual experiments with one exception: they were asked to fill out a short feedback sheet after completing each task (i.e., Visual world task, Flanker and LLAMA) with 4 open-ended questions. Participants were asked anonymously about i) their opinions on the instructions provided (e.g., *Were the instructions clear?*), ii) the volume and clarity of the audio recordings (e.g., *Did you understand the words you heard for the main experiment?*), iii) any technical issues with the eye-tracker (e.g., *Did you experience any technical issues during the eye-tracking task?*), and iv) the level of task complexity (e.g., *Were there any tasks that were too challenging?*).

No participants reported issues with the instructions, the audio setup of the VW task or the complexity of each task. Regarding technical issues, 2 participants reported having experienced problems with one Tobii eye-tracking device, 3 with one SMI eye-tracking device and 1 with the Eyelink portable eye-tracking device during calibration. Upon completion of the tasks, none of the participants indicated that they had knowledge of the experiment's goals or specific aims.

The pilot study was very useful in terms of assessing the average duration of the in-person experimental sessions and for trialling the experiment and its procedures before conducting the main study. After visually examining the pilot data, no issues were reported. The pilot data was not included in the main analyses performed in this project.

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