# Lexical Processing and Executive Function in Bilingual Children with and without Language Disorder

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# Abstract

The study of bilingualism and its interaction with Developmental Language Disorder (DLD) in children has often led to divergent theories and perspectives. This dissertation presents a comprehensive investigation into this complex interplay, employing a combination of behavioural analyses and Event-Related Potentials (ERPs). Across three distinct studies, it examines cognitive control, lexical processing, and executive functions in bilingual and monolingual children, both with and without DLD.

Study 1 critically reexamines the widely accepted notion of a bilingual cognitive advantage. It unveils that bilingual children face distinct processing challenges, marked by prolonged reaction times and unique neural patterns, especially when encountering unfamiliar lexical stimuli. These findings illuminate the intricate cognitive processing dynamics inherent in bilingual contexts, challenging existing perceptions and adding depth to our understanding of bilingual cognition. Study 2 shifts focus to bilingual children with DLD, juxtaposing their abilities with those of typically developing bilingual peers. Contrary to the prevalent belief that bilingualism intensifies language disorders, the study reveals a nuanced, facilitative role of bilingualism in processing familiar lexical items, offering a fresh perspective on bilingual language development. Study 3 furthers this exploration by comparing bilingual and monolingual children with DLD. It discovers that while bilingualism introduces specific challenges in processing unfamiliar words, it does not invariably exacerbate cognitive control or familiar word processing difficulties.

Collectively, these studies forge new paths in understanding the dynamic interplay between bilingualism and DLD. They propose that bilingualism can present both challenges and potential advantages in cognitive and linguistic development, compelling a revaluation of long-standing paradigms. This dissertation not only challenges established beliefs but also

emphasizes the importance of considering individual linguistic experiences and cognitive strategies in deciphering bilingualism's role in language disorders. This work highlights the multifaceted nature of bilingualism and DLD, advocating for a more comprehensive and individualized approach in this evolving field.

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# 1 Literature Review

## 1.1 Introduction

In today's ever-evolving global landscape, where cultural and linguistic diversity are not just common but expected, the phenomenon of bilingualism has transformed. The capacity to navigate multiple linguistic environments is increasingly vital in our interconnected world, elevating the significance of studying bilingualism's impact on cognitive development and language acquisition. Research by Kroll, Dussias, Biece, and Perroti (2015) illuminates the profound effects of dual language activation on linguistic processes such as speech, reading, and planning, extending even in a monolingual context. Despite growing insights, the exploration of bilingualism's implications on language disorders, particularly in children, remains in its nascent stages and warrants deeper investigation.

At the heart of this dissertation and research is Developmental Language Disorder (DLD), a condition that significantly affects language abilities without being linked to auditory deficits, global developmental delays, or neurological disorders. According to the CATALISE consensus, DLD encompasses a range of language impairments across diverse intellectual abilities, extending beyond the traditional definition of Specific Language Impairment (SLI) to include children with varied intellectual profiles (Bishop et al., 2016, 2017). This broad definition acknowledges that DLD can coexist with different levels of nonverbal intelligence, challenging the outdated requirement of normal nonverbal intelligence for diagnosis.

DLD is evident through difficulties in language processing and use, which manifest as limited vocabulary, problems constructing coherent narratives, and challenges with grammar and syntax. These issues significantly impact academic performance and social interactions, emphasizing the need to view these as comprehensive learning difficulties rather than isolated incidents. Advanced neuroimaging techniques reveal that these challenges are linked to specific variations in cortical surface areas associated with language functions, suggesting a complex pattern of brain structure alterations (Bahar et al., 2024).

A critical aspect of DLD in bilingual children involves lexical processing, which is essential for effective language acquisition. Research by McGregor et al. (2016) demonstrates that bilingual children with DLD encounter pronounced challenges in word learning, retrieval, and the development of semantic networks—hurdles that are more acute than those faced by their typically developing peers. This intersection of bilingualism and DLD necessitates a nuanced understanding of how these children integrate and manage linguistic elements across their languages.

Recent studies challenge the outdated notion that children with language disorders should avoid learning a second language, advocating instead that bilingual exposure may offer cognitive and linguistic benefits to children with DLD. Research by Kohnert et al. (2020) and Chéileachair et al. (2022) demonstrates that bilingual children with DLD can perform comparably to their monolingual peers in certain linguistic domains, countering previous beliefs that bilingualism exacerbates language disorders (Rezzonico et al., 2015; Tsimpli et al., 2015; Marini et al., 2019). Additionally, investigating executive functions—such as working memory, inhibitory control, and cognitive flexibility—in bilingual children with DLD is crucial. These executive skills, essential for language proficiency and cognitive control, are influenced by bilingual experiences (Gathercole et al., 2004; Woodard et al., 2016). Emerging research suggests that children with language disorders might develop unique cognitive strategies to manage complex tasks effectively, highlighting the adaptive nature of their cognitive processes (Reichenbach et al., 2016; Ladányi, 2018).

This dissertation aims to make a meaningful contribution, by enhancing our understanding of lexical processing and executive function in bilingual children, both with and without DLD.

Through a comprehensive exploration of bilingualism, DLD, and executive functions, and the intricate ways in which they intersect, this research seeks to inform and shape more effective, tailored strategies that address the unique cognitive profiles of bilingual individuals and children with DLD.

### 1.2 Overview of Bilingualism

Bilingualism is a multifaceted and intricate aspect of human communication, encompassing a wide spectrum of experiences and capabilities. It ranges from individuals exhibiting native-like proficiency in two distinct languages to those with functional competence in a secondary language alongside their native tongue. Definitions and conceptualizations of bilingualism vary based on linguistic, cognitive, and sociocultural factors, as explored by Cook (2003).

#### 1.2.1 Bilingualism in Child Development

In the context of child development, bilingualism covers both simultaneous and sequential language acquisition. Simultaneous bilinguals, who are exposed to two languages from birth, often achieve developmental milestones parallel to monolingual peers (Holowka et al., 2002). In contrast, sequential bilinguals, introduced to a second language during childhood or adolescence, may experience an elongated path to linguistic proficiency, influenced by factors such as age of second language exposure and specific sociocultural contexts (Genesee & Lindholm-Leary, 2012). Bilingual upbringing can significantly vary, encompassing diverse experiences and pathways (Kroll et al., 2015). This variation highlights the complexity of bilingual development and the need to consider individual differences when studying bilingualism in children.

#### 1.2.2 Cognitive and Neurobiological aspects of Bilingualism

Bilingual individuals often engage in a continual balancing act, managing the activation and interaction of two linguistic systems. This can lead to unique cognitive challenges, such as increased processing effort and longer response times in lexical retrieval tasks (Ivanova & Costa, 2008; Gollan & Ferreira, 2009). The phenomenon of language interference, where elements of one language permeate the use of the other, exemplifies the complex dynamics of bilingual cognition. Language interference and code-switching are salient features of bilingual communication. Bilinguals strategically manage and regulate their language systems, balancing the parallel activation and competition for cognitive resources (Wattendorf et al., 2012). Neurobiological studies reveal that the bilingual brain showcases remarkable adaptability, utilizing shared neural networks for both languages while managing the complexities of language control and cognitive resource allocation (Bialystok & Luk, 2011). However, these challenges are counterbalanced by cognitive benefits. Studies by Peal & Lambert (1962) and Bialystok (2010) demonstrate that bilingual individuals often exhibit enhanced capabilities in mental flexibility, problem-solving, and executive control. These cognitive advantages are believed to stem from regularly managing two languages, fostering a more agile and adaptable mind.

### 1.2.3 Socio-Cultural and Developmental Implications

Bilingualism profoundly influences socio-cultural identity and integration, affecting interactions within various societal contexts. Its impact extends beyond childhood, influencing cognitive aging and lifelong learning. Educational models for bilingual children, such as immersion and dual-language programs, play a crucial role in shaping linguistic and cognitive development, influencing proficiency and academic outcomes. Research suggests that bilingual children often start with challenges in lexical processing but gradually achieve proficiency levels comparable to monolingual peers (Gangopadhyay et al., 2019; Schröter & Schroeder, 2017)

Language exposure and age of acquisition significantly influence bilingual linguistic abilities. Earlier exposure and greater proficiency are linked to enhanced lexical processing and cognitive functions (Bedore et al., 2016; Wartenburger et al., 2003). Over time, bilingual children refine their lexical access mechanisms and become sensitive to language-specific orthographic structures. The exploration of bilingualism in children presents a complex and multifaceted picture, encompassing cognitive processes, linguistic development, and environmental influences. This comprehensive understanding lays a critical foundation for investigating bilingual children's lexical processing and executive function, particularly in the context of language disorders. It underscores the need for a multidimensional approach in studying bilingualism, appreciating its challenges and advantages, and recognizing its profound implications for cognitive and linguistic development.

## 1.3 Developmental Language Disorders (DLD)

Developmental Language Disorder (DLD) represents a significant deviation in language abilities, affecting approximately 7% of children globally (Tomblin et al., 1997). DLD occurs without related auditory or neurological deficits and is characterized by a broad spectrum of language impairments. According to the CATALISE consortium, the definition of DLD now includes a wider range of intellectual abilities, acknowledging that DLD can coexist with diverse intellectual profiles. This shift moves beyond the traditional confines of Specific Language Impairment (SLI), reflecting a more inclusive understanding of the disorder (Bishop et al., 2017; Leonard, 2014).

### 1.3.1 Diagnosis, and Behavioural Characteristics

DLD is diagnosed through a meticulous evaluation that considers a child’s performance across intelligence, verbal, and auditory assessments, ensuring that diagnoses are not confounded by intellectual disabilities or sensory impairments. Recent discussions have highlighted the need for revisiting diagnostic criteria to reflect the evolving comprehension of the disorder, with prevalence estimates ranging from 0.6% to 7.4%, depending on these criteria (Tomblin et al., 1997; Acosta Rodríguez et al., 2014).

Key behavioural manifestations of DLD include difficulties in grammar (e.g., using appropriate tense and syntax), vocabulary acquisition and narrative skills (e.g., storytelling and understanding). Individuals with DLD may exhibit pronounced difficulties in following complex instructions, engaging in conversations that require abstract language comprehension, and using language in socially appropriate ways. These behavioural characteristics often result in observable challenges in academic achievements and social interactions, highlighting the pervasive impact of DLD on daily living (Leonard, 2017).

Children with DLD typically require more exposures to new words than their typically developing (TD) peers, exhibiting slower word learning, retrieval difficulties, naming errors, and shallower word definitions. These challenges are indicative of the deeper cognitive processing issues inherent in DLD and necessitate specific interventions tailored to these unique learning needs (McGregor, Oleson, Bahnsen, & Duff, 2013). Additionally, differences in spoken word recognition abilities have been noted in children with DLD. Although they can perceive initial sounds of target words, they often require more acoustic information to recognize a word in speech, indicating nuanced differences in auditory processing and language comprehension. This aspect of language processing underscores the necessity for comprehensive assessments that consider the auditory dimension of language in DLD (Evans, Gillam, & Montgomery, 2015).

### 1.3.2 Neurobiological Aspects

Research into the brain structure of individuals with DLD reveals a complex and varied landscape. While studies have documented differences such as reduced grey matter volume in key areas for language processing, such as the inferior frontal gyrus and posterior temporal cortex, these structural differences are not uniformly present across all diagnosed individuals. This highlights the significant diversity within the disorder. Notably, advanced neuroimaging techniques have shown that these variations are particularly evident in specific cortical surface areas linked to language functions. For instance, reductions in cortical surface area, rather than uniform changes in cortical thickness, suggest a nuanced pattern of brain structure alterations that directly relate to linguistic deficits observed in DLD (Bahar et al, 2024). These findings underscore that while brain structure changes are associated with DLD, they do not consistently define the condition for every affected individual. This calls for continued research to deepen our understanding of the varied neuroanatomical causes and structures associated with DLD, advocating a move away from simplistic models that assume homogeneity across cases (Kornilov et al., 2015; Thompson et al., 2017).

The language acquisition process in children with DLD is intricately linked to the interplay between procedural and declarative memory systems. While procedural memory deficits, particularly affecting grammar, and phonological sequencing, pose significant challenges, the declarative memory systems governing lexical and semantic knowledge generally remain intact. This contrast highlights the complex interaction of memory systems in language learning in DLD and necessitates targeted intervention strategies (Ullman, 2005; Lum, Conti-Ramsden, Page, & Ullman, 2012).

### 1.3.3 Bilingualism and DLD

Bilingual children face the unique challenge of mastering two languages within the same developmental period in which monolingual peers tackle one. This distinction is crucial when considering the developmental trajectory of children with Developmental Language Disorder (DLD). While bilingualism inherently enriches a child's linguistic environment, it introduces complexities in diagnosing and addressing DLD, necessitating a nuanced understanding of language acquisition across diverse linguistic backgrounds. Bilingualism varies widely, with distinctions made between early (or simultaneous) bilinguals, who are exposed to two languages from birth, and late (or sequential) bilinguals, who acquire a second language after establishing foundational skills in their first language (Genesee et al., 2004). This distinction is vital, as the age and context of second-language acquisition significantly influences linguistic development and the manifestation of DLD. Managing two language systems significantly amplifies the complexities associated with DLD. This dual-language management increases the demands on cognitive resources, such as working memory and executive functions, intensifying the linguistic challenges these individuals face. The process of navigating between two languages can exacerbate the inherent difficulties in language acquisition and cognitive processing typical of DLD (García et al., 2022). However, bilingualism also offers unique cognitive benefits that can play compensatory roles. Enhanced attentional control and cognitive flexibility, conferred by the bilingual experience, can mitigate some of the difficulties associated with DLD. These cognitive advantages help in managing the increased linguistic demands, providing a form of natural support that can enhance the overall language and cognitive development in bilingual individuals with DLD (Bialystok et al., 2009; Kohnert, 2010).

### 1.3.4 Linguistic Challenges and Comparative Studies

Children with DLD exhibit marked deficits in key linguistic domains, including grammar, vocabulary, and narrative skills. These deficits are not merely additive in bilingual children but interact with the process of bilingual language acquisition in complex ways (Paradis et al., 2013). Proficiency development in both the first (L1) and second language (L2) among bilingual learners with DLD is dynamic, shaped by factors such as age, the amount and quality of language exposure, and the overall linguistic environment. Initial proficiency often appears stronger in L1, but with increased exposure and use, L2 skills can develop significantly (Bird, Genesee, & Verhoeven, 2016). This pattern mirrors the development trajectory seen in typically developing bilingual learners, where the dominant societal language often becomes more prominent over time.

Comparative studies examining sequential bilinguals with DLD reveal a complex picture of language abilities. For instance, in standardized language tests, these children often lag in L2 proficiency compared to their monolingual counterparts with DLD. However, they may demonstrate comparable abilities in narrative construction and understanding of macrostructures (Rezzonico et al., 2015; Tsimpli, Peristeri, & Andreou, 2015). These findings highlight the importance of considering the diverse language skills and the specific language context when assessing and supporting bilingual children with DLD.

Cross-linguistic transfer, where skills or knowledge in one language facilitate learning in another, is a critical factor in bilingual language development. Research indicates that similarities between L1 and L2 can aid in the acquisition of specific linguistic structures (Blom & Paradis, 2013). However, this transfer is not always uniform across different language domains and may not be bidirectional. Studies exploring the grammar and semantics in bilingual children with DLD, such as the work of Castilla-Earls et al, (2015) and Fiestas, Peña, Bedore, and Sheng (2011), demonstrate specific challenges in areas like word definition, suggesting difficulties in organizing semantic networks.

DLD represents a complex interplay of cognitive, linguistic, and neurobiological factors. The expanded definition by the CATALISE consortium reflects a more nuanced understanding of the disorder's diverse manifestations. The variability in brain structure findings and the impact of bilingualism highlight the heterogeneous nature of DLD, emphasizing the need for refined diagnostic criteria and targeted intervention strategies to address the wide variability among affected individuals. Future research should continue to explore these complexities to improve support for children with DLD.

**1.4 Lexical Processing: A Multidimensional Perspective in Language Acquisition**

Lexical processing, a cornerstone of language acquisition, extends beyond mere word recognition to encompass an intricate network of semantic relationships and cognitive processes integral to communication. The "lexical-semantic network," a concept established by Collins and Loftus (1975), is pivotal in understanding how words are organized within semantic memory. This network is characterized by interconnected conceptual nodes where activation of one node spreads to related nodes, thus priming associated words and concepts. In a well-developed network, multiple connections between nodes enhance word retrieval and comprehension efficiency.

Nation (2014) presents a comprehensive view of lexical processing, highlighting the word-level elements of language, distinct from syntactic or discourse components. Defining and measuring these processes remains a challenge due to the dynamic and interactive nature of language. Traditional tasks, while insightful, are influenced by non-linguistic factors such as memory and executive functions. A deeper understanding of lexical processing requires considering its multifaceted nature, encompassing everything a child knows about a word and its contextual use. Techniques such as the visual world paradigm, employing eye-tracking in response to spoken stimuli, offer implicit measures of language processing, revealing real-time patterns of word activation and recognition (McMurray et al., 2010).

Complementing behavioural methodologies, neurophysiological techniques like Electroencephalography (EEG) and Event-Related Potentials (ERP) provide crucial insights into the neural underpinnings of lexical processing. These tools allow observation of the brain's electrical responses to language stimuli, particularly through components like the N400, indicative of semantic processing. This neural evidence sheds light on the timing and nature of responses to word recognition and integration, offering a window into the brain's language processing mechanisms. In the context of language disorders and bilingualism, a multidimensional view of lexical processing becomes even more pertinent. Children with Developmental Language Disorder (DLD) or those navigating bilingualism may face unique challenges due to weaker or less extensive semantic networks. Such difficulties underscore the need for educational and therapeutic approaches that are tailored to enhance lexical development and fortify the lexical-semantic network.

### 1.4.1 Lexical Processing Monolingual Children with Developmental Language Disorders (DLD)

The study of lexical processing in monolingual children with and without DLD integrates cognitive, linguistic, and developmental aspects in a complex framework. Lexical skill in children is evaluated through diverse assessment tasks such as picture naming (Kohnert, 2013), word associations (Sheng, 2013), and picture-label matching (Pham & Kohnert, 2013). These tasks highlight different facets of lexical skills, underscoring the intricate nature of lexical processing in children. Children with DLD display atypical or less detailed phonological representations and abnormal phonological processing compared to their typically developing (TD) peers (Claessen et al., 2013). This reduction in phonological working memory capacity plays a significant role in broader language development. Early word acquisition delays are primary indicators of lexical-semantic deficits in DLD, key symptoms of speech and language development delays (Bishop et al., 2014).

Empirical studies, including those by Sheng (2013) and McMurray et al. (2010), demonstrate that children with DLD face challenges in learning new lexical items, with limitations in vocabulary size and depth. Furthermore, children with DLD require more exposures to new words for comprehension and production compared to typically developing peers. McGregor et al. (2013) highlighted that children with DLD learn fewer words, exhibit word retrieval difficulties, naming errors, and show reduced depth in word definitions. Alt et al. (2013) observed that these children often provide poorer word definitions, indicating a wider impact on their cognitive and linguistic development. Word association studies reveal sparse semantic representations in children with DLD, marked by immature word associations and errors (Sheng & McGregor, 2010).

In terms of language processing efficiency, children with DLD process language at a slower or less efficient rate. Fluent adult speakers, as noted by Liberman (1970), produce a significant number of words and phonetic segments per minute, a capacity that typically developing speakers can comprehend even under temporally constrained conditions. However, the reduced efficiency in processing information experienced by many children with DLD can have cascading effects, negatively impacting learning and classroom engagement. Kohnert (2013) observed that in instructional settings, children with DLD are often still processing a question when their typically developing peers are already formulating a response, demonstrating the practical implications of these processing challenges.

The study by Pizzioli and Schelstraete (2011) on monolingual children with DLD found that these children show higher susceptibility to lexical-semantic priming compared to TD peers, suggesting that children with DLD may rely more on lexical semantics as a compensatory strategy when faced with grammatical difficulties. Spoken word recognition presents significant challenges for children with DLD. Mainela-Arnold et al. (2010) used a forward gating paradigm and found that children with DLD required longer segments of speech to identify words. Detailed examination showed that these children often oscillated between correct and incorrect word guesses, indicating degraded phonological category boundaries and poorly specified lexical-phonological representations.

McMurray et al. (2010) explored spoken word recognition in adolescents with DLD using the visual word paradigm. They found that although initial activation of target words was normal, participants with DLD showed an atypical pattern later, with more looks to cohort and rhyme competitors than to the target word. This pattern was best explained by high levels of lexical decay, which hindered the full activation of target words, allowing competitors to remain more active.

### 1.4.2 Lexical Processing in Bilingual Children with and without Developmental Language Disorders (DLD)

The cognitive and linguistic processes involved in acquiring and using two languages are systematically different from those engaged in monolingual language use, leading to detectable changes in linguistic and cognitive outcomes for bilinguals (Kroll et al., 2015). The most salient feature of language use by bilingual children is their mixed use of languages, even in monolingual contexts (Meisel, 2006). Bilingual children frequently perform more poorly than monolinguals on linguistic tasks, a phenomenon that can be explained by differences in the linguistic representations developed during language acquisition and sustained through adulthood. Specifically, the representations created by bilinguals for each language are less rich or less accessible than those of monolinguals.

Kohnert, Windsor, and Yim (2011) found that Spanish-English bilingual children showed remarkable skills in English nonword repetition and rapid automatic naming, surpassing even native English speakers. Despite their strong English skills, these children initially faced some challenges in specific English language processing tasks compared to their monolingual peers, a disadvantage that appears to be temporary. Gangopadhyay et al. (2019) observed that the differences in lexical processing between bilingual and monolingual children decreased over time. In their longitudinal study, they noted that while monolinguals initially outperformed bilinguals in an English lexical decision task, this performance gap closed within a year, indicating that bilingual children eventually attain similar lexical processing efficiency as their monolingual counterparts.

Building upon these findings, Schröter and Schroeder (2018) conducted an experiment with German-English bilingual children using a "monolingual" lexical decision task in both English and German. They discovered that bilingual children's word recognition systems initially rely solely on lexical-level information, unlike bilingual adults and teenagers, who utilize sub-lexical orthographic information as well, a concept supported by Casaponsa and Duñabeitia (2016). This finding suggests that bilingual children initially use a language-nonselective approach to lexical access, developing sensitivity to language-specific orthographic structures over time. In contrast, bilingual adults often identify the language of a word early in the recognition process, relying more on sub-lexical cues. These insights provide a deeper understanding of the developmental trajectory of bilingual lexical processing, highlighting the dynamic evolution of language processing strategies from childhood to adulthood.

Studies indicate that bilingual children with DLD may initially show stronger skills in their first language (L1), which can shift to the second language (L2) with increased exposure and interaction (Paradis et al., 2003). Hirosh and Degani (2021) noted that the language used for learning and testing affects word learning and processing, making dual language testing in bilingual children with DLD unique. Anaya (2021) found that bilingual children with DLD performed lower than typically developing bilinguals in naming accuracy when considering responses from both languages. However, being bilingual does not exacerbate DLD symptoms, and bilingual children with DLD can benefit from continued growth in both languages. Windsor et al. (2010) and Verhoeven et al. (2017) suggest that maintaining a strong connection between L1 and L2 is vital, allowing children to use what they know in their first language to support learning in their second.

Rezzonico et al. (2015) and Westman et al. (2008) tested preschool children in lexical-retrieval tasks and observed significant effects of DLD but no interactions between bilingualism and DLD. They noted longer reaction times in non-word tasks for bilingual children with DLD, a phenomenon that Gollan et al. (2005, 2011) attributed to the "null presence or frequency" of these non-words in the child's lexicon. This highlights the importance of developing a strong first language lexicon to aid in second language processing.

In studies focusing on nonword repetition tasks, differences emerged between bilingual children with DLD and monolingual peers. Bishop et al. (2009) simulated DLD characteristics in typically developing English-speaking 6-year-olds. By introducing cognitive stress factors, such as compressed speech rate or increased memory load, they found a pattern of grammatical errors in the children that resembled those seen in DLD. This included better performance in noun morphology but poorer in verb morphology, suggesting that processing deficits underlie language difficulties in DLD.

The study by Chéileachair et al. (2020) offers further insights into bilingual children with DLD, revealing that they tend to perform better in accuracy and reaction times (RTs) when presented with words more frequently encountered in both of their languages. This finding underscores the importance of language exposure in bilingual lexical development. Similarly, Kohnert et al. (2020) emphasized that children with DLD are capable of effectively acquiring and utilizing two languages without exacerbating their language disorder symptoms. Additionally, Castillo et al. (2020) demonstrated that the duration of exposure to a second language positively correlates with performance on standardized linguistic tests for bilingual children, regardless of whether they have DLD. This highlights the significant role of prolonged language exposure in bilingual language development.

Complementing this, Thordardottir et al. (2014) emphasized the impact of acquisition mode, noting that simultaneous bilinguals, exposed to both languages from birth, may experience different linguistic development trajectories compared to sequential bilinguals. Notably, research by Tsimpli et al. (2015) showed that although bilingual DLD children did not differ from monolingual DLD in expressive vocabulary and sentence repetition tasks, they scored marginally lower on lexical diversity measures in a narrative production task. These findings suggest that in the lexical domain, bilingualism is associated with lower performance than monolingualism among children with DLD. This pattern contrasts with the pattern observed in the domain of morphosyntax, where monolingual DLD and bilingual DLD show similar patterns of performance (e.g., in grammatical morphology). Critically, the presence of a difference between monolingual DLD and bilingual DLD children in the lexical domain does not necessarily imply that bilingualism interacts with DLD to make it worse.

Marini et al. (2019) further contribute to this discourse by suggesting that exposure to a bilingual context is not a risk factor for lexical development in children with DLD. In fact, the presence of ambiguity in the bilingual lexicon, due to having two labels for each meaning, may provide children with DLD better scaffolding or cues for word retrieval. Ebbels et al. (2012) support this, noting that children with DLD can benefit from such cues to facilitate word retrieval. This might explain the unexpected performance of bilingual children with DLD in certain lexical processing tasks, highlighting the complex dynamics involved in lexical retrieval in the context of developmental language disorders.

The exploration of lexical processing in children with and without DLD, both bilingual and monolingual, paints a multifaceted picture of language development. The diversity in lexical challenges among these children calls for tailored educational and therapeutic approaches. The studies reveal a complex interplay between cognitive abilities, linguistic skills, and developmental trajectories, emphasizing that language disorders like DLD cannot be viewed in isolation and highlighting the potential for bilingualism even among children with DLD.

### 1.5 Executive Functions and Cognitive Control in Bilingual and Monolingual Children

Cognitive processing abilities, often termed executive function skills, have emerged as significant factors associated with academic success (Borella et al., 2010; Gathercole et al., 2004) and language proficiency (Woodard et al., 2016). Executive functions encompass a set of cognitive abilities that regulate and control various other cognitive processes and behaviours (Gilbert & Burgess, 2008). These core executive functions include working memory, inhibitory control/attention control, and cognitive flexibility (Diamond, 2013; Miyake et al., 2000). These functions are crucial in adapting to and learning within changing environments, significantly contributing to success in academic and professional settings (Im-Bolter, Johnson, & Pascual-Leone, 2006).

The Stroop task (Stroop, 1935) stands as a fundamental tool for probing executive control functions, specifically interference resolution, response inhibition, and response selection. In the Stroop task, participants encounter colour words printed in coloured ink and are instructed to name the ink colour while ignoring the word's meaning. In incongruent trials, where the word and colour do not match (e.g., 'red' printed in blue ink), participants must resolve the conflict between the word and colour stimuli before providing a correct response, leading to longer reaction times (RTs). Conversely, in congruent trials, where the word and colour coincide, the alignment of information facilitates the response, resulting in faster RTs. This task has found extensive use in cognitive research as a paradigm for investigating executive control functions (Marian & Spivey, 2003; Kroll, Bobb & Wodniecka, 2006).

### 1.5.1 Bilingualism, Monolingualism, and Bilingual Advantage

The hypothesis of a bilingual advantage posits that bilingual individuals exhibit superior executive function skills compared to monolinguals, attributed to the cognitive demands of managing two languages. This advantage is suggested to manifest in areas such as inhibitory control, cognitive flexibility, and attention management (Bialystok et al., 2012; Costa et al., 2009). However, this advantage is not uniform across all bilingual individuals. Factors like proficiency in a second language, age of acquisition (AoA), and task difficulty play a crucial role in determining the extent of this advantage (Kefi et al., 2004).

Critics like Paap and colleagues (Paap & Greenberg, 2013; Paap, Johnson, & Sawi, 2014; Paap, 2019) argue that the evidence supporting a bilingual advantage is inconsistent and often fails to account for confounding variables such as socioeconomic status, educational background, cultural influences, and individual differences in language proficiency and usage. When these confounding factors are rigorously controlled, the purported advantages often diminish or disappear (Paap et al., 2015). Inhibition control/attention control has been a focal point in the literature exploring the potential cognitive advantages of bilingualism (Adesope et al., 2010; Arizmendi et al., 2018). It is presumed that the need to focus on a target language system and inhibit the non-target language system requires additional control abilities. Over time, as neural networks become more efficient, inhibition control/attention control abilities are thought to be enhanced in bilinguals (Green & Abutalebi, 2013; Kałamała et al., 2021).

### 1.5.2 Studies on the Bilingual Advantage

Research into the bilingual advantage has produced mixed results. While some studies suggest that bilingualism enhances cognitive flexibility, attentional control, and working memory, other studies challenge the consistency of these benefits across different populations (Bialystok et al., 2009; Paap & Greenberg, 2013). A longitudinal study by Tran et al. (2014) involving 3-

year-olds from Argentina, Vietnam, and the USA showed that culture interacts with bilingualism in modulating performance on the Attention Network Task (ANT), emphasizing culture as a critical factor in explaining mixed findings. Similarly, Park et al. (2018) demonstrated that bilingual children showed a steep improvement in inhibition on the Flanker task over one year, while monolingual children's inhibition remained stable. These interactions suggest that bilingual experience can differentially influence the development of executive functions, leading to specific performance differences between bilinguals and monolinguals at certain developmental stages.

Furthermore, bilingual children often receive less linguistic input in each language compared to monolingual peers, potentially slowing their vocabulary and grammatical development, although their total vocabulary across both languages generally does not lag (Gathercole and Thomas, 2009; Vagh et al., 2009). Moreover, the interaction between bilingualism and cognitive control is not static but evolves, as evidenced by studies that trace changes in executive function over developmental stages. Bilingual children often exhibit a trajectory of cognitive development that can markedly differ from that of monolingual peers, heavily influenced by the quantity and quality of linguistic input and the specific languages involved (Hoff and Core, 2013). These nuances suggest that while some bilingual individuals may exhibit significant cognitive advantages, these benefits are closely tied to their linguistic environment and the complex interplay of additional variables such as cultural factors and longitudinal changes.

The discourse on the bilingual advantage is further complicated by methodological concerns and the heterogeneity of bilingual populations. Issues like socioeconomic status (SES) and culture intertwine with bilingualism, influencing cognitive research outcomes. Researchers often use SES as a covariate to address these differences, though this practice has been criticized for potentially violating statistical assumptions (Antoniou et al., 2016; Blom et al., 2017; Paap, Johnson, & Sawi, 2015). This highlights the necessity for careful methodological consideration to minimize confounding variables. The varied findings from longitudinal and cross-sectional studies suggest that bilingual advantages are not uniformly present across all settings or developmental stages (Costa et al., 2009; Hoff and Core, 2013).

**1.5.3 Stroop Task in Bilingual and Monolingual Children.**

Understanding the intricate relationship between cognitive control and language processing is essential for comprehending disparities between bilingual and monolingual individuals. The Stroop task has been extensively used in cognitive research to investigate executive control functions, particularly in resolving interference between stimulus dimensions, inhibiting conflicting responses, and selecting appropriate responses.

Recent investigations have shed light on the bilingual context, where both languages remain active during both comprehension and production (Marian & Spivey, 2003; Kroll, Bobb & Wodniecka, 2006). With two simultaneously active language systems, bilingual individuals rely on cognitive control skills to attend to the linguistic environment, select the appropriate language, inhibit the inappropriate one, and manage the conflict arising between the two. In contrast, monolinguals do not grapple with the constant challenge of conflicting lexical choices and tend to outperform bilinguals in lexical retrieval tasks, which bilinguals often find more effortful.

Sumiya and Healy (2008) found that Japanese–English bilinguals demonstrated pronounced between-language interference in a Stroop task. This interference scaled with proficiency in the weaker language, suggesting a nuanced interaction between linguistic overlap and cognitive processing efficiency. MacLeod's (1991) work and early studies (Preston & Lambert, 1969; Dyer, 1971; Fang et al., 1981) further substantiate the robust interference observed both within and between bilingual languages based on orthographic similarities. Marian, Blumfeld, Mizrahi, Kania, and Cordese (2013) tested bilinguals in a Stroop task, comparing within and between language conditions and showing consistent results. For both conditions, shorter RTs were observed in congruent conditions over incongruent ones. Furthermore, language proficiency impacted overall performance, meaning that when tested in their second language, participants' RTs were longer and less accurate. Shifting to younger participants, Eberhaut's study (2015) involved German-English bilinguals and German monolinguals, ages 11 to 12. All were tested in their L1, and the results showed that both groups performed similarly in incongruent trials, with longer RTs compared to the congruent trials, emphasizing similarities in performance patterns across the two groups.

Oliveira, Mograbi, Gabrig, and Charchat-Fichman (2016) explored the Stroop task performance in 9–12-year-old Brazilian monolingual children. Their findings revealed notable distinctions in reaction times (RTs) between age groups, specifically 9-10 and 11-12 years old. As interference increased, RTs and accuracy demonstrated a corresponding increase, while they decreased with age progression. This aligns with the dynamic nature of cognitive development during this age range, suggesting that age-related variations in cognitive control may influence Stroop task outcomes.

Furthermore, Duñabeitia et al. (2014) explored the performance of bilingual and monolingual children in congruent and incongruent trials of the Stroop task. Results in accuracy and reaction times (RTs) found no signs of a difference in the performance of these two groups. These findings lead the authors to conclude that the so-called bilingual advantage in executive control tasks seems to be non-existent in children. Yet, this narrative is nuanced by the insights of Tzelgov, Henik, & Leiser (1990), who posited that heightened language proficiency diminishes the interference effect. This is corroborated by Marian et al.'s (2013) study, which found that language proficiency significantly impacts performance, particularly in bilingual contexts. Their research indicates that as bilingual individuals become more proficient, their ability to manage and resolve linguistic interference in tasks like the Stroop test becomes more efficient, underscoring the complex relationship between bilingualism and cognitive control.

In contrast, Desjardins and Fernandez (2018) conducted a study using the Stroop task to examine cognitive performance in Spanish–English bilinguals who acquired both languages early in life and use them daily. Contrary to expectations, the results did not demonstrate a cognitive advantage in inhibiting task-irrelevant information for the bilingual group compared to their monolingual peers. The absence of a bilingual advantage was particularly evident in incongruent conditions, while both groups performed similarly in congruent trials. It is noteworthy that despite being fully proficient Spanish–English bilinguals, the testing was conducted exclusively in their first language (Spanish).

### 1.5.4 DLD and Executive Functions

Managing two languages places high demands on cognitive resources, which can be particularly challenging for children with Developmental Language Disorder (DLD) who may face difficulties in aspects such as working memory and cognitive flexibility (Leonard, 2014; Kapa et al., 2017). However, empirical evidence suggests that bilingual children with DLD can develop language skills, often aided by their bilingual exposure, indicating the potential cognitive and linguistic benefits of bilingualism (Kohnert et al., 2020; Chéileachair et al., 2020). Despite these potential benefits, evidence supporting a consistent bilingual advantage in school-age children is notably scarce, with inhibitory skills exhibiting considerable instability across the lifespan.

Bialystok (2012) suggests that bilingual advantages may only manifest in individuals with high proficiency in both languages and at the cognitive "peak" of development. Additionally, children with DLD tend to underperform compared to their typically developing peers in executive function measures, impacting their ability to focus on relevant information during language acquisition (Leonard, 2017; Montgomery et al., 2015). Inhibition control or attention control has been a focal point in the literature exploring the potential cognitive advantages of bilingualism (Arizmendi et al., 2018). The presumed need to focus on a target language system and inhibit the non-target language system is thought to require additional inhibition control/attention control. Despite the potential enhancement of these abilities in bilinguals over time (Green & Abutalebi, 2013; Kałamała et al., 2023), evidence suggests that children with DLD tend to underperform their typically developing peers in these measures. These difficulties may impact their ability to focus on relevant information during language acquisition, affecting the processing and acquisition of subtle grammatical features and potentially leading to comprehension issues (Leonard, 2017; Montgomery et al., 2015).

The relationship between bilingualism and cognitive control in children with DLD embodies a complex interplay of both challenges and potential cognitive benefits. Research indicates that bilingual children may experience variable outcomes in cognitive control tasks, suggesting that effective management of two languages can enhance skills such as attentional control and task-switching capabilities. These cognitive benefits are attributed to the ongoing demands of navigating two linguistic systems, highlighting a sophisticated connection between bilingualism, cognitive control, and language disorders. However, the extent and consistency of these benefits are influenced by several critical factors, including the age at which a second language is introduced, the proficiency achieved in each language, and the quality of engagement with both languages (Kohnert & Windsor, 2004; Bialystok et al., 2009).

Moreover, the interaction between bilingualism and cognitive control in DLD presents varied complexities. While studies have documented enhancements in aspects of cognitive control among typically developing bilinguals, the implications for those with DLD are more nuanced. The consensus in current research acknowledges that although bilingualism introduces additional challenges in language acquisition for children with DLD, it may also offer significant cognitive advantages, such as improved attentional control. This multifaceted interaction suggests that bilingualism is not inherently disadvantageous for individuals with DLD and may indeed provide distinct benefits. Such an intricate relationship underscores the need for a nuanced understanding of how bilingualism influences cognitive control and language development in children with DLD, emphasising the importance of tailored educational and therapeutic strategies based on individual linguistic and cognitive profiles (Greenhalgh et al., 2017).

Studies of inhibition control/attention control, such as those conducted by Yang and Gray (2017) and Ebert et al. (2019), found no significant differences in the conflict/flanker effect for accuracy or response time between monolingual school-age children with and without DLD across different language contexts. This indicates that bilingualism does not exacerbate or ameliorate subtle deficits in non-linguistic attention skills associated with DLD. This consistency in cognitive processes across different language contexts is further highlighted in studies where both typically developing and DLD populations exhibit similar patterns of response, regardless of their bilingual or monolingual backgrounds.

### 1.5.5 Stroop Task and DLD

For children with DLD, tasks like the Stroop task reveal how they manage interference and cognitive control demands. Studies suggest that children with DLD may show higher susceptibility to lexical-semantic priming compared to their typically developing peers, relying more on lexical semantics as a compensatory strategy when faced with grammatical difficulties (Pizzioli & Schelstraete, 2011). Kuntz (2012) observed that both typically developing and disordered populations, including those with DLD, exhibit Stroop interference. This interference is thought to arise from the conflict between controlled and automatic processing like reading. Kuntz's study found that English monolingual pre-teens with DLD performed poorly in incongruent conditions compared to neutral conditions, as well as to age-matched typical control peers. This suggests that children with DLD may have a more limited processing capacity, potentially due to poor resource allocation or a greater need to devote resources to certain aspects of language processing than their typically developing peers.

Reichenbach et al. (2016) investigated 5–6-year-old non-reading children using a modified Stroop task. The task involved rapidly naming the colour of black and white fruits and vegetables and then repeating the task with objects coloured incongruently to their natural colour (e.g., a blue strawberry). This setup created conflict between the presented and the object's typical colours. Results indicated both DLD and TD groups were slower in the second part, but DLD children were not significantly slower than TD counterparts. This suggests that, based on this task, DLD children can proficiently overcome interference in a Stroop task.

Ladányi (2018) compared the performance of DLD and TD groups on various cognitive tasks, including the backward digit span, n-back, and Stroop tasks. Surprisingly, the DLD group demonstrated weaker performance on the backward digit span and n-back tasks but not on the Stroop task. This challenges assumptions of overlapping cognitive control requirements between the Stroop task and word retrieval tasks, suggesting that the cognitive processes involved may not fully align. Ladányi (2018) proposes that poor reading skills in DLD children may influence the Stroop effect differently. Despite potentially weaker cognitive control, the Stroop effect may not be heightened because reading skills are less automatic than TD peers. This raises questions about the intricate relationship between cognitive control, reading skills, and task demands.

The influence of bilingualism and DLD on executive function is a subject of ongoing debate. While studies such as those by van den Noort et al. (2019) and Ware et al. (2020) suggest a positive impact, bilingual children with DLD face compounded cognitive demands, especially evident when transitioning from congruent to incongruent conditions. For instance, children with DLD may code-switch more frequently due to poor inhibitory control, which might yield differences in the frequency with which they suppress nontarget information activated compared to their TD peers (Spaulding, 2010**).**

### 1.6 EEG, ERP, and N400

To further investigate the neural underpinnings of cognitive and language processing in children with DLD, methodologies such as Electroencephalography (EEG) and Event-Related Potentials (ERPs) provide invaluable insights. EEG, particularly through the lens of ERPs, has emerged as a critical tool in cognitive neuroscience for elucidating the neural substrates of language processing. The N400 component, a hallmark of ERP studies, epitomizes this pursuit. The N400 is a negative deflection in the ERP waveform that peaks at around 400 milliseconds after stimulus onset and has a larger amplitude over the centro-parietal than anterior areas of the scalp (Kutas & Hillyard, 1983). The N400 has generally been associated with semantic processing and is not simply an index of a semantic anomaly: it is a brain response to any meaningful stimuli (Kutas & Federmeier, 2000). Its distribution across the scalp has been found to vary depending on the eliciting stimulus (auditory vs visual; pictures and faces vs words). Moreover, studies using single words suggest that the N400 is associated with difficulty in identifying a string of letters, and the more difficult the recognition process, the larger the N400 amplitude (Barber & Kutas, 2007). Thus, the N400 has been shown to reflect lexical and semantic processes associated with word recognition, being larger whenever a word is more difficult to process or integrate into its surrounding context (Lau, Phillips & Poeppel, 2008).

The analysis of neural activity using ERPs offers many diverse possibilities thanks to the multidimensionality of the data (e.g., temporality, scalp distribution). This fundamentally differs from behavioural measures that typically include only accuracy and reaction times (RTs). To date, research on language processing using ERPs has shed light on the human capacity to understand the complexity of language and to cope with different types of linguistic information including prosodic, phonemic, semantic, syntactic, and pragmatic information, which are necessary for comprehension and production of utterances, and eventually for communication of information (Tendolkar et al., 2005)

### 1.6.1 Lexical Processing, ERP, and N400: Studies in Typically Developing Bilingual and Monolingual Children

For bilingual lexical processing, the application of ERP with a focus on the N400 has shed light on the cerebral mechanics of how bilingual individuals process and integrate lexical items from two distinct linguistic systems (Moreno, Rodríguez-Fornells, & Laine, 2008; Morgan-Short, 2014). Their use in second language learning, however, is more recent and limited, but over the past decade, a remarkable number of studies that look primarily at word learning – including lexical and syntactic processing – have been published (Batterink & Neville, 2014; Ferreira, Román, & Dijkstra, 2018).

Research has consistently demonstrated that bilinguals exhibit distinctive N400 modulations when processing words in their second language (L2), indicative of the unique neural adaptations necessitated by bilingual language comprehension. For instance, the differential N400 responses observed in bilinguals when processing cognates compared to non-cognates highlight the cognitive intricacies in bilingual semantic integration. These modulations in N400 amplitude and latency underscore the influence of factors such as linguistic congruence, cross-linguistic similarities, and language proficiency on bilingual lexical processing (Moreno, Rodríguez-Fornells, & Laine, 2008; Batterink & Neville, 2014; De Diego Balaguer et al., 2005).

ERP studies with monolingual participants have identified factors such as frequency and lexicality influencing the N400 component. Frequency effects typically manifest as a more negative waveform for low-frequency words compared to high-frequency ones, while lexicality affects the N400, with pseudowords eliciting stronger negativity than real words (Braun et al., 2006). Building on the understanding of lexical processing in monolingual individuals, Abel et al. (2018) tested children ages 11-14 years. Presenting pseudowords and familiar words, they observed a heightened N400 response to pseudowords compared to familiar words, shedding light on the distinct N400 patterns associated with the recognition of pseudowords and familiar words in the developing linguistic abilities of children.

For instance, the research by Lehtonen et al. (2012) highlights how Finnish–Swedish bilinguals exhibit an augmented sensitivity to word frequency, morphological structure, and lexicality in visual word recognition tasks compared to their monolingual counterparts. This is evidenced by more pronounced N400-type effects for pseudowords, suggesting a heightened neural response to linguistic stimuli, potentially arising from their varied linguistic exposure and processing demands. Kotz (2001) further contributes to this understanding with a study involving thirty-two participants assigned to either Spanish (L1) or English (L2). The study's findings that both bilingual groups displayed similar N400 effects to nonwords reveal direct access to lexical representations in both languages, challenging the notion of L1 mediation in L2 processing. This equivalence in N400 responses underscores the neural efficiency and adaptability inherent in bilingual language processing.

### 1.6.2 Lexical Processing, ERP, and Developmental Language Disorders (DLD)

While bilingual studies offer invaluable insights, the research on ERP measures in children with Developmental Language Disorders (DLD), though less extensive, is profoundly illuminating. These studies typically reveal variations between TD children and those with DLD in aspects such as ERP latency, duration, scalp distribution, and amplitude.

Understanding these differences is vital, as it sheds light on the distinctive neural pathways involved in language processing in DLD.

One notable study by Miles and Stelmack (1994) delved into the N400 response patterns in children with various learning disabilities, including reading and spelling impairments. The study's significance lies in its exploration of how these disabilities influence semantic processing capabilities, as reflected in the N400 component, a crucial marker of semantic integration. The absence of the N400 effect in these children with learning disabilities could be indicative of impairments in auditory–verbal associative systems, hindering effective semantic integration during the task. This study's findings are particularly relevant in understanding the specific semantic processing difficulties encountered by children with learning disabilities, adding a layer of complexity to our comprehension of developmental language disorders and specific learning impairments.

Further contributing to this field, Fonteneau and van der Lely (2008) investigated the neural responses of children with grammatical DLD (grammatical-specific language disorder) to both syntactic and semantic violations. They showed that semantic violations (i.e., a noun that violated the verb's semantic [animacy] feature selection restrictions in auditorily presented sentences) produced a predicted robust electrophysiological response (N400) in children with DLD, as well as TD children. Violations that relied on structural syntactic dependencies produced a robust early left anterior negativity (ELAN) component in TD children, postulated to index early automatic processing of structural dependencies. The ELAN component was not present in the data obtained from children with DLD, who instead displayed a later N400 in response to these violations (the absence of the ELAN nearly perfectly classified individual children as having DLD). The authors suggested that these results support the presence of selective grammatical deficits in children with grammatical DLD, with the appearance of the N400 indexing "a relative strength in semantic processing" and under this view, children's morphosyntactic deficits are functionally decoupled from their language ability in other (i.e., lexical) domains.

Similarly, Neville, Coffey, Holcomb, and Tallal (1993) found that children, ages 9, with combined DLD and reading disability showed a larger N400 in response to both anomalous and non-anomalous sentence-final words; moreover, the amplitude of the difference waveform (anomalous–non-anomalous) was larger in children with DLD compared to TD children. The findings were interpreted by the authors as indicative of greater compensatory effort required by children with DLD for successful integration of words with context.

Cummings and Čeponienė (2010) presented bimodal stimuli to 16 children with DLD aged 7-15 years. Using visual-auditory presentation of images (e.g., ROOSTER) with verbs (the lexical condition, e.g., crowing) or environmental sounds (e.g., a rooster crowing). The findings revealed intriguing domain-specific disparities in semantic integration abilities. In trials involving environmental sounds, children with DLD demonstrated comparable accuracy and neural responses to semantic incongruencies as their typically developing counterparts, as indicated by similar N400 effects. However, the picture–word trials painted a different picture. Here, children with DLD tended to have lower accuracy rates, and more importantly, they exhibited a significantly delayed N400 effect. This latency in the N400 response was suggestive of a verbal-specific semantic integration deficit.

Malins et al. (2013) investigated ERP responses to words presented in a cross-modal picture–word paradigm to children ages 4-8, with and without DLD. Their study involved an experimental manipulation not only of the degree of the semantic congruency of the presented word but also of the degree of the phonological overlap between the match and the mismatch words. In their study, both groups of children displayed significant N400 effects in response to words that were both semantically and phonologically unrelated to the target match word (e.g., see SHELL, hear "mug"), and an enhanced N400 effect to cohort mismatches (e.g., see DOLL, hear "Dog") that overlapped with the target word initially. In addition, both groups showed a similar earlier phonological mapping negativity (PMN) effect, suggesting that children with DLD are capable of developing online phonological expectations and detecting violations of these expectations. However, only TD children displayed a significant attenuation of the N400 effect in response to rhyme mismatches (e.g., see CONE, hear "Bone"). The lack of this rhyme attenuation effect in the DLD children led the authors to suggest that children with DLD are either not as sensitive to rhyming as TD children (potentially due to problems with establishing robust phonological representations) or are not efficient at suppressing lexical alternatives during spoken-word recognition.

These findings were supported by Pijnacker et al. (2017) who observed N400 onset delays in a group of Dutch children with DLD compared to typically developing children of the same age. In their study, children listened to simple sentences with semantically incongruent final nouns while watching unrelated silent short video clips. The N400 onset for the control group ranged between 300–500 msec, while for the group with DLD, it extended from 500–800 ms. Notably, the N400 response had a broader scalp distribution in the DLD group, in contrast to the more posterior distribution observed in typical children. Furthermore, the study revealed that smaller N400 amplitudes in the DLD group correlated with lower scores on tasks assessing various language and cognitive abilities, including grammar, vocabulary, language comprehension, and nonverbal IQ.

Lastly, Evans et al. (2022) delved into the neural correlates of lexical-phonological and lexical-semantic processing in adolescents with DLD and procedural memory impairment, alongside their TD peers. Notably, an N400 component was elicited in response to semantic incongruency (***Giraffes have long SCISSORS***) in both groups, suggesting a shared mechanism in this aspect of language processing. However, disparities emerged in the localization of the N400. For the

TD groups, this was distributed predominantly over the right hemisphere whereas the adolescents with DLD exhibited a more bilaterally distributed pattern of activation. This could be an indication of qualitative differences in the underlying representations of words in the lexicons of adolescents with DLD.

**1.6.2 Stroop Effect, ERP, and N400: Studies in Bilingual and Monolingual Children**

The application of the Stroop effect in conjunction with Event-Related Potentials (ERP) and the N400 component offers profound insights into cognitive control mechanisms in bilingual and monolingual children. These studies are pivotal in unravelling the complexities of language processing and executive function across diverse linguistic backgrounds.

The intersection of bilingualism, executive control, and language processing presents a nuanced landscape. Bilinguals often demonstrate cognitive advantages due to the demands of managing two languages. This is evidenced in studies by Coderre and Van Heuven (2014), where bilinguals showed enhanced abilities to control interference and select relevant linguistic information, facilitated by the parallel activation of both languages. ERP studies using the Stroop test have been crucial in exploring how bilinguals process colour and word information, revealing differences in cognitive control and language processing. For instance, Naylor, Stanley, and Whicha (2012) explored bilingual language processing and colour congruency in Spanish–English bilinguals using a Stroop test and EEG. The study revealed key findings in the ERP data, particularly the N450 component, in response to colour-word congruence. The N450 effect was pronounced for colour incongruence, with larger negative amplitudes in incongruent trials between 350 and 550 msec post-stimulus onset. This effect, consistent within and between languages, indicated the N450's sensitivity to colour congruence irrespective of the language involved.

Ergen et al. (2014) contributed to this field by conducting a Stroop task with EEG recordings on 23 English-Turkish participants. The stimuli were three colour names in Turkish: “KIRMIZI” (RED), “MAVİ” (BLUE), “YEŞİL” (GREEN). Their ERP data revealed that the N450 negative peak was more pronounced in the incongruent stimuli, especially in the post-stimulus 400–500 msec range, a critical window for observing colour-word interference markers in the Stroop test. Furthermore, the colour-word incongruency-related difference in N450 was maximal over the parietal region, with a more positive late slow potential in the incongruent condition, reaching significance around 600 msec.

Heidlmayr et al. (2015) observed diminished ERP effects in bilinguals compared to monolinguals during a Stroop task, particularly in the N400 and late positive components (LPC). This bilingual advantage, specific to the Stroop task, suggests potential benefits in stages of conflict processing related to interference suppression (N400 effect) and conflict resolution (late sustained negative-going potential). This finding underscores the nuanced nature of the bilingual advantage, emphasizing the importance of specific ERP components in bilingual inhibitory control. Furthermore, Coderre et al. (2014) conducted a study with 25 Chinese-English bilinguals and 28 English monolinguals, examining their responses to a Stroop task in both L1 (Chinese) and L2 (English) while recording EEG data. The results showed a bilingual advantage in conflict processing, with smaller N400 amplitudes in bilinguals compared to monolinguals. However, no significant behavioural conflict-specific bilingual advantage was found when comparing monolinguals to bilinguals in their L1. The ERP data indicated that conflict processing was evaluated via the N400 component, with a slightly more negative N400 amplitude for the bilingual L1 compared to monolinguals, although this difference was not statistically significant.

### 1.6.3 ERP, Stroop and DLD

In the context of bilingualism, the necessity to produce a word in the target language while suppressing the competing non-target language indicates the development of a specialized inhibitory control mechanism (Garbin et al., 2010). This mechanism, which may be language-specific (Green, 1998) or domain-general (Piai et al., 2013), endows bilinguals with enhanced executive control across various tasks, including the Stroop task. Proficiency across languages moderates these benefits, with unbalanced bilinguals relying on inhibitory control to restrict access and balanced bilinguals using a language-specific selection mechanism to manage cross-language interference.

Liu et al. (2014) studied children with DLD while performing a colour-word stroop task, and found that these children might experience difficulties in suppressing irrelevant information due to an inefficient inhibitory control mechanism. The study revealed larger N450 amplitudes in the incongruent condition, suggesting increased processing effort. Additionally, an interaction between brain region and group was noted, with DLD children showing more negative amplitudes in the frontal region and more positive amplitudes in the occipital region than controls. This pattern might indicate compensatory brain functions in DLD children, employing additional cognitive resources for interference control. Interestingly, the study also observed larger N450 amplitudes in DLD children in both congruent and incongruent conditions, prompting questions about the N450's role in cognitive processes beyond interference control.

The interplay of the Stroop effect, ERP data, and the N400 component in the context of bilingualism and DLD underscores the multifaceted nature of cognitive control and language processing. The enhanced N450 and N400 responses in bilingual individuals during Stroop tasks reflect their refined inhibitory control mechanisms, honed by the demands of navigating dual-language systems. These findings not only illuminate the cognitive advantages inherent in bilingualism but also reveal the intricate dynamics of executive functioning in language processing.

**1.7 Summary**

The literature review has explored the realms of bilingualism, Developmental Language Disorder (DLD), and their impact on cognitive development and executive functions in children. This synthesis of the existing literature provides a comprehensive understanding of the current state of research in these interconnected areas. The review began with an in-depth look at bilingualism's effects on lexical processing, drawing on studies by researchers such as Kroll et al. (2015) and McGregor et al. (2013). It highlighted the unique challenges bilingual children face, particularly those with DLD. These challenges are not just in terms of language acquisition but also in the intricacies of managing two linguistic systems. The research suggests that while bilingualism can complicate lexical development, it does not inherently impede the learning process, even for children with DLD. This challenges previous assumptions about bilingualism's negative impact on language disorders. A significant portion of the review focused on DLD, delving into its characteristics and how it manifests in both monolingual and bilingual children. Studies by Bishop (2014) and Leonard (2017) provided insights into the cognitive deficits associated with DLD, including issues with working memory, processing speed, and executive functions. This section underscored the importance of early and accurate diagnosis and intervention, which are crucial for supporting children with DLD.

Another key theme explored was the role of executive functions and cognitive control in bilingual children, particularly those with DLD. Research by Gathercole et al. (2004) and Woodard et al. (2016) was instrumental in demonstrating how bilingual experiences can shape these cognitive skills. The review highlighted that bilingual children with DLD might develop unique cognitive strategies to manage complex tasks, which emphasizes the adaptive nature of their cognitive processes. The literature review also encompassed the advancements in EEG and ERP methodologies, focusing on the N400 component. The works of Moreno et al. (2008) and Batterink & Neville (2014) were pivotal in illustrating the distinct neural mechanisms involved in bilingual language comprehension. These studies reveal how children with DLD, in particular, show divergent N400 responses, indicating atypical lexical processing pathways and underscoring the need for targeted research and intervention strategies in bilingual contexts.

The literature review presented a multi-dimensional perspective on the interplay between bilingualism, DLD, and executive functions in children. It emphasized the need for further research to unravel the complex dynamics of bilingualism and DLD, particularly in the context of cognitive development and executive functions. This review sets the foundation for the subsequent investigation in this dissertation, aiming to contribute new insights and perspectives to this vital field of study.

## 2 Methods

This dissertation embarks on an in-depth exploration of the complex interplay between bilingualism and Developmental Language Disorder (DLD), focusing on lexical processing and executive functions. Integrating an array of methodologies, including Event-Related Potentials (ERPs) emphasising the N400 component, alongside behavioural analysis such as reaction times (RTs), this research aims to dissect the intricate cognitive landscapes of bilingual and monolingual children, both with and without DLD. By challenging and expanding existing paradigms, the dissertation aspires to pioneer new insights and understandings in bilingual language development.

The following section will describe the methods for the whole project, including group description, materials, stimuli, procedure, and the aim/hypothesis of each paper. Additionally, each paper will be individually outlined to provide a comprehensive understanding of the methodologies employed and the specific research objectives addressed.

### 2.1 Participants

The participant groups for this project remained constant throughout three subsequent studies, each designed to address distinct research questions. This consistent approach ensures that comparisons across studies are robust and meaningful.

- The first study contrasts Bilingual Typically Developing (TD) and Monolingual TD groups to explore how bilingualism influences cognitive control and lexical processing in typically developing children.
- The second study delves into the interaction between bilingualism and DLD by comparing Bilingual DLD to Bilingual TD groups—the same Bilingual TD participants as in the first paper.

- The third and final study focuses on the differential impacts of bilingual and monolingual environments on children with DLD, comparing Monolingual DLD against Bilingual DLD children, using the same Bilingual DLD participants from the second paper.

A total of 130 Chilean children, ages 7-10 years (mean = 8.3 years, SD = 1.11), participated in this study. The cohort was divided into four distinct groups: Bilingual Developmental Language Disorder (Bilingual DLD), Bilingual Typically Developing (Bilingual TD), Monolingual Developmental Language Disorder (Monolingual DLD), and Monolingual Typically Developing (Monolingual TD). All participants were native Spanish speakers. For those in the bilingual groups, English was as their second language, and each group will be described in detail in the following sections.

In compliance with ethical standards, consent was obtained from parents or guardians before participation, followed by the completion of a questionnaire (detailed in Appendix 1). This questionnaire collected essential background information, including the educational backgrounds of the parents or guardians, the primary language(s) spoken within the household, and sibling presence. The University of Essex Social Sciences Ethics Sub-Committee granted full ethical approval for the study, ensuring that all necessary ethical considerations were addressed.

Testing for all groups was conducted from May to August 2021, subsequent to the national Covid-19 lockdown in Chile, which spanned from April 2020 to April 2021. Furthermore, at the time of testing, all participants had resumed full-time education, with an average of two months back in school, providing a stable basis for our assessment. It is crucial to acknowledge the implementation of the "inclusion law" in Chile in 2016, mandating the integration of students with special educational needs—such as Autism, Dyslexia, DLD, Down syndrome, and others—into mainstream education. This law states that public schools must provide specialized educational support, including access to special education teachers, speech, and language therapists (SLTs), and psychologists. Notably, while this legislation directly applies to public educational institutions, private schools are eligible for funding to employ bilingual SLTs for their students.

Prior to inclusion in the study, children in the Bilingual DLD and Monolingual DLD groups underwent clinical assessments by an SLT but also, by the SLTs at the school, based on standard guidelines dictated by the Chilean Ministry of Education (Decree-Law N170, 2010)[1]. These guidelines follow the same criteria for clinical diagnoses as stated in the International Statistical Classification of Diseases and Related Health Problems (11th Ed.; ICD-11; World Health Organization, 2019) and the Diagnostic and Statistical Manual of Mental Disorders (5th Ed.; DSM-5; American Psychiatric Association, 2013). The diagnosis was shared upon the consent of parents or caregivers. Participants with an additional diagnosis of Autism, ADHD, Dyslexia, or Dyscalculia were explicitly excluded. Given the native Spanish-speaking background of all participants and the homogeneous nature of the cohort regarding their first language, a formal assessment of Spanish language proficiency was deemed unnecessary.

However, to rigorously account for potential confounding factors influencing language development and cognitive processing, several key variables were included as covariates in our statistical models. These included socioeconomic status (SES), derived from the educational levels of parents or guardians and Nonverbal IQ. English proficiency was specifically included as a covariate for the analyses in paper 2, acknowledging the critical role of second language skills in our examination of bilingualism's impacts. Age and sex were also considered as

[1] https://especial.mineduc.cl/normativa/decretos-e-instructivos/

standard covariates across all analyses to ensure a comprehensive control for demographic influences.

This methodological approach aimed to mitigate the influence of variability in language proficiency and educational experiences, enabling a focused examination of bilingualism's and DLD's specific effects. Despite our rigorous efforts to maintain balanced comparisons between groups, we recognize the possibility that unaccounted variables might influence our results. For instance, factors such as the quality of bilingual instruction, extent of engagement in language-rich activities outside of school, and individual differences in language learning aptitude represent avenues for further exploration. These elements could offer additional insights into the complexities of bilingual development and how it intersects with linguistic and cognitive outcomes in children with DLD.

### 2.1.1 Bilingual TD group

The Bilingual TD group consisted of 32 participants (18 girls and 14 boys) from three diverse bilingual schools in Chile, where English instruction commenced from kindergarten (age 4) onwards. The majority (26 children) began their education in these settings in kindergarten, with a few exceptions[2] joining later. Parents/carers of the Bilingual TD group were native Spanish speakers, with 90% holding undergraduate degrees and the remaining 10% possessing either an MA or a PhD. All participants were right-handed, with two requiring glasses. Information regarding SES, L2 proficiency, IQ, etc, can be found on table 1.

### 2.1.2 Bilingual DLD group

The Bilingual DLD group comprised 36 participants (21 girls and 15 boys), selected from the same bilingual schools as the Bilingual TD group. This group had similar initial conditions in terms of the age of exposure to English and the educational environment. Thirty participants

[2] Four participants joined in year 1 after being home-schooled. Two participants, with prior education in bilingual schools (kindergarten and year 1), transferred from a different city in years 2 and 3.

initiated their educational journey in these bilingual schools in kindergarten, while the remaining six students joined in year 1. Additionally, six students attended nurseries with prior instruction in English. In addition to their school-based English exposure, 30 participants attended weekly speech and language therapy sessions in Spanish and additional bilingual SLT support within the school setting, highlighting the specialized support provided to accommodate their developmental language needs.

The participants in the Bilingual DLD group also underwent SLT assessments to confirm their DLD diagnosis, ensuring that their inclusion was based on specific language development criteria. Moreover, all children had a reported Non-Verbal IQ above 70. Among the participants, five had siblings diagnosed with Developmental Language Disorder (DLD), and none of the parents or caregivers reported diagnoses of Autism, Attention Deficit Hyperactivity Disorder (ADHD), Dyslexia, or Dyscalculia. Parents/carers of these participants were all native Spanish speakers, with 85% holding an undergraduate degree, 5% holding an MA or PhD, and the remining 10% hold a BTEC degree. All participants were right-handed, with eight of them wearing glasses. For a more detailed information regarding participants IQ, L2 proficiency, this is on table 1.

On average, both TD and DLD children were exposed to English for about 30-35 hours per week through formal education. This exposure was augmented by after-school activities and private tutoring in English and Mathematics[3], ensuring a comprehensive and robust bilingual experience. English proficiency was assessed using the “Cambridge English: Pre-A1 starters,” a basic level test designed for young learners. This test requires children to demonstrate their ability to recognize colours, answer personal questions, and provide one-word responses, offering a standardized measure of early English language skills. Importantly, the assessment

[3] This was for all the participants, with an average of 2 hours per week of extracurricular activities.

does not operate on a pass/fail basis but rather awards up to five shields for competency recognition. All children, both in the Bilingual TD and DLD groups, undertook this test upon transitioning from Kindergarten to Year 1, establishing a baseline of English understanding pertinent to their age and educational background. Results indicated that children demonstrated a proficiency level that was consistent with their age and educational exposure. On average, both groups achieved a mean score of 3.50 (SD=0.80), as detailed in table 1. This score signifies a solid foundational understanding of English, aligned with their extensive exposure and the educational strategies employed to support their bilingual development.

It is important to note that both the Bilingual TD and DLD groups scored similarly on the English proficiency test. This might seem surprising, as TD and DLD children typically exhibit distinct cognitive and linguistic profiles. However, the "Cambridge English: Pre-A1 Starters" test primarily assesses basic language skills through structured prompts, which may not capture the more complex language processing deficits characteristic of DLD. The similar scores reflect the robust English language instruction all participants received rather than indicating equivalent language processing skills across complex linguistic contexts. This underscores the necessity for employing more discriminating assessments in future studies to differentiate language processing abilities more effectively.

The transition to homeschooling during the COVID-19 pandemic presented an unprecedented challenge to maintaining the consistency and intensity of bilingual exposure. Despite these disruptions, efforts were made to continue English language learning at home to the best extent possible, through various home-based learning activities, as reported by parents. This engagement helped mitigate potential regressions in language proficiency. The full-time return to school at the time of testing allowed for a re-immersion in the English-speaking educational environment, though future analyses will need to carefully consider the potential impacts of this period on language proficiency and development. By the time of testing (May to August

2021), all participants had returned to full-time education, with the schools operating normally following the easing of lockdown measures, with the school day ranging from 8:30 am to 4:15 pm.

The decision for parents to enrol their children in bilingual education is significantly influenced by broader societal and economic trends in Chile. Recognizing English as a critical asset for academic and professional advancement in the global job market motivates many parents. This inclination reflects a societal shift towards valuing bilingualism to enhance cognitive flexibility, cultural awareness, and secure advantages in a globalized world. Moreover, the socio-economic status (SES) and educational levels of parents play a crucial role in these educational choices. Parents in bilingual groups, often with higher SES and education levels, are driven by aspirations for upward mobility and a global outlook. They see bilingual education as a strategic decision to enhance their children's future educational and career opportunities. Understanding these motivations highlights the intersection of socio-economic factors with the pursuit of bilingualism as a pathway to cultural and economic success.

### 2.1.3 Monolingual TD group

The Monolingual TD group consisted of 30 children, including 13 girls and 17 boys, recruited from four different public schools in Chile. This group diverged notably from its bilingual counterparts by receiving only six hours of English instruction per week in a standard public-school setting. The initiation of formal education varied within this group; only nine participants started at the age of 4 in kindergarten, primarily due to the absence of nursery facilities or policies in public schools regarding the minimum age for enrolment. Consequently, the remaining 21 participants attended nursery until eligible for Year 1. Parents and caregivers in this group were native Spanish speakers, with a distinct educational background compared to the bilingual groups. Parental backgrounds across the groups presented a varied educational landscape, with a minority of Monolingual TD parents holding undergraduate degree, with only

3 having pursued undergraduate degrees, and the remaining 27 not having attended university for bachelor's degrees. Additionally, 4 parents completed apprenticeships.

### 2.1.4 Monolingual DLD group

The Monolingual DLD group encompassed 33 participants, with 20 girls and 13 boys, all native Spanish speakers, recruited from four different public schools in Chile. The majority, 28 participants, began their educational journey at the age of 4, with the remaining five joining in Year 1. Reflecting a typical public-school curriculum, these students received about six hours of English instruction per week from kindergarten onwards. Significant support was extended to the Monolingual DLD participants in line with the "schooling inclusion law" of 2016, facilitating access to two hours of weekly sessions with school-based speech and language therapists (SLTs). Additional external SLT sessions were provided for four participants. Family dynamics within the Monolingual DLD group revealed a spectrum of developmental conditions, including siblings with DLD and Down's syndrome and two parents reported a previous diagnosis of Attention Deficit Hyperactivity Disorder (ADHD). Parents/carer of the MDLD group, were all High School graduates, with 6 of them pursuing undergraduate education. At the time of testing, participants from both groups attended school on a pre-lockdown basis, with school day ranging from 8:30 am to 3:45 pm. Furthermore, extracurricular activities for both groups included English academies, with 8 Monolingual DLD and 10 Monolingual TD attending 2 hours a week.

**Table1: Participants demographic information.**

SES (parental education) information was coded following the International Standard Classification of Education (ISCED; UNESCO Institute for Statistics, 2012). This ranged from 0 (less than primary education) to 8 (doctoral or equivalent).

| Group/Variable | Bilingual TD | Bilingual DLD | Monolingual TD | Monolingual DLD |
|---|---|---|---|---|
| **Participants** | 32 | 36 | 30 | 33 |
| **Age (Years)** | M=8.31, SD=1.07 | M=8.30 SD=1.15 | M=8.30, SD=1.10 | M=8.30, SD=1.10 |
| **Sex** | 18Girls, 14 Boys | 21Girls, 15Boys | 13 Girls, 17 Boys | 20 Girls, 13 Boys |
| **SES (Parental Education)** | M=6.13, SD=0.49 | M=6.11, SD=0.57 | M=4.33, SD=0.74 | M=4.24, SD=0.65 |
| **Non-verbal IQ** | M=91.73, SD=4.35 | M=89.39, SD=4.76 | M=90.69, SD=4.09 | M=85.03, SD=3.64 |
| **L2 Proficiency** | M=3.59, SD=0.79 | M=3.50, SD=0.84 | N/A | N/A |

## 2.2 Materials and Stimuli

### 2.2.1 Lexical Decision Task (LDT)

The Lexical Decision Task (LDT) is integral to this study, grounded in foundational theories of lexical-semantic networks (Collins and Loftus, 1975) and informed by contemporary insights into lexical processing dynamics (Nation, 2014). This task was chosen to understand the impact of Developmental Language Disorder (DLD) on lexical processing, involving significant challenges in language acquisition and use, as described by Bishop et al. (2017). The LDT aims to uncover how these linguistic challenges manifest differently in bilingual and monolingual children. In bilingual contexts, the LDT explores how a second language influences first-language lexical processing and vice versa, offering insights into the cognitive flexibility of bilingual individuals. This exploration is crucial for understanding the intersection of bilingualism and DLD, aiming to discern if and how bilingualism modulates the linguistic challenges inherent in DLD.

Including English and Spanish words, along with nonwords, facilitates a direct assessment of bilingual lexical access, reflecting research by Bialystok et al. (2012) and Kroll and Stewart (1994). This approach allows for detailed comparisons across bilingual TD (typically developing), bilingual DLD, and their monolingual counterparts, shedding light on the potential cognitive and linguistic advantages or disadvantages conferred by bilingualism. The LDT's inclusion of nonwords also helps isolate lexical access and processing efficiency, further elucidating the linguistic capabilities of children with DLD compared to their typically developing peers.

### 2.2.2 Nonword Generator

In the Lexical Decision Task (LDT), nonwords were created using the SCOPE Lab Nonword Generator[4], and designed to produce stimuli that do not resemble real words in either English and Spanish, both phonologically and orthographically. Opting for nonwords over pseudowords is essential. Nonwords do not trigger the lexical access processes typically associated with known words. This processing is necessary to determine their nonword status, involving a deeper level of cognitive engagement that is distinctly different from the recognition processes activated by pseudowords. Using nonwords ensures that our task accurately measures the ability to categorize and process linguistic stimuli based solely on the structure presented during the test, without interference from pre-existing word knowledge. This approach also helps in assessing true lexical decision-making abilities, as participants cannot rely on familiar linguistic cues. The generator's customization features allow for precise control over phoneme selection, orthographic patterns, and character length. This precision

[4] https://sc.edu/study/colleges_schools/artsandsciences/psychology/research_clinical_facilities/scope/generate.php

ensures that the nonwords are appropriately challenging yet accessible for our diverse participants. Examples of nonwords include "AALKN" and "FWNOL," which are specifically designed to prevent any recognition bias that could arise from familiarity with the linguistic features of the participants' known languages, thereby eliminating any potential advantage bilingual individuals might have in recognizing nonwords that resemble English or Spanish structures.

### 2.2.3 Bilingual Task Version

For the Bilingual version of the task, participants were presented with a total of 80 stimuli, consisting of 40 nonwords, 20 Spanish words, and 20 English words. In designing the Spanish words, special characters such as <ñ> or accents like those in **"más"** (more) or **"música"** (music) were deliberately excluded. This decision was crucial not only for consistency with nonwords, which also lack special characters, but more importantly, to ensure that the task challenges the participants' lexical processing abilities rather than relying on visual cues for language identification. By removing these distinctive orthographic markers, we prevent participants from making quick visual identifications of the words' language origin, which could otherwise lead to a superficial categorization based purely on appearance rather than deeper lexical processing. This measure aligns with our goal to assess true lexical access, where each decision on word or nonword status requires cognitive processing of the linguistic content without shortcuts through visual identification.

English words used in this task were selected from the "English Syllabus for primary schools"[5] utilized in Chile, with their Spanish version[6] adapted accordingly. The selected stimuli, (English, Spanish and NonWords) had a character length ranging from 5 to 7 characters (mean

[5] https://www.curriculumnacional.cl/portal/EducacionGeneral/Ingles-Propuesta-curricular/

[6] https://www.curriculumnacional.cl/portal/Educacion-General/Lenguaje-y-comunicacion-Lengua-y-literatura/

= 6.12, SD = 0.74). The Spanish words included familiar terms such as helado (ice cream), flores (flowers), galleta (biscuit), among others, and English words included words such as house, mother or chicken. (For list of stimuli, refer to appendix 2). Direct translations were excluded, which means that if “chicken” was included as an English word, its Spanish equivalent “gallina” was excluded. This choice was made to prevent any bias or advantage that could arise from recognizing the same concept in both languages, which might inadvertently affect lexical processing speed or accuracy due to familiarity rather than linguistic or cognitive ability. By excluding direct translations from the list of English and Spanish words presented to the bilingual group, we aimed to ensure that each lexical decision was based on the participant's ability to process each word as a unique lexical item, thereby providing a more accurate measure of bilingual lexical access and semantic processing abilities.

### 2.2.4 Monolingual Task Version

The monolingual version adapted the bilingual structure for participants who speak only Spanish, maintaining a total of 80 stimuli. It comprised 40 Spanish words and 40 nonwords, excluding any English words. This parallel structure was essential for a fair comparison of lexical decision-making abilities across groups, ensuring that participants faced a comparable lexical challenge within their linguistic capabilities. The selection and presentation of Spanish words were designed to ensure that both bilingual and monolingual participants encountered similar lexical challenges. For bilingual participants, the addition of English words introduced an extra layer of complexity while maintaining an equivalent number of stimuli across both groups. This methodological approach allowed us to make balanced comparisons in lexical decision-making abilities without the undue influence of repeated or directly translated words.

### 2.3.1 Stroop Task

The Stroop Task, introduced by John Ridley Stroop in 1935, is central to this study due to its proven effectiveness in analysing cognitive flexibility and inhibitory control—key components of executive function (Stroop, 1935). This task is particularly valuable in identifying how these cognitive processes manifest among bilingual and monolingual children, both with and without Developmental Language Disorder (DLD). It provides a direct measure of executive control, distinctly separating it from the lexical access investigated through the Lexical Decision Task (LDT). For bilingual children, especially those with DLD, the Stroop Task illuminates how dual-language challenges affect executive control, potentially highlighting differences in cognitive flexibility and inhibitory control influenced by bilingualism. Conversely, for monolingual children, the task isolates executive function deficits specific to DLD, clarifying the impact of the disorder on cognitive control mechanisms. Through the Stroop Task, the study explores how executive functions like inhibitory control and attentional shifting interact with linguistic deficits characteristic of DLD.

Research indicates that the enhanced executive control observed in bilinguals might mitigate some cognitive challenges associated with DLD, suggesting a potential bilingual advantage (Bialystok, 2012; Miyake et al., 2000). This task is crucial in assessing the interplay between bilingualism, executive functioning, and DLD, offering a detailed view of cognitive processing across diverse participant groups. Employing a colour-word Stroop Task with manual responses ensures that findings reflect the participants' true cognitive processing abilities, free from verbal response biases.

Importantly, our approach through the Stroop Task is not aimed at confirming or negating the bilingual advantage theory outright. Instead, it seeks to explore executive functioning across various dimensions—whether domain-specific, task-dependent, or potentially influenced by language. This exploration is vital for painting a comprehensive picture of the cognitive landscapes navigated by both bilingual and monolingual individuals, particularly those contending with DLD.

### 2.3.2 Bilingual Stroop Task

The bilingual version of the Stroop Task was designed to present colour names in both the participants' native language (Spanish) and their second language (English), introducing a dual-language challenge that adds a layer of cognitive complexity. This task required participants not only to suppress the automated response to read the word but also to navigate between two linguistic systems, thereby engaging cognitive control mechanisms more intensively. The task utilized a nonverbal response format, where participants indicated their answers by pressing keys on a colour-coded keyboard corresponding to the colour of the text, rather than articulating their responses. This response format was chosen to concentrate assessment on cognitive control by eliminating the confounding factor of language production, making the task suitable for children with DLD. The task comprised 90 trials, divided equally between congruent (e.g., the word "RED" printed in red) and incongruent (e.g., the word "GREEN" printed in red) conditions, using the colours **RED**, **GREEN**, **YELLOW**, and **BLUE**, and their corresponding translations in Spanish.

### 2.3.3 Monolingual Stroop Task

The monolingual Stroop Task was conducted entirely in Spanish. This adaptation allowed for a direct assessment of inhibitory control and cognitive flexibility within a monolingual framework, isolating these cognitive processes from the bilingualism's complexities. Like the bilingual version, this task utilized a nonverbal response format to ensure that differences in executive function could be attributed to cognitive processes rather than language production abilities. The monolingual task also consisted of 90 trials, maintaining a balanced measure of cognitive control abilities across participant groups. This direct comparison is crucial for elucidating the cognitive impacts of bilingualism, offering insights into how managing two languages influences executive functioning.

The inclusion of the Stroop Task in this study serves as a critical tool for examining the subtleties of executive function—specifically cognitive flexibility and inhibitory control—across bilingual and monolingual children, with and without Developmental Language Disorder (DLD). This task uniquely allows for an exploration of how executive functioning might differ across linguistic backgrounds and developmental conditions, without presupposing a bilingual advantage.

### 2.4 Procedure Lexical Decision Task (LDT) and Stroop Task

#### 2.4.1 Experiment Procedure

The testing occurred in a quiet and unoccupied classroom at each school, selected to create an optimal environment for participant focus and to minimize potential disruptions and noise that might affect performance. To prevent electrical interference, the classroom lights were turned off during the experiments. Stimuli were designed and presented using PsychoPy software (Peirce et al., 2019) on an ASUS ZenBook laptop. The laptop was positioned in front of the participants, who remained comfortably seated throughout the entire experiment.

In the lexical decision task, stimuli were displayed on a black background with a white 20-point Arial font (see Figure 1 for the experiment layout). Responses were recorded using the laptop keyboard. Clear and comprehensive oral and written instructions were provided in Spanish to ensure maximum understanding of the tasks. This procedure, which aimed to create a standardized and controlled environment for data collection, took around 45 minutes to complete. For the Stroop task, stimuli appeared in green, red, yellow, and blue 20-point Arial font on a black background (see Figure 2 for the experiment layout). Participants recorded their responses using the laptop keyboard. Detailed oral and written instructions were provided in Spanish to ensure full comprehension of the tasks. The entire procedure took approximately 45 minutes to complete.

### 2.4.2 Lexical Decision Task

During the lexical decision task, participants were tasked with categorizing stimuli as either words or non-words. The initial practice trials consisted of eight stimuli, four words and four non-words. Following the practice trials, participants were asked about their comprehension of the task. In cases of a negative response, instructions were repeated, and participants were allowed to repeat the practice trials. The experimental task was divided into two blocks, each comprising 40 stimuli presented in a randomized order. For the bilingual version, each block included 10 English words, 10 Spanish words, and 20 non-words. The monolingual version included 20 Spanish words and 20 non-words in each block. (Refer to section 2.2.1 for more information regarding each task).

After completing the first block, participants were permitted a short break before proceeding to the second block. The testing sequence was the same for both groups and each trial commenced with a fixation cross displayed centrally for 1000 milliseconds, succeeded by a stimulus shown for 3000 milliseconds. Subsequent to the stimulus presentation, a response screen prompted the participant to classify the item as a word or non-word by pressing the 'A' (words) or 'L'(nonwords) key, respectively. This response screen remained visible for up to 3000 milliseconds, allowing for participant reaction. Once a response is recorded, the stimulus immediately disappears, and the stimulus was not displayed during this response period. Participants were instructed to press the key as quickly and accurately as they could, with the next trial automatically initiated if no response was recorded within the 3-second interval.

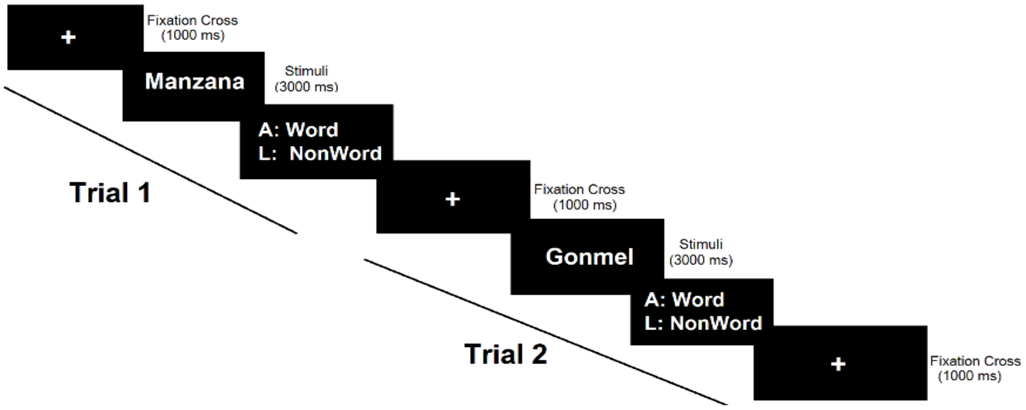



**Figure 1:** Lexical decision task layout

### 2.4.3 Stroop Task

The Stroop task was administered following the lexical decision task, with a short break between the two tasks. Similar to the lexical decision task, all participants (Bilingual and Monolingual) underwent an 8-stimuli practice trial for the Stroop task, comprising 4 congruent and 4 incongruent items. After the practice trial, participants were asked if they understood the task. If their response was 'no,' additional instructions were provided, and participants repeated the practice trial to ensure comprehension.

As in the lexical decision, two version of the task were created, one for monolingual and one for bilinguals (refer to section 2.3.2 for more information regarding each task). The task comprised a total of 90 trials, divided in 3 blocks (30 stimuli per block) and each block encompassing 15 incongruent and 15 congruent conditions. Colours utilized in this task were RED, GREEN, YELLOW, and BLUE, with their corresponding translations in Spanish. The testing sequence commenced with a fixation cross displayed on the screen for 1 second, followed by the presentation of the priming condition lasting for 2.5 seconds and the subsequent Stroop sequence, presented on screen for 3 seconds.  For the Stroop sequence, participants were required to press the corresponding colour on the keyboard for each sequence. To facilitate this, coloured squares were placed on the keyboard, and participants were instructed to press them as quickly and accurately as possible, with the next trial automatically initiated if no response was recorded within the 3-second interval.

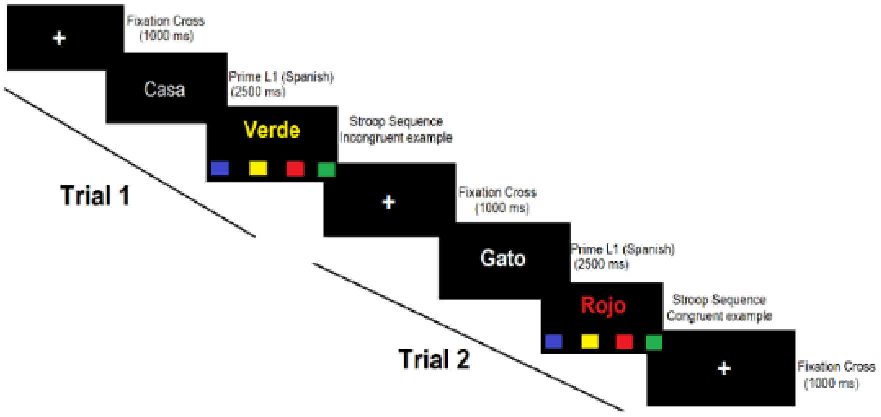



**Figure 2:** Stroop task layout

### 2.4.4 Priming

In our study, the priming phase was primarily used to activate the general lexical system before administering the Stroop task. This activation involved presenting participants with Spanish words for 2.5 seconds to uniformly engage the lexical networks of all participants, whose first language is Spanish. This standardized approach was intended to ensure that any cognitive activation was as uniform as possible across the sample, helping to stabilize the starting cognitive conditions before measuring executive control. The use of Spanish for priming is consistent with the participants' native language, simplifying the cognitive setup. While our priming phase focused on the potential interference effects from L1 to L2, it essentially served to establish a baseline activation of the lexical network. This setup limits our ability to extensively analyse different types of priming or their specific effects on bilingual cognitive processing.

It is important to note that this phase is not designed to provide a comprehensive analysis of linguistic activation's effects on subsequent task performance, especially in the contexts of bilingualism and Developmental Language Disorder (DLD). Instead, it offers a preliminary look at how general lexical activation may influence cognitive control strategies within a controlled experimental setting. Given the scope and limitations of our study, findings related to this specific priming setup should be interpreted with caution, as they do not explore broader types of linguistic priming or include comparative priming conditions. While the priming phase helps in understanding the interplay between language processing and executive control, the effects of the primes were not analysed in the main results of this study. This decision was made to maintain focus on the core cognitive control processes of the Stroop task. However, the potential influence of priming on task performance remains a valuable topic for future research. Investigating how different priming conditions affect the performance of bilinguals and individuals with DLD could provide deeper insights into the cognitive strategies used to navigate linguistic and cognitive challenges, potentially enriching our understanding of the bilingual advantage hypothesis and the cognitive profiles associated with DLD.

### 2.4.5 EGG Procedure

The EEG procedure for both the lexical decision and Stroop tasks adhered to a consistent protocol for all participants. EEG signals were acquired using the BioSemi system 32, featuring 32 Ag-AgCl scalp electrodes positioned in accordance with the 10-20 system. These electrodes covered specific regions of the scalp, enabling comprehensive neural signal recording. The two mastoid electrodes served as a reference for the EEG recordings. Additionally, ocular movements were recorded using three electrodes strategically placed around the eyes. While this ocular data was captured, it was intentionally omitted from the analysis. EEG data was transmitted to a BioSemi Active Two amplifier box, and ERP triggers were coded using PsychoPy3 (Peirce et al., 2019). Continuous monitoring of outputs was maintained in BioSemi Actiview throughout each session. If electrode adjustments were deemed necessary, these were carried out during designated breaks in the experiment.

**2.5 Implications of using both tasks**

The simultaneous use of the Lexical Decision Task (LDT) and the Stroop Task enables a comprehensive evaluation of Developmental Language Disorder (DLD), bridging linguistic processing and executive control. This dual-task methodology uncovers the distinctive manifestations of DLD across cognitive and linguistic functions and highlights the potential of bilingualism to modulate these effects. Through detailed comparisons, it illuminates the interplay between DLD and bilingualism, offering insights into areas of resilience or vulnerability provided by bilingual experiences. This approach allows for conclusions about the protective or compensatory effects of bilingualism against the linguistic challenges associated with DLD. For typically developing children, both bilingual and monolingual, these tasks provide critical insights into the debated 'bilingual advantage' in executive functioning. By examining task performance across groups, we contribute to the ongoing discourse on how bilingualism impacts cognitive and linguistic processing differently from monolingualism.

The rationale behind using both tasks lies in their complementary strengths. The LDT offers insights into linguistic processing challenges characteristic of DLD, while the Stroop Task provides an understanding of cognitive control challenges. Together, they offer a nuanced understanding of DLD beyond what either task could achieve alone, highlighting the importance of considering both linguistic and executive functions. Our study also aims to bridge the research gap concerning the interaction between executive functions and linguistic abilities, particularly in bilingualism and DLD. In essence, our approach enriches our understanding of how executive functioning intersects with linguistic processing and bilingual experiences, providing significant insights into the complex interplay between language experience, executive function, and cognitive processing across diverse linguistic environments.

### 2.5.1 Integrating ERPs with Behavioural Data

Event-Related Potentials (ERPs), derived from EEG recordings, represent brain responses to specific sensory, cognitive, or motor events. By measuring ERPs, we can assess neural activities associated with different stages of cognitive processing. Incorporating ERPs, particularly the N400 component, into our study enhances our analysis by bridging observable behavioural outcomes and the underlying cognitive mechanisms. While reaction times from tasks like the LDT and Stroop Task provide valuable insights into cognitive processing efficiency, they do not illuminate the cognitive processes at work. ERPs allow us to examine these processes in real-time, offering a dynamic view of semantic processing and executive control (Kutas & Federmeier, 2011).

Integrating ERPs with behavioural data enables a nuanced exploration of potential differences in cognitive and linguistic processing strategies between groups. For instance, while behavioural data might show similar task performance outcomes between groups, ERP data can reveal distinct neural processing pathways through differences in amplitude, latency, or distribution of the N400. Such distinctions are crucial for understanding cognitive differences underlying language and executive functions in both bilingual and monolingual individuals with and without DLD (Steinhauer & Connolly, 2008). This multimodal approach enriches our investigation by examining how bilingualism influences neural mechanisms underlying language processing and executive functioning. This is crucial for assessing whether bilingual experiences confer specific processing advantages or present unique challenges, especially in the context of DLD (Bialystok, 2012; Kroll & Bialystok, 2013). By leveraging the complementary strengths of ERPs and behavioural measures, our study advances our understanding of the neural bases of language and executive function, and the cognitive benefits and challenges associated with bilingualism and DLD. This integration allows us to draw more comprehensive and accurate conclusions about the cognitive and linguistic processes involved, thereby enhancing the robustness and depth of our findings.

## 2.6 Research Aim and Hypothesis

### 2.6.1 Overarching Aims

The overarching goal of this dissertation is to examine the complex interplay between bilingualism and Developmental Language Disorder (DLD), exploring how bilingualism influences cognitive and linguistic processing in children with and without DLD. This research aims to outline how bilingual experiences might enhance or complicate language and cognitive functions, contributing new insights into bilingual language development and DLD.

### 2.6.2 Study-Specific Aims and Hypotheses:

**Study 1:** Language Complexity Unveiled: Lexical Processing and Stroop Effect in Bilingual and Monolingual Children

**Aim:** This study seeks to understand the specific impacts of bilingualism on cognitive control and lexical processing in typically developing children. Through an in-depth analysis of RTs and N400 components during lexical decision and Stroop tasks, the study aspires to illuminate the differences of bilinguals' cognitive and lexical demands, when compared to their monolingual peers.

**Hypothesis:** Bilingual children are expected to exhibit longer RTs and larger N400 amplitudes compared to monolingual peers in tasks requiring high linguistic and executive functioning. This reflects the additional complexity and effort involved in managing dual-language systems, challenging the conventional notion of a consistent bilingual cognitive advantage. This hypothesis is supported by research from Ivanova & Costa (2008), Gollan & Ferreira (2009), and Bialystok et al. (2012).

**Study 2:** Insights into Bilingual Minds: Lexical Processing and Cognitive Control in Developmental Language Disorder

**Aim:** This study aims to explore the interplay between bilingualism and Developmental Language Disorder (DLD) by examining lexical processing and executive function abilities in bilingual children with and without DLD. The research will investigate how bilingualism may either compound or alleviate the cognitive and lexical processing challenges associated with DLD.

**Hypothesis:** It is anticipated that bilingual children with DLD will demonstrate pronounced challenges in processing nonwords and in their L2, potentially resulting in extended RTs and distinctive N400 responses. These challenges highlight the complex dynamics of managing two linguistic systems under the cognitive constraints of DLD. In the Stroop task, bilingual children with DLD are expected to exhibit greater difficulties in conflict resolution, reflecting compromised executive functions. This hypothesis draws on the work of Paradis, Schneider, & Duncan (2013) and Genesee, Paradis, & Crago (2004). This study will evaluate whether bilingualism exacerbates or mitigates the linguistic and cognitive complexities inherent in DLD, contributing to a deeper understanding of how bilingualism interacts with language disorders.

**Study 3:** Cognitive Processing in Bilingual and Monolingual Children with DLD

**Aim:** This study focuses on examining the impact of bilingualism on cognitive processing among children with Developmental Language Disorder (DLD). It seeks to assess how bilingual and monolingual contexts differentially influence the processing of familiar and unfamiliar lexical items and the resolution of cognitive conflicts in children with DLD.

**Hypothesis:** The hypothesis posits that bilingualism adds complexity to cognitive processing in children with DLD, particularly with unfamiliar words. Bilingual DLD children are expected to encounter greater difficulties than their monolingual DLD peers, manifesting as longer RTs and distinct neural responses, such as enhanced N400 amplitudes. In the Stroop task, bilingual children with DLD are hypothesized to show greater difficulty managing cognitive conflicts, evidenced by increased RTs and error rates during incongruent conditions. This study draws on insights from Anaya (2018), Windsor et al. (2010), and Verhoeven et al. (2012).

# 3 - Study 1: Language Complexity Unveiled: Lexical Processing and Stroop Effect in Bilingual and Monolingual Children

## 3.1 Abstract

This study investigates lexical processing and cognitive control in bilingual and monolingual children, using behavioural measures and Event-Related Potentials (ERPs). Participants, aged 7-10, underwent both the Stroop and Lexical Decision tasks. Contrary to the prevailing assumption of a universal bilingual advantage, our findings reveal complex, context-dependent outcomes. Bilingual children displayed prolonged response times for Non-Words in the Lexical Decision Task and experienced robust interference effects in the Stroop Task, with significantly longer reaction times in both congruent and incongruent conditions. These results suggest that the bilingual advantage is not consistent across different cognitive tasks and that bilingualism can also present specific challenges. ERP analysis, particularly focusing on the N400 component, showed distinct neural response patterns between the groups, suggesting deeper or more effortful processing among bilinguals. This was especially evident in incongruent conditions, indicating enhanced cognitive effort and conflict resolution processes. Furthermore, the study also considered socioeconomic status (SES) as a covariate, which played a significant role in modulating cognitive performance outcomes, underscoring that higher SES is often linked to better educational resources but does not straightforwardly mitigate the cognitive complexities associated with bilingualism.

## 3.2 Introduction

The term 'lexical-semantic network' refers to a theoretical concept encompassing an individual's vocabulary, the organization of words in semantic memory, and processes facilitating access to this stored information (Nation, 2014). Nation (2014) specifically defines lexical aspects, encompassing knowledge, processing, and learning, with a particular focus on word-level aspects of language. Understanding and measuring lexical processes is a complex task, as it involves everything a child knows about a word and its usage (Nation, 2014). Tasks like naming or matching pictures with labels unveil different facets of lexical abilities in bilingual children. Investigating language and executive control through paradigms like language switching offers insights into cognitive processes in bilingual individuals (Meuter & Allport, 1999). Cognitive control includes suppressing irrelevant information and selecting appropriate responses. Vihman (2014) notes that bilinguals activate multiple languages, potentially leading to slower response times in speed tasks compared to monolinguals. As research on bilingualism increases, controversies about its advantages intensify (Antón et al., 2019). Debates surrounding bilingual advantage involve discussions on linguistic challenges, such as a smaller vocabulary size in the second language and slower lexical processing. The language environment, influencing cognitive development, is a crucial determinant (Goldin-Meadow et al., 2014).

One way to explore effort in bilingual processing is by studying brain responses to linguistic stimuli directly. EEG, a non-invasive method, records neural activity and is vital in cognitive neuroscience, particularly in studying lexical and syntactic processing. Event-Related Potentials (ERPs), derived from EEG data, offer a detailed understanding of brain responses to linguistic stimuli (Ward, 2015). In this context, our study delves into the differences in lexical processing, cognitive control, and executive functions in bilingual and monolingual children. Through behavioural measures and ERPs, we aim to contribute novel insights into the cognitive processes shaping language abilities in this dynamic population, potentially informing more effective bilingual education and language development strategies.

### 3.2.1 Bilingualism and Lexical Processing in Children: Contrasts with Monolinguals

Research on bilingualism has increasingly underscored the intricate interplay between cognitive and linguistic processes, particularly distinguishing bilingual children from monolingual counterparts (Kroll, Dussias, Biece, & Perroti, 2015). Bilinguals, navigating the complexities of multiple languages during crucial developmental stages, offer unique insights into cognitive and linguistic adaptations. Bilinguals often engage in strategic management and regulation of their language systems, balancing the parallel activation and competition for cognitive resources (Wattendorf et al., 2014). The bilingual brain, as revealed in studies by Bialystok & Luk (2011), showcases remarkable adaptability, utilizing shared networks for both languages while managing the complexities of language control and cognitive resource allocation. The integrated nature of bilingual language processing, while involving complex cognitive dynamics, also encompasses unique developmental patterns in language acquisition. Ivanova and Costa (2008) and Gollan et al. (2005) observe challenges in bilingual language processing, such as diminished lexical access efficiency and accuracy, even in dominant languages. These challenges could stem from factors like weaker language-specific lexical representations and increased lexical competition. However, research by Marchman and Martínez-Sussman (2012) highlighted that bilingual children from middle-income families possess a breadth of vocabulary consistent with monolingual peers when both languages are considered. This phenomenon is exemplified by how bilingual children may use words like “AGUA” for water in Spanish and "DOG" in English, demonstrating a unique distribution of concepts across their languages. This reflects how the social context of language interacts with the child's development, leading to a nuanced understanding of bilingual lexical acquisition.

Kohnert, Windsor, and Yim (2011) found that typically developing Spanish-English bilingual children aged 8 to 13 years performed better on English nonwords than native English speakers. This was also observed in tasks involving rapid automatic naming. However, when other language-based processing measures were administered to the same participants, bilinguals showed a relative disadvantage compared to monolingual peers in English language processing tasks. This occurred despite the bilinguals having over five years of regular experience with

English in mainstream educational settings, relative dominance in English, and performance at or above grade level in English-only classrooms.

In a longitudinal study on lexical processing in Spanish-English bilingual children, Gangopadhyay et al. (2019) found that initially monolingual children outperformed bilinguals in an English lexical decision task. However, this difference dissipated one year later, indicating that bilingual children were able to catch up to their monolingual peers in lexical processing skills. Notably, no significant differences in reaction times (RTs) were observed between the groups, suggesting a consistent level of lexical access efficiency across both monolingual and bilingual children. Expanding upon these insights, Schröter and Schroeder (2017) investigated German-English bilinguals through a monolingual lexical decision task in both languages. Their findings pointed to an initial reliance on lexical information in early stages of word recognition in bilingual children, a stark contrast to bilingual adults who integrate sub-lexical stages of orthographic processing.

This developmental trajectory underscores the evolving nature of bilingual lexical access, gradually adapting to language-specific orthographic structures. The study also highlights the importance of considering developmental stages in bilingual language acquisition research, as the strategies and processes employed by bilingual individuals may change significantly with age and experience. Wartenburger et al. (2003) added another dimension to this exploration by comparing three groups of bilinguals on grammatical and lexical processing tasks. They found that early bilinguals (who acquired a second language from birth) had more automatic access to grammar representations in their second language compared to late bilinguals (who acquired a second language after age 18), even with similar proficiency levels. This suggests a nuanced impact of the age of language acquisition on cognitive linguistic processes, with early bilingualism potentially leading to different cognitive outcomes than late bilingualism.

Finally, Torregrossa, Bongartz, and Tsimpli (2021) conducted a study with Greek-German bilingual children using a lexical decision task in each language. The findings highlighted differential response patterns, with slower response times for low-frequency German words, illuminating the complex nature of lexical processing in bilingual individuals. This study contributes to the understanding of frequency effects in bilingual lexical access and highlights the need for further research into how bilinguals manage lexical competition between languages. These studies collectively emphasize the importance of considering factors such as language proficiency, exposure, and age of acquisition in understanding bilingual cognition and language processing. This comprehensive perspective not only challenges previous assumptions about bilingualism but also opens avenues for future research to explore the underlying mechanisms of these observed variations in bilingual populations.

### 3.2.2 Cognitive Control and Executive Functions in Bilingual and Monolingual Children: A Comparative Review.

Understanding the intricate relationship between cognitive control and language processing is pivotal for discerning the nuanced disparities between bilingual and monolingual individuals. The Stroop task, developed by Stroop (1935), serves as an essential tool in this investigation, probing complex functions like interference resolution, response inhibition, and response selection. Despite superficial similarities in meaning across languages, research, such as that by MacLeod (1991), consistently underscores significant interference in bilingual contexts. This interference highlights the complex dynamics of controlling language, underscoring the unique cognitive demands placed on bilingual individuals.

The literature presents a dichotomy regarding the potential bilingual advantages in cognitive control tasks. Early studies by Bialystok, Craik, & Luk (2008) and Abutalebi & Green (2013) propose enhanced executive control among bilinguals. These findings suggest a potential redefinition of cognitive benefits associated with bilingualism, yet they are met with equally compelling evidence to the contrary. Research by Paap and Greenberg (2013) and Kousaie and Phillips (2012) presents a counter-narrative, finding no significant bilingual benefits. This contradiction illuminates the complexity of interpreting results, which may be influenced by factors such as language proficiency, social context, and task conditions (Blom et al., 2017). The discrepancy in these findings highlights the need for a more nuanced understanding of how bilingualism intersects with cognitive control, moving beyond simplistic notions of 'advantages' or 'disadvantages'.

Bilingual individuals are a notoriously heterogeneous group. There are confounds with bilingualism and factors like socioeconomic status (SES) and culture, and researchers do not agree on the best ways to address these issues. Some researchers use SES as a covariate (Antoniou et al., 2016; Blom et al., 2017; Carlson & Meltzoff, 2008) to manage real differences between bilingual and monolingual populations. However, this practice has been criticized by Paap, Johnson, and Sawi (2015), who pointed out that it may violate statistical assumptions to covary when the covariate and the groups are not independent, as is the case when the groups differ on the covariate measure. The alternative is matching, but Paap et al. (2015) noted that there are many alternative factors on which one might match, such as potential cultural, rather than SES, differences. While there is no clear, agreed-upon solution to these issues, it suggests that researchers need to consider these issues carefully and present an approach to minimize these confounding variables. One possible explanation is that cognitive advantages only appear in highly proficient bilinguals, and grouping children from varying environments masks these advantages (Bialystok, 2018).

Transitioning to the developmental aspects of bilingualism, studies examining the maturation of automatic and controlled processes propose that increasing language proficiency correlates with a decrease in the Stroop interference effect (Tzelgov, Henik, & Leiser, 1990). This suggests a refined ability to manage competing linguistic demands, reinforcing the hypothesis that bilingualism may confer subtle modifications in cognitive control mechanisms. The developmental trajectory of these abilities highlights the importance of longitudinal studies to trace cognitive changes over time.

Research has also focused on how cognitive control evolves as bilingual children mature, further dissecting the intricate relationship between language proficiency and executive functions. In exploring age-related differences, Sabourin and Vinerte (2015) examined French-English simultaneous and early bilinguals using a Stroop task in English. Despite no differences in performance between groups, a visible Stroop effect in incongruent conditions was noted. This finding provides insight into how bilinguals, regardless of their language acquisition history, navigate linguistic interference, challenging the notion of a uniform bilingual advantage.

Further enhancing our understanding, Marian, Blumfeld, Mizrahi, Kanua, and Cordese (2013) conducted a nuanced study with bilinguals, comparing within and between language conditions in a Stroop task. Their findings of shorter reaction times in congruent conditions, regardless of the language context, underscore the impact of language proficiency on cognitive processing. Longer reaction times observed when bilinguals were tested in their second language add another layer to the complex relationship between bilingualism and cognitive control.

The dynamics of cognitive development are further illuminated by Oliveira, Mograbi, Gabrig, and Charchat-Fichman (2016), who explored Stroop task performance in Brazilian monolingual children aged 9–12 years. Their findings revealed notable distinctions in reaction times (RTs) between age groups, specifically 9-10 and 11-12 years old. As interference increased, RTs and accuracy demonstrated a corresponding increase, while they decreased with age progression. This aligns with the dynamic nature of cognitive development during this age range, suggesting that age-related variations in cognitive control may influence Stroop task outcomes. The varied performance observed in these age groups underlines the dynamic and evolving nature of cognitive control during childhood, a factor that becomes even more pronounced in the context of bilingual language processing. In the context of bilingual children, research by Duñabeitia et al. (2014) explored the performance of bilingual and monolingual children in congruent and incongruent trials of the Stroop task. Results in accuracy and reaction times (RTs) found no signs of a difference in the performance of these two groups. These findings lead the authors to conclude that the so-called bilingual advantage in executive control tasks seems to be non-existent in children.

Furthermore, Desjardins and Fernandez (2018) investigated Spanish–English bilinguals, challenging expectations of a cognitive advantage in inhibiting task-irrelevant information. The absence of a bilingual advantage, particularly in incongruent conditions, stood out, despite the participants being fully proficient Spanish–English bilinguals. However, it's essential to acknowledge potential limitations, such as the exclusive testing in the first language (Spanish) and the age range of participants, emphasising the need for nuanced interpretation. Eberhaut's study (2015) also involved German-English bilinguals and German monolinguals, ages 11 to 12. All were tested in their L1, and the results showed that both groups performed similarly in incongruent trials, with longer RTs in comparison to the congruent trials, emphasizing similarities in performance patterns across the two groups.

In longitudinal studies, such as those by Tran et al. (2014) and Park et al. (2015), the interaction between culture and bilingualism was shown to affect performance on tasks like the Attention Network Task (ANT) and the Flanker task, respectively. These findings suggest that bilingual experiences can differentially influence the development of executive functions, not uniformly affecting all components or developmental stages. Furthermore, bilingual children often receive less linguistic input in each language compared to monolingual peers, which may slow their vocabulary and grammatical development, although their total vocabulary across both languages typically does not lag (Gathercole and Thomas, 2009; Vagh et al., 2009).

The relationship between bilingualism and cognitive control evolves over time, influenced by the quantity and quality of linguistic input and the specific languages involved. For instance, bilingual children often exhibit a developmental trajectory that can significantly differ from that of monolingual peers, suggesting that cognitive advantages are closely tied to their linguistic environment and a complex interplay of additional variables such as cultural factors and longitudinal changes (Hoff and Core, 2013).

The exploration of cognitive control and executive functions in bilingual and monolingual children reveals a complex interplay influenced by factors such as language exposure, proficiency, and task conditions. While some studies suggest potential advantages for bilinguals, others emphasize the absence of significant differences. The contradictory nature of findings across studies underscores the complexity of the multifaceted relationship between language and cognitive control. Future research should consider refining methodologies, exploring specific age groups, and investigating the impact of bilingualism in real-world contexts.

### 3.2.3 Language Processing and Cognitive Control in Bilingual and Monolingual Children: Insights from ERPs

Event-Related Potentials (ERPs) have become indispensable for unravelling the complexities of lexical and syntactic processing in both first (L1) and second (L2) language contexts (Moreno et al., 2008; Morgan-Short, 2014). While traditionally applied extensively in L1 processing, there is a growing interest in their applicability to second language learning, particularly in word learning and processing domains (Batterink & Neville, 2014; Ferreira et al., 2018). The multifaceted nature of ERP data, capturing temporality and scalp distribution, provides a distinct advantage over traditional behavioural measures, offering valuable insights into neural activity during language processing (Mueller et al, 2005). Research into bilingual language processing using ERPs has generally revealed a reduced amplitude and delayed latency of the N400 in response to L2 compared to L1 (Newman et al., 2013). However, inconsistencies across studies may be attributed to variations in experimental methodology, including tasks, materials, languages under investigation, types of bilingual populations, or experimental designs.

ERP studies with monolingual participants have identified factors such as frequency and lexicality influencing the N400 component. Frequency effects typically manifest as a more negative waveform for low-frequency words compared to high-frequency ones, while lexicality affects the N400, with pseudowords eliciting stronger negativity than real words (Braun et al., 2006). Building on the understanding of lexical processing in monolingual individuals, Abel et al. (2018) tested children ages 11-14 years. Presenting pseudowords and familiar words, they observed a heightened N400 response to pseudowords compared to familiar words, shedding light on the distinct N400 patterns associated with the recognition of pseudowords and familiar words in the developing linguistic abilities of children.

Furthermore, Lehtonen et al. (2012) delved into lexical processing by examining the effects of word frequency, morphological structure, and lexicality on visual word recognition in early Finnish–Swedish bilinguals and a comparable group of Finnish monolinguals. The study aimed to investigate the interaction between morphology and frequency, exploring whether bilinguals exhibit processing difficulties when performing a lexical decision task with high and low-frequency words, and pseudowords. ERP results revealed group differences observed from 550 msec onwards, indicating that increased negativity (N400) for pseudowords was more prolonged and more negative in bilinguals than monolinguals. This investigation into the lexical processing abilities of early bilinguals compared to monolinguals highlights the nuanced effects of bilingual language exposure on cognitive functions, suggesting a more complex and adaptive bilingual cognitive architecture.

In a similar vein, Kotz (2001) conducted a study with thirty-two participants randomly assigned to either the Spanish (L1) or English (L2) condition, determining the language in which the experiment was conducted. Participants were presented with stimuli in their respective L1 or L2, including non-words. Analysis of the ERP data revealed that both groups exhibited an equivalent N400 effect in response to non-words, suggesting that proficient bilinguals access lexical representations in both L1 and L2 similarly. This similarity in N400 responses implies that access to L2 is not mediated through L1; instead, fluent bilinguals appear to directly access lexical representations in their second language. Building upon these lexical processing insights, the focus now shifts to understanding how these linguistic intricacies are interwoven with cognitive control mechanisms, as evidenced in bilinguals' performance in tasks requiring executive functions.

While lexical processing reveals basic language comprehension mechanisms, studies on executive functions, particularly using the Stroop task, illuminate how bilinguals manage cognitive control in language tasks. Heidlmayr et al. (2012) found reduced N400 amplitudes in bilinguals compared to monolinguals during a Stroop task. While monolinguals demonstrated significant conflict effects at the N400 and a late positive component (LPC), bilinguals, when tested in their first language, exhibited only a significant N400 effect. Comparisons of the group waveforms suggested that the amplitude of the N400 was reduced for bilinguals relative to monolinguals, hinting at a potential bilingual advantage in conflict processing. In a related study, Coderre and van Heuven (2014) further explored the role of language-specific characteristics in potential group differences by testing bilinguals in a Stroop task in both languages. Bilingual participants performed two sessions, one for each language (L1 Chinese and L2 English), on consecutive days, while monolingual participants performed only one session (in English). When comparing N400 peaks, there was a more negative N400 for bilinguals in L2 compared to monolinguals in incongruent conditions.

Building on these insights, Naylor, Stanley, & Whicha (2015) conducted a study investigating bilingual language processing and colour congruency using a Stroop task. Their results indicated that incongruent trials elicited a larger negative amplitude than colour-congruent trials between 300 and 500 msec post-stimulus onset. This effect was consistent within and between languages, especially in the bilingual population exposed to two languages in the same task, suggesting that the N400 was sensitive to colour congruence. The consistency of the N400's sensitivity to colour congruence in bilinguals across languages underlines the universal nature of cognitive control processes, regardless of linguistic context, and raises intriguing questions about the neural basis of cognitive flexibility in bilinguals. Additionally, Ergen et al. (2014) recorded EEG during a Stroop task, using stimuli with three colour names in Turkish, “KIRMIZI” (RED), “MAVİ” (BLUE), “YEŞİL” (GREEN). The ERP data showed that the N400 peak was larger for incongruent stimuli, providing further evidence of the N400's sensitivity to Stroop task conditions.

ERP studies offer a powerful lens into the cognitive processes underlying language acquisition and processing, with an initial focus on lexical processing followed by insights into the N400 component in both monolingual and bilingual contexts. Shifting attention to executive functions and cognitive control, studies provide valuable perspectives on inhibitory control in bilingual individuals. Understanding these complexities necessitates careful consideration of experimental design, task selection, and the intricate interplay of linguistic and cognitive factors.

### 3.3 Study

In this study, our primary objective was to investigate the influence of bilingualism on cognitive control and lexical processing in children, aligning with our aim to understand the specific impacts of bilingualism on these cognitive functions. We aimed to discern the impact of bilingualism on participants' performance through two distinct tasks: the Lexical Decision Task and the Stroop Task. During the Lexical Decision Task, we examined how bilingual and monolingual children recognize and process familiar and unfamiliar words in their respective languages—Spanish and English for bilinguals, and Spanish for monolinguals. We measured both reaction times (RTs) and event-related potentials (ERPs) during this task to gain insights into their behavioural and neural responses.

In the Stroop Task, we delved into the cognitive control abilities of the participants, aiming to identify any influences of bilingualism on their performance. Similarly, in the Stroop Task, we measured both RTs and ERPs. Through a comparative analysis of responses between bilingual and monolingual children, we sought to unravel the intricate relationship between bilingualism and its effects on cognitive control and lexical processing. Our hypothesis posits that bilingual children will exhibit longer RTs and larger N400 amplitudes compared to their monolingual peers in tasks requiring high linguistic and executive functioning. This is anticipated to reflect the additional complexity and effort involved in managing dual-language systems, challenging the conventional notion of a consistent bilingual cognitive advantage.

### 3.4 Methods

#### 3.4.1. Participants

This study included 62 Chilean children aged 7 to 10 years (mean = 8.5, SD = 1.09), divided into Bilingual Typically Developing (Bilingual TD) and Monolingual Typically Developing (Monolingual TD) groups. All participants were native Spanish speakers, with those in the Bilingual TD group also fluent in English as their second language. Detailed demographic data can be found in Table 1. Ethical approval for this research was secured from the University of Essex Social Sciences Ethics Sub-Committee, and all necessary parental consents were obtained prior to participation. Additional participant information was collected through a comprehensive questionnaire, detailed in Appendix 1.

Testing was conducted from May to August 2021, following the national COVID-19 lockdown in Chile, when all participants had resumed their full-time education. This provided a stable basis for assessing the impact of bilingualism on cognitive and lexical processing. To ensure robust and comparable results, the study controlled for several key variables such as socioeconomic status (SES), derived from the educational levels of parents or guardians, nonverbal IQ, age, and sex.

### 3.4.2 Bilingual group

This group consisted of 32 participants (18 girls, 14 boys) from three bilingual schools, where English exposure began in kindergarten. Most children (26) started at age 4. The parents of these children were highly educated, with 90% holding at least an undergraduate degree. The average exposure to English was 30-35 hours per week. English proficiency was assessed using the "Cambridge English: Pre-A1 Starters," with scores averaging 3.59 (SD=0.79). Refer to Table 1 for further details and Section 2.1.1 of the methods chapter for an extended participant profile.

### 3.4.3 Monolingual group

The Monolingual group consisted of 30 children (13 girls, 17 boys) from four different public schools, receiving only six hours of English instruction weekly. Only 10% of their parents pursued higher education, showcasing a socio-educational contrast with the Bilingual group. Some students supplemented their limited curriculum-based English exposure by enrolling in

English language academies. Additional comprehensive data on this group's demographics and schooling environment can be found in Section 2.1.3 of the methods chapter.

**Table 1: Participants demographic information.**

SES (parental education) information was coded following the International Standard Classification of Education (ISCED; UNESCO Institute for Statistics, 201). This ranged from 0 (less than primary education) to 8 (doctoral or equivalent).

| Group/Variable | Bilingual TD | Monolingual TD |
|---|---|---|
| **Participants** | 32 | 30 |
| **Age (Years)** | M=8.31, SD=1.07 | M=8.30, SD=1.10 |
| **Sex** | 18Girls, 14 Boys | 13 Girls, 17 Boys |
| **SES (Parental Education)** | M=6.13, SD=0.49 | M=4.33, SD=0.74 |
| **Non-verbal IQ** | M=91.73, SD=4.35 | M=90.69, SD=4.09 |
| **L2 Proficiency** | M=3.59, SD=0.79 | N/A |

## 3.5 Materials and Stimuli

### 3.5.1 Lexical decision task

The Lexical Decision Task (LDT) is used to assess lexical processing abilities, focusing on the ability of children to distinguish between words and nonwords. This task highlights differences in lexical access and semantic processing among bilingual and monolingual children, emphasizing the impact of bilingualism. Two versions of the task were designed, specifically for bilingual and monolingual groups. For detailed task design and stimulus information, refer to Section 2.2.1 in the General Methods and Appendix 2 for the stimulus list.

### 3.5.2 Nonwords.

Nonwords were created using the SCOPE Lab Nonword Generator to ensure no resemblance to real words in English or Spanish, crucial for eliminating recognition biases that might benefit bilinguals. This control over phoneme selection and orthographic patterns ensures the nonwords are challenging yet accessible. For a detailed description of the nonword generation process and examples, see Section 2.2.2

### 3.5.3 Bilingual Task Version

In the bilingual Lexical Decision Task, participants were presented with 80 stimuli, composed of 40 nonwords and 40 words, equally divided between Spanish and English. To ensure a rigorous assessment of lexical processing, Spanish words excluded special characters, which would visually indicate the language origin. English words were selected from the "English Syllabus for primary schools" employed in Chile, with the Spanish version adapted to match linguistic complexity. Direct translations were avoided to eliminate potential biases from recognizing the same concept in both languages. Nonwords were designed to be phonologically and orthographically distinct from real words, with character lengths ranging from 5 to 7 characters. For additional details on stimulus selection please refer to section 2.2.3

### 3.5.4 Monolingual Task Version

The monolingual version of the Lexical Decision Task mirrors the bilingual setup but is tailored for participants who only speak Spanish. It consists of 80 stimuli, divided evenly between 40 Spanish words and 40 nonwords, ensuring no English words are included. This setup is designed to maintain consistency with the bilingual task structure, facilitating an equitable comparison of lexical processing abilities across different linguistic contexts. Spanish words were chosen based on criteria such as word length and familiarity to ensure the task's difficulty remains consistent. The avoidance of direct translations and selection of nonwords prevent potential biases from linguistic familiarity, ensuring a balanced evaluation of lexical decision-making skills. For further details on the methodology and rationale behind the stimulus selection, refer to Section 2.2.4 in the General Methods.

### 3.6.1 Stroop task

Introduced by John Ridley Stroop in 1935, the Stroop Task is a cornerstone in the study of cognitive flexibility and inhibitory control. These cognitive functions are essential components of executive function, assessing an individual's ability to manage cognitive interference effectively. In this study, the Stroop Task was employed to explore these cognitive processes, focusing on differences among bilingual and monolingual children.

### 3.6.2 Bilingual Stroop Version

In the bilingual Stroop Task, participants encountered colour names in both Spanish and English, adding cognitive complexity by requiring them to suppress automatic reading responses and navigate between two languages. This version used a nonverbal response format, where responses were indicated by pressing coloured-coded keys, focusing on cognitive control without language production interference. Comprising 90 trials split evenly between congruent and incongruent conditions, this setup aimed to highlight the challenges and cognitive dynamics unique to bilingual individuals. For detailed procedural descriptions and experimental settings, please refer to Section 2.3.2

### 3.6.3 Monolingual Stroop Version

The monolingual version mirrored the bilingual setup but was conducted solely in Spanish, allowing for a direct comparison of inhibitory control and cognitive flexibility in a monolingual context. This version also included 90 trials and used a nonverbal response format to isolate executive function from linguistic influences, providing a clear measure of how monolingualism impacts cognitive processes. For a detailed description of the task, refer to Section 2.3.3

These tasks, particularly the Stroop Task, are essential for understanding how executive functions such as inhibitory control and cognitive flexibility are modulated by language experience in bilingual and monolingual contexts. By contrasting these tasks with the Lexical Decision Task, which assesses lexical processing abilities, the study provides a comprehensive view of the cognitive distinctions and similarities in bilingual and monolingual children. This approach aims not to definitively prove or disprove the bilingual advantage but to enrich our understanding of how bilingualism interacts with and influences executive functioning and linguistic processing.

## 3.7 Procedure Lexical decision and Stroop Task

### 3.7.1 Experiment Procedure

The Lexical Decision Task and Stroop task were conducted in a quiet, unoccupied classroom to minimize distractions and optimize concentration. To reduce electrical interference, the room's lighting was turned off during the session. Stimuli were displayed using PsychoPy software on an ASUS ZenBook laptop positioned in front of the participants. The visual stimuli consisted of words and nonwords shown on a black background in a clear, white 20-point Arial font (see Figure 1 for a visual depiction). Participants responded using the laptop keyboard, with both oral and written instructions provided in Spanish to ensure clarity and comprehension. For the Stroop task, stimuli were presented on a black background in various colours (green, red, yellow, and blue) using a 20-point Arial font. Participants responded using the laptop keyboard, with the entire session lasting approximately 45 minutes. A more detailed description can be found on section 2.4. from the methods section. The entire procedure was designed to maintain a uniform testing environment, facilitating reliable data collection. Each session typically lasted about 45 minutes.

### 3.7.2 Lexical Decision Task

Participants decided whether each stimulus was a word or a nonword. The task began with practice trials of four words and four nonwords to familiarize participants. If necessary, instructions were repeated, and practice trials were redone. The experimental task included two blocks of 40 stimuli each, presented randomly. Bilingual participants received an equal mix of English and Spanish words with nonwords, while monolingual participants received only Spanish words and nonwords. Each trial started with a fixation cross for 1000 milliseconds, followed by the stimulus for 3000 milliseconds. Participants pressed 'A' for words and 'L' for nonwords, with a response window of 3000 milliseconds. Trials ended automatically if no response was recorded. Participants were instructed to respond quickly and accurately. For detailed procedures and settings, refer to section 2.4.2.

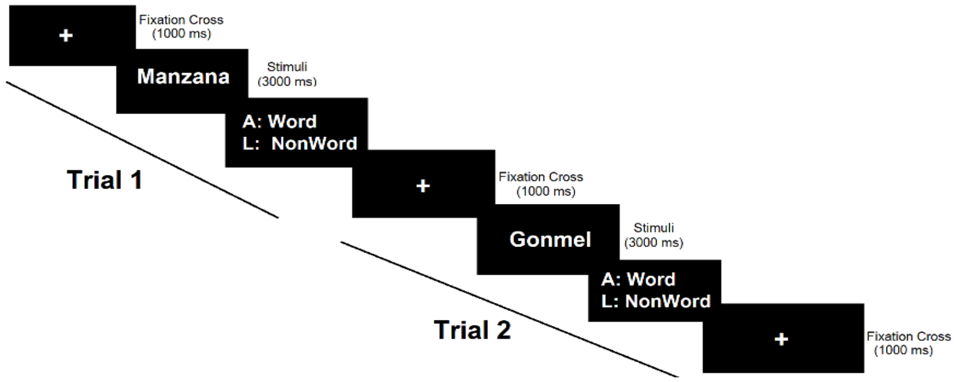



**Figure 1:** Lexical decision task layout

### 3.7.3 Stroop Task

Following the lexical decision task, participants engaged in the Stroop task, beginning with practice trials of eight stimuli (four congruent and four incongruent) to ensure familiarity. If needed, instructions were repeated, and practice trials were redone. The Stroop task included 90 trials divided into three blocks of 30 trials each, with an equal mix of congruent and incongruent conditions. Participants used a color-coded keyboard to press the key matching the text colour. Each trial began with a fixation cross for one second, followed by a priming condition for 2.5 seconds, and then the Stroop stimulus for three seconds. Participants were instructed to respond quickly and accurately, with the system proceeding to the next trial if no response was recorded within the three-second window. Detailed procedural descriptions are available in section 2.4.3.

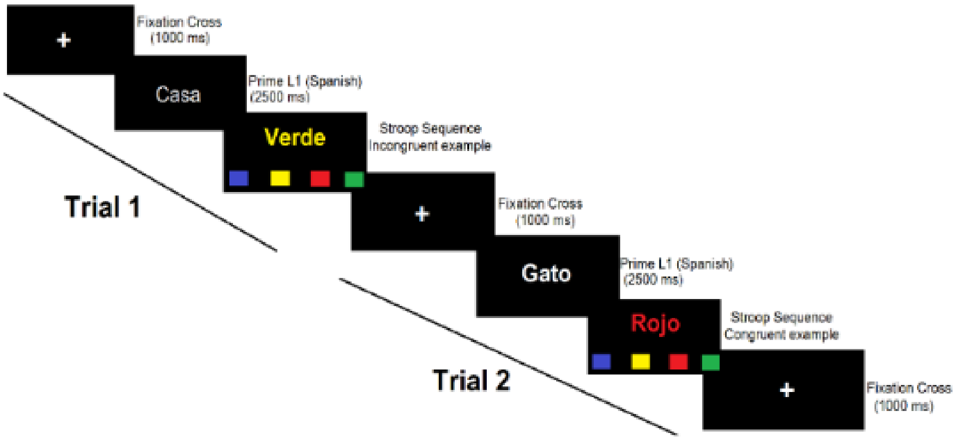



**Figure 2:** Stroop task layout

### 3.7.4 Priming

In the Stroop task, a priming phase exposed participants to Spanish words for 2.5 seconds to activate linguistic networks before the executive control challenges. Using Spanish, the native language of all participants, ensured consistent activation and supported findings that priming effectiveness varies with language proficiency and similarity (Brauer, 1998; Bialystok, 2001; Costa, Hernández, & Sebastián-Gallés, 2008). These priming normalized cognitive conditions, enhancing the reliability of the examination of executive functions. While its direct effects were not analysed in this study, the priming phase provides valuable insights for future research on how pre-activated linguistic networks might influence executive function strategies. For a detailed description of the priming methodology, refer to Section 2.4.4

### 3.7.5 EEG Procedure

The EEG protocol for the lexical decision and Stroop tasks was uniform across all participants to ensure consistency. We utilized a 32-channel BioSemi system, arranging electrodes according to the 10-20 system to cover key scalp regions for comprehensive neural activity recording. Reference signals were collected via two mastoid electrodes, and ocular movements were monitored with three additional electrodes, though this data was excluded from our primary analysis. Data transmission was managed through a BioSemi Active Two amplifier, with event-related potential (ERP) triggers set via PsychoPy3 software (Peirce et al., 2019). Output monitoring was continuous via BioSemi Actiview, with any necessary electrode adjustments made during breaks to maintain data integrity. This standardized approach across tasks ensured the reliability of our neural response data, critical for comparing cognitive processes activated during each task.

## 3.8 Data Analysis

### 3.8.1 Behavioural Analysis

Four participants were excluded from the analysis due to poor-quality data and consistent movement during the task (1 Bilingual and 3 Monolingual). Behavioural and ERP data from the LDT and Stroop task, were analysed using LMERs in RStudio version 4.1.2. For the behavioural data, Reaction times (RTs) were log-transformed to achieve a normal distribution. Only correct responses were included in the analysis to ensure the accuracy of the data. No additional trimming of outlier RTs was performed beyond this transformation.

Fixed effects in the Lexical Decision Task (LDT) included word type (words vs. non-words) and group (bilingual TD vs. monolingual TD), with age, sex, socioeconomic status (SES), and non-verbal IQ as covariates to control for potential confounding variables Participants and words were included as random effects to account for variability between individuals and items. For the Stroop Task, fixed effects of congruency (congruent vs. incongruent) and group were analysed, incorporating the same covariates to account for individual differences. Participants and stimuli were included as random effects, ensuring that random variability in responses was properly accounted for in the analysis.

Interaction analyses were conducted to explore nuanced relationships between groups and the type of word, including a 2x2 interaction for the Lexical Decision Task and a 2x2 interaction with congruency and group for the Stroop Task. The exclusion of English conditions from the bilingual group's analysis in both tasks underscores a methodological choice to maintain focus on cross-linguistic comparisons grounded in the Spanish language, thereby enhancing the clarity and interpretability of the findings.

### 3.8.2 ERP Analysis

EEG recordings for both the Lexical Decision Task and the Stroop Task were processed using the same methodology, employing EEGlab (v2021.1) and ERPlab (v8.10). The data for each task was analysed at a sampling rate of 256Hz, with a bandpass filter set at 0.1Hz high pass and 30Hz low pass to ensure optimal signal quality. This filtering strategy was recommended by Luck (2014) to isolate neural signals pertinent to cognitive processing. Independent Component Analysis (ICA) was utilized to identify and manually remove artifacts, primarily targeting blink components and other noise. On average, 4 components per participant were removed, ensuring the integrity and cleanliness of the EEG data for detailed ERP analysis. Following ICA, data was re-referenced to mastoids, and epoched between -200 to 1000 ms, a window selected to capture the full range of anticipated ERP components, from early sensory responses to later cognitive processes like the N400. Artifact rejection was implemented in two phases using a moving window peak-to-peak threshold, first targeting only eye channels and then all scalp channels. While the analytical procedures remained consistent, there were task-specific differences in trial numbers and rejection rates. Each participant in the Lexical Decision Task started with 80 trials. After artifact rejection, Bilingual participants had an average rejection rate of 5.1%, resulting in about 76 trials retained (95% retention), while Monolingual participants saw a 4.3% rejection rate, keeping about 77 trials (96% retention). In the more cognitively demanding Stroop Task, participants began with 90 trials. Here, Bilingual participants faced a 5.5% rejection rate, retaining approximately 85 trials (94.5% retention), comparable to the 4.7% rejection rate for Monolingual participants, who also retained about 85 trials.

The mean amplitude for the N400 component, a robust indicator of lexical-semantic processing, was specifically measured between 350-550 ms. This time window was chosen to align with the typical developmental trajectory of the N400 component observed in children, reflecting their cognitive abilities to process language. Our selection of electrodes was based on their established relevance in detecting the N400 component, which is primarily observed in centro-parietal regions, critical for language processing. The electrodes included in our region of interest (ROI) — CZ, C3, C4, CP5, CP1, CP2, CP6, P7, P3, PZ, P4, and P8 — were chosen based on their proven ability to detect changes in brain activity associated with semantic tasks. This choice is supported by studies from Kutas and Federmeier (2011) and Moreno and Kutas (2005), which highlight these areas' sensitivity to lexical and executive function processes. For our statistical analysis, we employed a Linear Mixed-Effects Model (LMER), treating electrodes within the ROI as random effects. This approach allowed us to account for the unique contribution of each electrode to the ERP measurements while controlling for random variability. By treating electrodes individually, we could more accurately assess the impact of task conditions on ERP amplitudes without assuming uniform responses across all electrodes within the ROI.

Our study primarily investigated the N400 component to explore cognitive control and lexical processing in bilingual and monolingual children. While early visual word recognition components like P1 and N1 are essential in pre-lexical processing, our task design emphasized deeper linguistic engagement, which may have deemphasized these early components in the ERP data. While not examined in detail here, variations in the N2 component, which arises around 200 ms and is linked to conflict monitoring (Szücs and Soltesz, 2012), could reflect different cognitive control strategies between bilingual and monolingual children. Future research could benefit from including these early components to gain a comprehensive view of cognitive processing.

## 3.9 Results

### 3.9.1 Lexical Decision: Bilingual and Monolingual Differences

**Table 2:** Reaction Time (RTs)

| Group | Spanish | Nonword |
|---|---|---|
| Bilingual | 6.91 (0.44) | 7.07 (0.42) |
| Monolingual | 6.89 (0.34) | 6.99 (0.40) |

**Table 3:** Accuracy

| Group | Spanish | Nonword |
|---|---|---|
| Bilingual | 99.3 | 92.0 |
| Monolingual | 99.8 | 94.8 |

An analysis of variance was conducted to examine the effects of type (nonword vs. Spanish), group (Bilingual TD vs. Monolingual TD), and their interaction on reaction times, controlling for age, sex, IQ, and socioeconomic status (SES) as covariates. The results revealed a significant main effect of type, ($F$ (1, 55.0) = 33.71, $p < .001$); and group, ($F$ (1, 262) = 13.51, $p<.001$). Furthermore, SES had a significant effect, ($F$ (1,388) = 12.82, $p<.001$. Additionally, the interaction between group and type was also significant ($F$ (1, 417) = 10.25, $p<.001$). The covariates age, ($F$ (1,344) = 0.793, $p = .373$); sex, ($F$ (1, 421) = 1.14, $p = .285$); and Nonverbal-IQ (NVIQ) ($F$ (1, 371) = 1.05, $p = .304$), did not show significant values.

**Table 4:** Model results for Lexical Decision: Reaction Time Analysis

| **Parameter** | $DF$ | Mean_Sq | F | p |
|---|---|---|---|---|
| Type | 1 | 4.32 | 33.71 | <.001 |
| Group | 1 | 1.729 | 13.51 | <.001 |
| Age | 1 | .101 | .793 | .373 |
| Sex | 1 | .146 | 1.14 | .285 |
| NVIQ | 1 | .135 | 1.05 | .304 |
| SES | 1 | 1.641 | 12.82 | <.001 |
| Group*Type | 1 | 1.315 | 10.25 | <.001 |

Post-hoc analyses were performed to delve deeper into the interaction effect between group and type on reaction times. The results are detailed below:

**Non-Words:** A significant difference emerged between the Bilingual and Monolingual groups (estimate = 0.0900, SE = 0.0147, t = 6.125, p < .001). Bilingual participants exhibited longer reaction times compared to Monolingual participants for Non-Words.

**Spanish Words:** No significant difference in reaction times was observed between the Bilingual and Monolingual groups for Spanish Words

These post-hoc findings (Table 5 and Figure 3) provide insights into the specific differences in reaction times between participant groups for different stimulus types in the Lexical Decision Task. The longer reaction times for Bilingual participants in response to Non-Words suggest a distinctive processing pattern compared to Monolingual participants in this specific context.

**Table 5:** Post hoc analysis

| **Type: Spanish** | Estimate | SE | *t* | *p* |
|---|---|---|---|---|
| Bilingual – Monolingual | .016 | .017 | .957 | .338 |
| **Type: Non-Words** | | | | |
| Bilingual – Monolingual | .090 | .014 | 6.125 | <.001 |

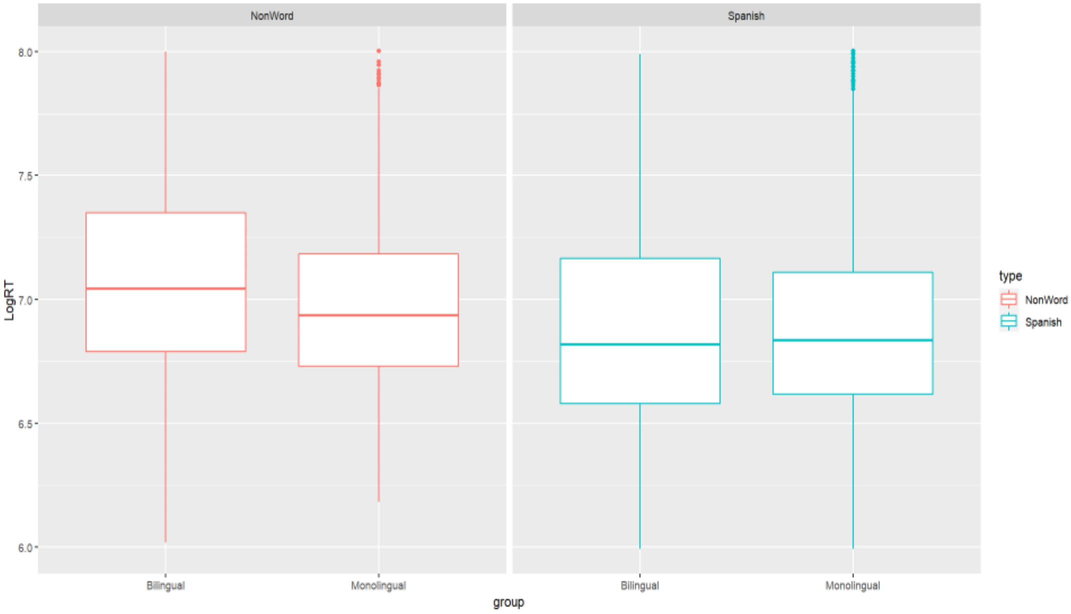



**Figure 3:** Bilingual children exhibited significantly longer response times for nonwords compared to their Monolingual Peers.

### 3.9.2 ERP Analysis: Lexical Decision Task

The analysis focused exclusively on electrodes within the Region of Interest (ROI), ensuring a targeted examination of the N400 component. The results, as seen in Table 6, revealed a significant effect for type ($F(1, 356) = 10.84$, $p < .001$), and group ($F(1, 356) = 3.11$, $p < .001$). A significant interaction effect between type and group was observed ($F(1, 356) = 7.65$, $p < .001$), highlighting that the impact of the type of word on ERP responses varied between the two groups. This interaction unveils a nuanced relationship between word type and neural processing, providing valuable insights into the distinctive patterns of ERP responses in bilingual and monolingual children.

**Table 6:** Model results for lexical decision ERP analysis

| **Parameter** | *DF* | MeanSq | F | p |
|---|---|---|---|---|
| Type | 1 | 121.75 | 10.83 | <.001 |
| Group | 1 | 34.96 | 3.11 | <.001 |
| Group*Type | 1 | 85.88 | 7.64 | <.001 |

The post hoc analyses further explored the interaction effect. For Non-Words, there was a significant difference in N400 amplitude between Bilingual and Monolingual groups, with Bilingual participants exhibiting a significantly more negative N400 amplitude compared to Monolingual participants. (estimate = -0.5989, SE = 0.166, t = -3.607, p <.001). However, for Spanish stimuli, there was no significant difference in N400 amplitude between the two groups.

**Table 7:** Post hoc analysis

| Type: Spanish | Estimate | SE | *t* | *p* |
|---|---|---|---|---|
| Bilingual – Monolingual | -.113 | .154 | -.731 | .464 |
| Type: Non-Words | | | | |
| Bilingual – Monolingual | -.509 | .164 | -3.10 | <.001 |

**Figure 4: LDT Spanish waves, electrodes CZ, PZ, CP1, CP2**

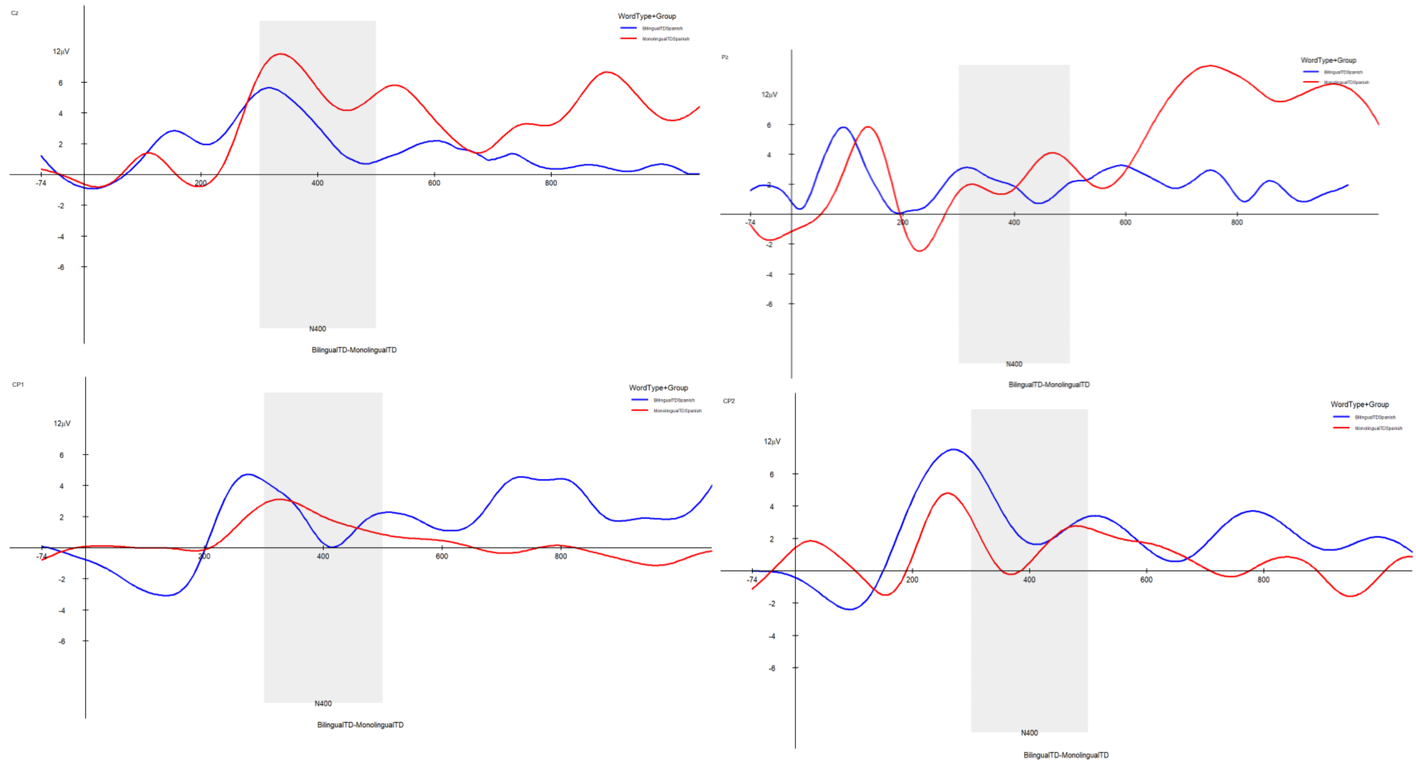
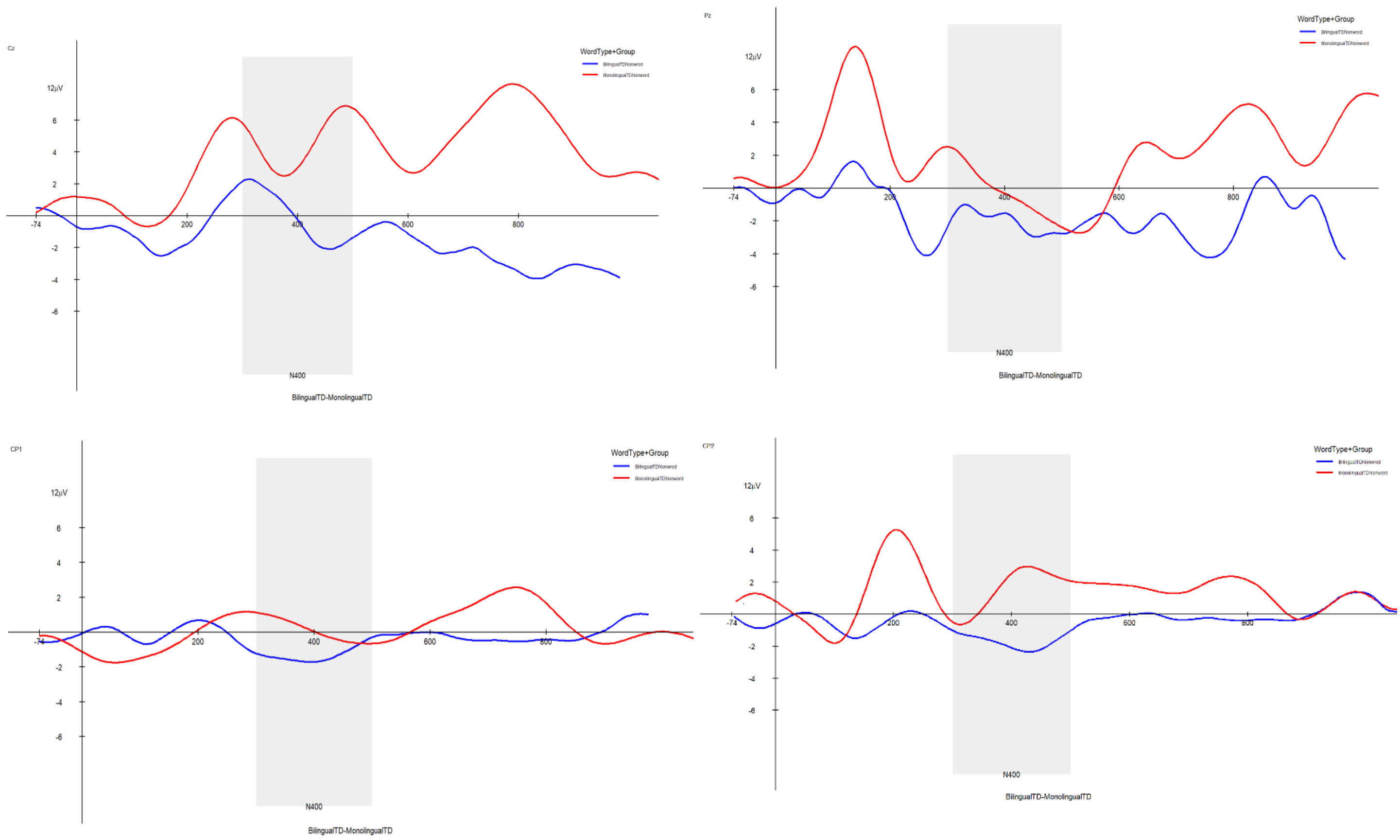



**Figure 5: LDT Nonwords waves, electrodes CZ, PZ, CP1, CP2**



### 3.9.3 Stroop Task: Bilingual and Monolingual Differences

**Table 8:** Reaction Time (RTs)

| Group | Congruent | Incongruent |
|---|---|---|
| Bilingual | 6.97 (0.40) | 7.01 (0.40) |
| Monolingual | 6.89 (0.37) | 6.95 (0.37) |

**Table 9:** Accuracy

| Group | Congruent | Incongruent |
|---|---|---|
| Bilingual | 100 | 95.2 |
| Monolingual | 100 | 100 |

Results from the Stroop task, presented in Table 10, revealed a significant effect of congruency (F (1, 434) = 17.79, p < .001), group (F (1, 437) = 104.38, p <.001) and SES (F1,185) = 5.11, p<0.00. Additionally, the interaction between group and congruency also showed significant results (F (1,393) = 36.18, p<.001). Non-significant effect was found for age, (F (1, 235) = .119, p = .730); sex (F (1,434) = 1.03, p<.308; and Nonverbal-IQ (NVIQ), (F (1, 31.5) = 0.11, p<.740.

**Table 10:** Model results for Stroop Task reaction time analysis

| **Parameter** | *DF* | Mean_Sq | F | p |
|---|---|---|---|---|
| Group | 1 | 2.22 | 17.79 | <.001 |
| Congruency | 1 | 13.08 | 104.38 | <.001 |
| Age | 1 | .014 | .119 | .730 |
| Sex | 1 | .121 | 1.03 | .308 |
| NVIQ | 1 | .013 | .111 | .740 |
| SES | 1 | .599 | 5.11 | <.001 |
| Group*Congruency | 1 | 4.24 | 36.18 | <.001 |

The post-hoc analysis summarised in Table 11 further elucidates the group differences observed in the Stroop task. In both congruent and incongruent conditions, Bilingual participants exhibited significantly longer RTs compared to Monolingual participants. These post-hoc findings provide valuable insights into how language background influences the processing of conflicting stimulus and response information in the Stroop task.

**Table 11:** Post hoc analysis

| Congruency: Congruent | Estimate | SE | *t* | *p* |
|---|---|---|---|---|
| Bilingual – Monolingual | .015 | .016 | 9.57 | <.001 |
| Congruency: Incongruent | | | | |
| Bilingual – Monolingual | .080 | .016 | 5.00 | <.001 |

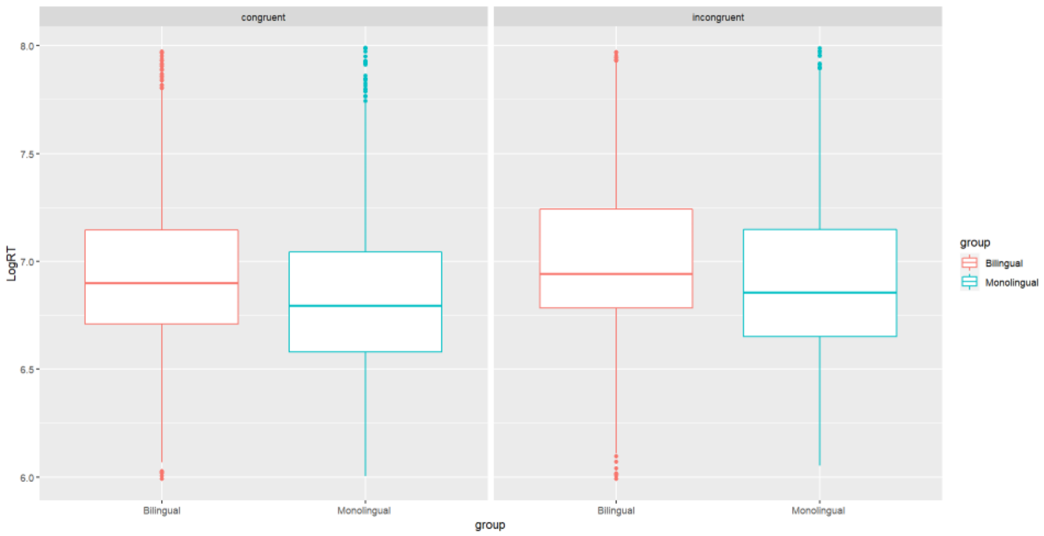



**Figure 5:** Bilingual participants showed longer RTs for both, congruent and incongruent conditions, challenging assumptions about a clear 'bilingual advantage.'

### 3.9.4 ERP Analysis: Stroop Task Bilingual and Monolingual

ERP results, summarized in Table 12, were analysed using electrodes selected from our region of interest. Results revealed significant effects for both congruency ($F(1, 259) = 5.06$, $p < .001$), and group (F (1, 259) = 4.84, p < .001), reflecting overall differences in N400 between Bilingual and Monolingual groups during the Stroop task. The most substantial finding was the interaction effect between congruency and group (F (1, 259) = 27.54, p < .001), highlighting that the impact of congruency on N400 responses varies between the two groups.

**Table 12:** Model results for Stroop Task ERP Analysis

| **Parameter** | *DF* | Mean_Sq | F | p |
|---|---|---|---|---|
| Congruency | 1 | 56.90 | 5.06 | <.001 |
| group | 1 | 54.46 | 4.84 | <.001 |
| Congruency*group | 1 | 310.28 | 27.54 | <.001 |

To further elucidate the interaction effect, post-hoc analyses were conducted. In the Congruent condition, the contrast between Bilingual and Monolingual groups yielded a non-significant difference indicating comparable N400 responses. However, in the Incongruent condition, a significant difference emerged (estimate = -2.367, SE = 0.738, t- = -3.208, p <.001), revealing that Bilingual participants exhibited more negative N400 amplitudes compared to Monolingual participants. This post-hoc provides further evidence of distinct neural processing patterns between Bilingual and Monolingual groups in response to incongruent stimuli during the Stroop task

**Table 13:** Post hoc analysis

| **Congruency: Congruent** | Estimate | SE | *t* | *p* |
|---|---|---|---|---|
| Bilingual – Monolingual | -.211 | .739 | -.285 | .776 |
| **Congruency: Incongruent** | | | | |
| Bilingual – Monolingual | -2.36 | .738 | -3.20 | <.001 |

**Figure 6: Stroop Task Congruent Condition electrodes CZ, PZ, CP1, CP2**

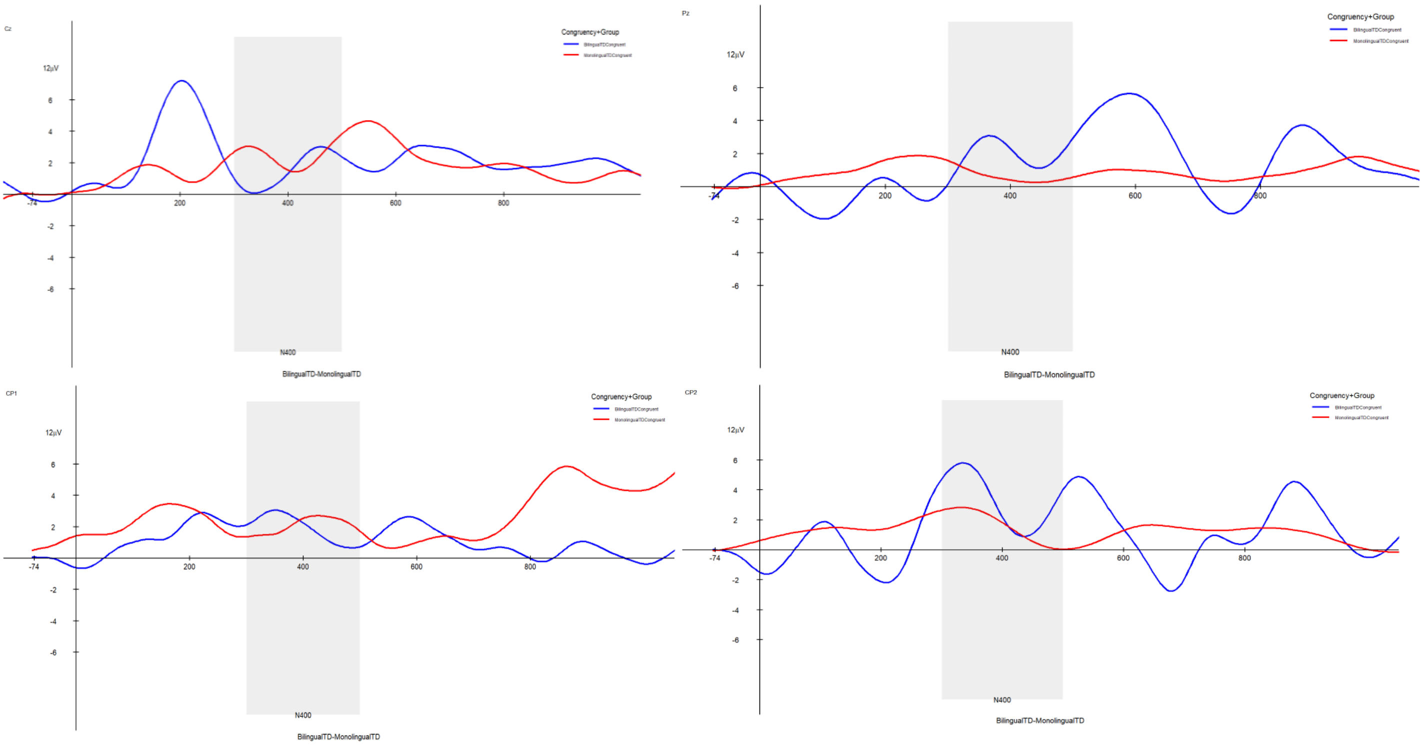
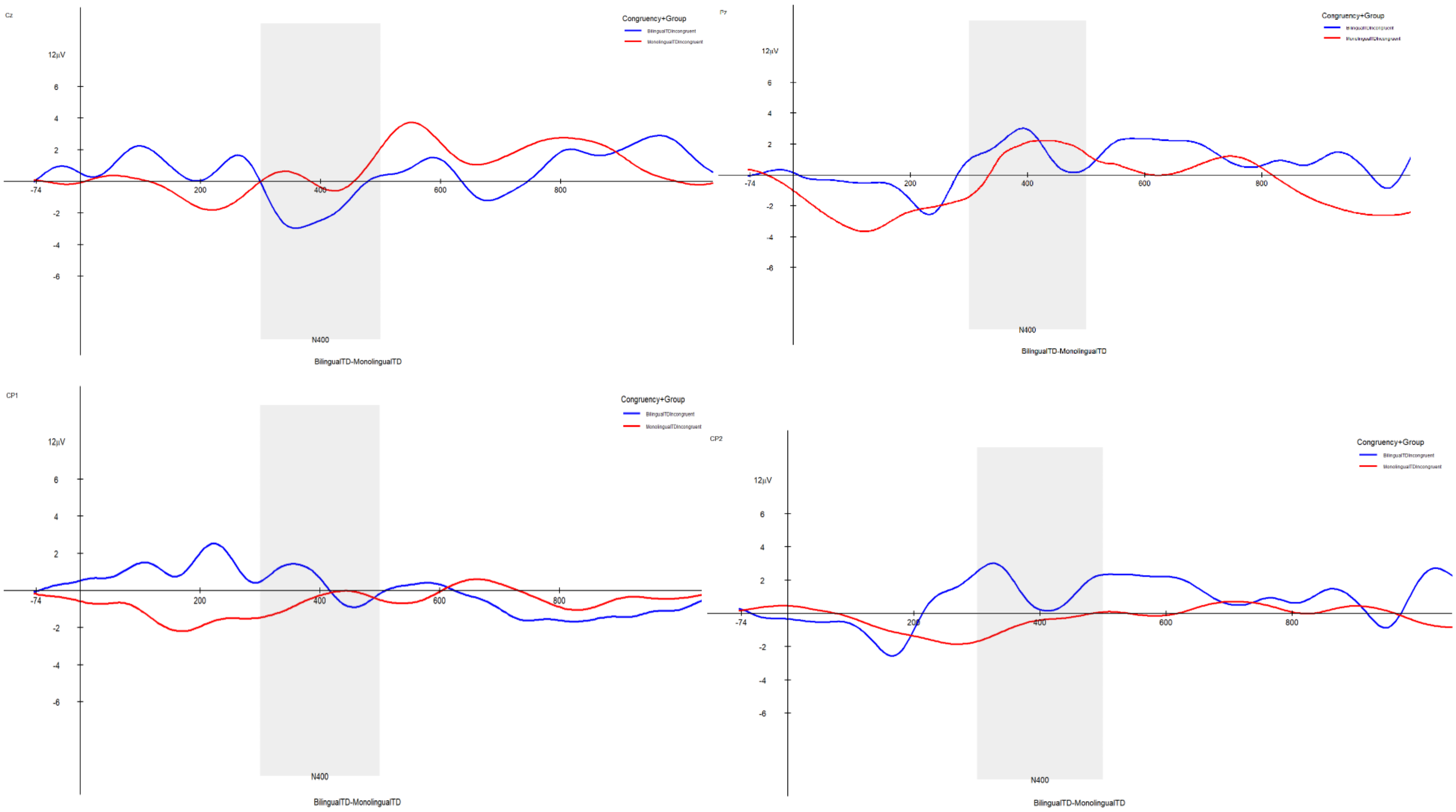



**Figure 7: Stroop Task Incongruent condition electrodes CZ, PZ, CP1, CP2**



### 3.10 General Discussion

This study embarked on an exploration into the realms of cognitive control and lexical processing in bilingual and monolingual children. Utilizing both the Lexical Decision Task and the Stroop Task, we aimed to unravel the intricate dynamics defining bilingual cognitive processing. By integrating behavioural measures with Event-Related Potentials (ERPs), our investigation probed deep into the cognitive landscape, comparing, and contrasting the performances of children aged 7-10. This comprehensive analysis was central to understanding how bilingualism influences cognitive functions, particularly focusing on aspects of inhibitory control and language processing.

#### 3.10.1 Unravelling the Complexities of Bilingual Lexical Processing: Insights from Lexical Decision Tasks

The pronounced differences in processing nonwords between bilingual and monolingual participants, particularly highlighted by longer reaction times (RTs) in bilingual children, underscore the unique cognitive challenges inherent in bilingualism. This finding aligns with discussions by Altman et al. (2020) and Gollan et al. (2014), which emphasize the significance of proficiency, language exposure, and age of acquisition in shaping cognitive processes.

As shown in our results, bilingual children exhibited significantly longer RTs and more pronounced N400 amplitudes when processing non-words (Tables 4 and 6), suggesting heightened cognitive effort and deeper semantic processing. The behavioural findings are complemented by our ERP data, providing a dual layer of evidence suggesting bilingual children exert heightened cognitive effort, particularly when processing unfamiliar lexical items, likely due to the complexities of managing two linguistic systems. These insights enrich our understanding of the cognitive complexities faced by bilingual children, in line with studies by Kutas & Federmeier (2000) and Kotz (2001), which highlight the sensitivity of the N400 component to lexical access and semantic processing.

To interpret the longer reaction times in bilingual children, it is crucial to consider multiple dimensions. While these might reflect an increased cognitive load, they also point to a larger lexical search space, as bilinguals manage an extensive lexical repository spanning two languages. This greater search space, indicative of the richness of the bilingual lexicon, necessitates more time for lexical retrieval, mirroring complexity rather than mere cognitive difficulty. This interpretation is supported by findings from Kroll and Rossi (2013) and Branzi et al. (2014), which suggest that bilingual lexical access involves complexities that extend beyond mere cognitive delay, often due to the simultaneous activation and inhibition of competing lexical items from both languages. Recent studies underscore that both languages in a bilingual individual are concurrently activated, influencing each other even in monolingual contexts (Wattendorf et al., 2014). This joint activation can complicate linguistic tasks for bilinguals, as each language influences and modifies the other once bilingual proficiency is attained. This dynamic interaction between languages challenges the earlier models that proposed separate linguistic representations, suggesting instead that bilinguals do not function as two independent monolinguals.

The absence of significant differences in processing Spanish words between bilingual and monolingual children highlights the pivotal role of language familiarity and proficiency. Supported by Schröter and Schroeder (2018), our results suggest that in familiar linguistic contexts, bilingual children can attain processing efficiency akin to their monolingual peers. This challenges the conventional narrative of a bilingual disadvantage, underscoring the adaptability and proficiency exhibited by bilingual children in familiar language scenarios. Additionally, our study engages with the concept of nonword classification complexity in bilingual contexts, as proposed by Jones and Brandt (2019). The varying degrees of challenge in classifying nonwords among bilingual children underline the unique adaptations and strategies employed in their lexical processing. This observation contributes to the broader discourse on bilingual cognitive and linguistic development, illuminating how language exposure and acquisition intricately interact with processing efficiency.

### 3.10.2 Bilingual Cognitive Control: A Comprehensive Analysis of Stroop Task Performance

Our analysis of the Stroop Task illuminates the complex cognitive dynamics underpinning bilingual cognitive control. The congruency effects, evidenced in both behavioural and ERP data, resonate with the established Stroop interference phenomena described by MacLeod (1991). Contrary to the expected bilingual advantage in inhibitory control tasks (Bialystok, Craik, & Luk, 2008), bilingual children displayed prolonged reaction times (RTs) in both congruent and incongruent conditions. This observation diverges from traditional narratives and prompts a deeper examination of the underlying cognitive mechanisms.

Incongruent trials showed pronounced negative N400 amplitudes, indicating intensive cognitive processing and possibly enhanced neural activity during conflict resolution (Abutalebi & Green, 2007). This suggests deeper engagement with the task, contrasting with typical expectations of bilingual advantages (Costa et al., 2008). These results demonstrate that bilinguals experience increased cognitive load and engage more profoundly with cognitive conflicts, perhaps utilizing enhanced neural mechanisms for managing linguistic interference (Rodriguez-Fornells et al., 2002).

The ERP differences were less pronounced in congruent conditions, where cognitive conflicts are naturally fewer. This suggests that while bilinguals engage deeply in conflict scenarios, their processing remains efficient in non-conflict tasks, akin to monolingual peers. This dual pattern of heightened cognitive effort and deeper engagement illustrates the adaptive strategies employed by bilinguals, reflecting increased cognitive flexibility rather than a straightforward advantage or disadvantage (Bialystok et al., 2006; Blom et al., 2017). The clear distinction in ERP responses between congruent and incongruent conditions raises questions about the differential engagement in these scenarios. Although RTs were extended in both conditions, the significant ERP findings in incongruent trials underscore that the cognitive processes involved in conflict resolution are particularly demanding and complex, corroborating the idea that bilingual cognitive processing involves intricate temporal dynamics (Wang et al., 2016).

Specifically, the enhanced N400 amplitudes in incongruent conditions suggest that bilinguals engage in more extensive conflict-monitoring and resolution mechanisms than monolinguals, likely due to their regular practice of managing interference between two languages. This aligns with Costa and Sebastián-Gallés (2014), who note how bilingualism refines the brain's executive control systems through continuous management of linguistic interference. These insights highlight that the longer RTs in both conditions, coupled with pronounced N400 in incongruent trials, signify greater difficulty but also deeper engagement in managing the heightened linguistic conflict inherent in these scenarios.

### 3.10.3 Integration of Socioeconomic Status (SES)

Socioeconomic status (SES) plays a pivotal role in shaping cognitive performance, particularly in bilingual contexts. Higher SES typically correlates with better educational resources and is often considered a facilitator of enhanced cognitive outcomes. However, as demonstrated in both the Lexical Decision and Stroop tasks, higher SES does not straightforwardly counteract the cognitive complexities associated with bilingualism. Instead, it provides a spectrum of access to linguistic and cognitive resources, subtly influencing performance outcomes. Research by Antoniou et al. (2016) and Blom et al. (2017) emphasizes the need for methodological rigor in controlling for SES, as its influence can affect the results of cognitive tasks. Hart and Risley (1995) and Fernald et al. (2013) have shown that SES profoundly impacts language exposure and acquisition, affecting linguistic processing capabilities. This interplay suggests that while SES enhances cognitive and linguistic resources, it does not fully alleviate the cognitive challenges associated with bilingualism.

To accurately isolate the effects of bilingualism from those of SES, precise matching on SES or robust within-group comparisons are crucial. This approach, supported by Paap, Johnson, & Sawi (2015), ensures that observed cognitive advantages are genuinely attributable to bilingualism rather than external socioeconomic factors. Future research should continue to employ such controls, as advocated by Wu and Thierry (2013) and Crivello et al. (2016), to clarify the nuanced impact of SES on bilingual cognitive processing.

### 3.10.4 Conclusion

Our comprehensive exploration into cognitive control and lexical processing through the Lexical Decision and Stroop tasks has revealed that bilingual cognitive functioning is nuanced and context dependent. The Lexical Decision Task highlighted the complexity inherent in bilingual lexical retrieval, suggesting a broader and more challenging search space due to the simultaneous management of two linguistic systems. This complexity manifests not simply as increased difficulty but as an interaction between cognitive load and the richness of the bilingual lexicon. Our ERP data further demonstrated heightened cognitive effort in bilingual children, particularly when processing unfamiliar lexical items.

The Stroop Task provided additional insights into how bilinguals manage cognitive flexibility and resolve conflicts, challenging the traditional notion of a uniform bilingual advantage. Bilingual children exhibited extended reaction times across congruent and incongruent conditions, with more negative N400 amplitudes in incongruent trials indicating a deeper neural sensitivity to conflict. These findings suggest that while bilinguals may encounter certain cognitive challenges, they also possess remarkable adaptability and cognitive flexibility. This underscores the importance of considering task-specific demands when evaluating bilingual cognitive advantages.

Socioeconomic status (SES) was found to be pivotal in shaping cognitive performance in bilinguals. While higher SES is generally associated with better educational resources, our findings indicate that SES does not uniformly mitigate the cognitive complexities inherent in bilingualism. Instead, SES subtly influences cognitive outcomes by providing varied access to linguistic and cognitive resources. This nuanced understanding calls for more sophisticated educational and cognitive interventions that consider both the advantages and challenges faced by bilingual individuals.

Moving forward, it is crucial for future research to rigorously control for socioeconomic factors and to delve deeper into how SES interacts with cognitive processing in bilinguals. This will help ensure that observed cognitive benefits are attributed to bilingualism rather than external factors. Additionally, future studies should include a broader demographic and a wider array of cognitive tasks to capture the daily linguistic challenges faced by bilinguals. By refining our approaches, we can better understand the diverse nature of bilingual cognition and develop tailored educational strategies that harness the strengths of bilingual children.

Our study contributes to the ongoing discourse on bilingualism by challenging simple narratives of a uniform bilingual advantage or disadvantage. By integrating behavioural and ERP data, we have provided a more sophisticated understanding of bilingual cognitive processing, emphasizing the context-dependent nature of bilingualism. These findings pave the way for future research to uncover the intricacies of bilingual cognition and enrich our understanding of its multifaceted implications in diverse language contexts

# 4- Study 2: Insights into Bilingual Minds: Lexical Processing and Cognitive Control and Developmental Language Disorder

## 4.1 Abstract

This study delves into the complex interplay of lexical processing and cognitive control in bilingual children with and without Developmental Language Disorder (DLD). Tests like the Lexical Decision Task and Stroop Task helped us to examine the impact of bilingualism and language disorders on reaction times (RTs) and event-related potentials (ERPs). In the Lexical Decision Task, Bilingual DLD children exhibited prolonged RTs for NonWords, emphasizing the considerable challenge posed by unfamiliar words. Contrary to expectations, their performance in processing familiar words in English and Spanish mirrored Bilingual Typically Developing (TD) peers, suggesting that lexical familiarity plays a crucial role in mitigating difficulties. The Stroop Task revealed pronounced interference effects, particularly in the English-incongruent condition for Bilingual DLD children. Prolonged reaction times highlighted challenges in managing conflicting information, shedding light on the nuanced relationship between bilingualism, DLD, and cognitive processing. ERP analysis further elucidated language-specific neural responses, emphasizing the unique challenges faced by Bilingual DLD individuals during incongruent trials. Aligning with existing literature, our findings challenge the assumption that bilingualism exacerbates language disorders. Instead, they underscore the crucial role of lexical familiarity in shaping performance across linguistic tasks. The ERP results contribute to understanding cognitive conflict monitoring mechanisms, emphasising language-specific modulation in bilingual children with DLD.

## 4.2 Introduction

The cognitive and linguistic processes involved in bilingual language use present unique challenges and outcomes, shaping the linguistic behaviours of bilingual children. Bilingual speakers, as defined by Kroll, Dussias, Biece, and Perroti (2015), navigate a complex interplay where both languages remain active during speech processing, reading, and speech planning. Simultaneous activation of languages, even in ostensibly monolingual contexts, has become a hallmark of bilingual language processing. This co-activation extends beyond the native language influencing the second language (L2); the L2 also exerts influence on the native language (Wattendorf et al., 2014). Despite the understanding that both languages are jointly activated during linguistic processing, there is a scarcity of research exploring language disorders in this bilingual population.

Lexical processing plays a pivotal role in language comprehension and production, yet there is a notable gap in our understanding of lexical skills in bilingual children, particularly those with Developmental Language Disorder (DLD). This study seeks to address this gap by examining differences in lexical processing and cognitive control between bilingual children with and without DLD. Our methodology involves measuring response times (RTs) and event-related potentials (ERPs) in a lexical decision task encompassing English, Spanish, and NonWords. Additionally, cognitive control and executive functions will be assessed by using a Stroop Task. By shedding light on the intricate relationship between language and cognition in bilingual children, this research aims to contribute valuable insights to both theoretical understanding and practical interventions for language disorders in this population.

### 4.2.1 Bilingualism and Developmental Language Disorder

Developmental Language Disorder (DLD) is a significant linguistic challenge affecting approximately 7% of children globally. Characterized by profound difficulties in acquiring and utilizing both spoken and written language forms, DLD transcends simple auditory or neurological deficits. Reflecting the broadened understanding by the CATALISE project, DLD encompasses a spectrum of language impairments across a continuum of intellectual abilities, thereby extending beyond the traditional confines of Specific Language Impairment (SLI) to include individuals with diverse intellectual profiles (Bishop et al., 2017).

DLD is characterized by pronounced difficulties in language acquisition and use, including complex sentence production and comprehension, restricted vocabulary, and challenges in the pragmatic use of language in social contexts. These difficulties significantly impact academic performance and social integration (Snowling et al., 2017). Additionally, DLD is associated with cognitive deficits such as challenges in working memory, executive functions, and resource allocation, which are crucial for broader cognitive development (Leonard, 2017).

Advanced imaging studies have specifically documented variations in the morphology and connectivity of regions critically implicated in language processing. These include significant alterations in the cortical surface areas of the left hemisphere's language-dominant areas—specifically, the inferior frontal gyrus (Broca's area) and the superior temporal gyrus (Wernicke's area). Notably, these changes are characterized by reduced surface areas rather than uniform changes in thickness, indicating specific patterns of brain structure alteration (Bahar et al, 2024). Additionally, discrepancies in the arcuate fasciculus, a white matter tract essential for linking these language processing regions, suggest atypical neurodevelopmental trajectories in DLD. These findings not only validate the complexity of neurological underpinnings in DLD but also necessitate precise, targeted interventions that consider these detailed structural differences (Mayes, Reilly, & Morgan, 2015; Verhoeven et al., 2012).

The heterogeneity of DLD, with its varying severity levels, impacts both the understanding and production of spoken language, presenting a unique set of challenges in bilingual contexts (Tomblin et al., 1997). In bilingual contexts, positive cross-linguistic transfer has been identified as a facilitator in acquiring a second language (L2) (Blom & Paradis, 2013). Contrary to some assumptions, evidence suggests that bilingualism does not exacerbate the linguistic acquisition challenges in children with DLD. In fact, bilingualism may provide unique opportunities for language learning and cognitive development in this population, highlighting the potential benefits of bilingual exposure (Kohnert, 2010). Word learning is a particularly challenging area for school-age children with DLD. They often struggle with aspects of semantic knowledge, morphology, syntax, lexicon, pragmatics, and phonology, which are crucial components of effective language use (Leonard, 2017). These challenges are further compounded in bilingual children who must navigate these linguistic hurdles in multiple languages. While deficits in lexical and phonological development are noted, morphosyntactic deficits tend to be more pronounced, indicating a specific area of vulnerability in bilingual children with DLD (Claessen et al., 2013).

Bilingualism involves managing two linguistic systems, which can enhance cognitive functions such as attentional control, working memory, and the ability to switch tasks effectively. This management is particularly beneficial in children with DLD, offering them unique opportunities for cognitive and linguistic enrichment. Cognitive processing abilities, often referred to as executive function skills, are crucial in this context. They have been associated with academic success and language abilities, reflecting their foundational role in educational outcomes (Borella et al., 2010; Diamond, 2013; Gathercole et al., 2004).

Studies have shown that bilingual individuals often exhibit enhanced executive functions, including better attentional control, cognitive flexibility, and inhibitory control. These enhancements are attributed to the constant need to switch between languages and inhibit the non-target language, providing bilinguals with a cognitive workout that may strengthen these executive functions (Bialystok, Craik, & Luk, 2012). However, the extent of these advantages and the underlying mechanisms remain areas of active research and debate. For individuals with DLD, bilingualism introduces additional variables into this already complex equation. While some evidence suggests that bilingualism can provide cognitive benefits that may help mitigate some of the challenges associated with DLD, other studies indicate that managing two languages may place additional demands on an already compromised language system (Kohnert, 2010).

The nature of the interplay between bilingualism and cognitive control is influenced by factors such as the age of bilingual exposure, language proficiency, and the similarity between the languages in question, making it a rich area for further investigation. This interaction is not straightforward, as research has demonstrated that bilingualism does not inherently exacerbate language learning difficulties associated with DLD. Instead, managing two languages can offer distinct cognitive and linguistic benefits, suggesting that bilingual exposure may be advantageous for children with DLD (Blom & Paradis, 2013; Kohnert, 2010). Furthermore, the relationship between bilingualism and cognitive control within the context of DLD presents a layered complexity. Whereas bilingualism has been documented to enhance aspects of cognitive control in typically developing individuals, its implications for those with DLD are less clear. The consensus acknowledges that while bilingualism may introduce additional challenges in language acquisition for those with DLD, it also posits potential cognitive benefits, such as enhanced attentional control. This multifaceted interaction suggests that bilingualism is not inherently detrimental to individuals with DLD and may, in fact, confer certain advantages, highlighting the intricate interplay between bilingualism, cognitive control, and language disorders (Greenhalgh et al., 2017).

Bilingualism and DLD in children present a dynamic and intricate challenge. Understanding the cognitive and linguistic processes in bilingual children with DLD is crucial for developing effective assessment and intervention strategies. The evidence suggests that being bilingual can be an asset in the language development journey of children with DLD. This highlights the importance of culturally responsive and linguistically appropriate approaches in supporting these children. Future research should continue to delve into the unique developmental trajectories and intervention outcomes of bilingual children with DLD, aiming to optimize their language development and cognitive processing. Embracing the linguistic diversity and potential of bilingual children with DLD is essential in fostering their academic and social success.

### 4.2.2 Lexical Processing: Differences between DLD and TD Bilinguals

The intricate interplay of lexical processing in bilingual children, especially those with Developmental Language Disorder (DLD), is fundamental for understanding the nuances of language development. The "lexical-semantic network," as defined by Collins and Loftus (1975), serves as a cornerstone in comprehending how words are stored in semantic memory and organized for efficient retrieval. This network, comprised of interconnected conceptual nodes, facilitates coactivation, allowing for the swift retrieval of related words when one node is stimulated. However, the efficiency of this network is not uniform across all children, particularly those with DLD. Poor lexical concepts and a limited vocabulary within semantic categories contribute to weaker activation in lexical-semantic networks (Krethlow et al., 2020). This becomes evident in tasks such as picture naming tests, where bilingual children with DLD consistently exhibit lower accuracy and longer reaction times compared to their typically developing (TD) peers (Anaya et al., 2021). However, understanding how bilingualism interacts with DLD to shape these lexical-semantic networks is a complex and evolving area of research.

A comprehensive investigation by Kambanaros and Grohmann (2015) examined naming accuracy and error types in a multilingual child with DLD compared to Cypriot Greek bilingual TD children. Across three languages (Bulgarian, Cypriot Greek, and English), the child with DLD consistently scored lower, revealing comparable lexical-retrieval deficits that transcended language boundaries. Such cross-language consistencies in lexical deficits emphasize the pervasive nature of these challenges in bilingual populations. The role of bilingualism in shaping lexical processing becomes more apparent in studies that specifically address word learning and recall. Barak et al, (2022) exploration of Hebrew-speaking children, encompassing both monolingual and Russian-Hebrew bilinguals, illuminated a nuanced picture. While bilingualism itself did not hinder word learning in typically developing bilingual children, the presence DLD significantly impeded word learning. Importantly, even bilingual children with typical development exhibited lower word retrieval skills compared to their monolingual counterparts, underlining the intricate relationship between bilingualism and lexical processing in children.

Bridging these studies, Holmstrom et al. (2015) examined the effect of DLD on the lexical organization of bilingual children. The authors explored word associations of bilingual DLD and Bilingual TD Arabic–Swedish speaking children. Longitudinal findings revealed more syntagmatic associations ***(e.g., words that rhyme)*** in the bilingual DLD group and more paradigmatic associations ***(e.g., words that share the same word class)*** in the bilingual TD group. Because syntagmatic associations are characteristic of younger children, these findings suggest that lexical organization develops more slowly in bilingual DLD children compared to bilingual TD children, further highlighting the intricate and evolving relationship between bilingualism and DLD in lexical development.

In specific assessment tasks like non-word repetition, Thordardottir and Brandeker (2013) analysed the performance of French-English sequential bilinguals with and without DLD. Their findings were intriguing: bilingual DLD children performed similarly to their TD peers regardless of language exposure level. This underscores the significance of considering both language exposure and diagnostic category when assessing bilingual populations. In line with

Marini et al. (2019), these results suggest that bilingual exposure, even for children with DLD, does not detrimentally affect lexical development.

Research by Tsimpli et al. (2015) indicated that bilingual children DLD did not differ significantly from monolingual DLD children in expressive vocabulary and sentence repetition. However, bilingual DLD children showed slightly lower lexical diversity in narrative tasks. This suggests that bilingual DLD children might have a slight disadvantage in lexical skills compared to their monolingual counterparts, hinting at the intricate interplay between bilingualism and DLD on specific aspects of lexical development.

### 4.2.3 Cognitive Control and Executive Functions: The Role of Bilingualism and DLD

Cognitive control, which is crucial for managing conflicts and interference between contradictory representations (Novick, Trueswell, & Thompson-Schill, 2010) plays a pivotal role in understanding the disparities between typically developing (TD) and Developmental Language Disorder (DLD) bilingual children. It is essential to delve deeper into what the combination of bilingualism and DLD truly means for executive functions (EF).

One of the valuable tools for investigating cognitive control in bilingual processing is the Stroop task, introduced by Stroop in 1935. This task is widely employed in cognition research to study executive control functions, emphasizing interference resolution between stimulus dimensions, response inhibition, and response selection. Conflicts arise in incongruent trials, requiring participants to resolve conflicts between word and colour stimuli (e.g., 'red' printed in blue ink), leading to longer reaction times (RTs). Conversely, congruent trials, where word and colour align, facilitate quicker RTs.

The influence of bilingualism and DLD on executive function is a subject of ongoing debate. While studies such as those by van den Noort et al. (2019) and Ware et al. (2020) suggest a positive impact, bilingual children with DLD face compounded cognitive demands, especially evident when transitioning from congruent to incongruent conditions. For instance, children with DLD may codeswitch more frequently due to poor inhibitory control, which might yield differences in the frequency with which they suppress nontarget information activated, compared to their TD peers (Spaulding, 2010). This complexity is highlighted in a study by Reichenbach et al. (2016), who investigated 5–6-year-old non-reading children using a modified Stroop task. The task involved rapidly naming the colour of black and white fruits and vegetables and then repeating the task with objects coloured incongruently to their natural colour (e.g., A Blue Strawberry). The task's design, involving the rapid naming of the colour of incongruently coloured fruits and vegetables, presented a unique cognitive challenge. The findings indicated that both DLD and TD groups experienced slower responses in the incongruent condition, yet the performance gap was not significant, suggesting a comparable ability in DLD children to proficiently manage interference.

Expanding on this, Ladányi (2018) compared DLD and TD groups across various cognitive tasks, including the backward digit span, n-back, and Stroop tasks. Intriguingly, the DLD group demonstrated weaker performance in the first two tasks but not in the Stroop task. This outcome challenges conventional assumptions about overlapping cognitive control demands across different tasks and proposes that the cognitive mechanisms involved in the Stroop task may diverge significantly from those in word retrieval tasks. This raises the possibility that less automatized reading skills in DLD children could result in reduced conflict in incongruent Stroop conditions, altering the traditional understanding of how cognitive control interplays with reading skills and task requirements. Recent longitudinal studies have added another layer of complexity, showing how cultural contexts and developmental trajectories interact with bilingualism to affect executive function. For example, Tran et al. (2014) found that culture significantly modulated performance on the Attention Network Task (ANT) in 3-year-olds from Argentina, Vietnam, and the USA, illustrating cultural influences on EF development.

Similarly, Park et al. (2015) observed that over one-year, bilingual children exhibited significant improvements in inhibition on the Flanker task, unlike their monolingual counterparts, suggesting that bilingual experiences might differentially influence the developmental rates of specific EF components at certain developmental stages.

Furthermore, the interrelation between bilingualism and cognitive control within the context of DLD presents a layered complexity. Whereas bilingualism has been documented to enhance aspects of cognitive control in typically developing individuals, its implications for those with DLD are less straightforward. The consensus acknowledges that while bilingualism may introduce additional challenges in language acquisition for those with DLD, it also posits potential cognitive benefits, such as enhanced attentional control. This indicates a multifaceted interaction, where bilingualism is not inherently detrimental to individuals with DLD, and may, in fact, confer certain advantages, highlighting the intricate interplay between bilingualism, cognitive control, and language disorders (Greenhalgh et al., 2017).

The relationship between bilingualism and cognitive control in DLD showcases both potential benefits and challenges. Bilingual individuals often exhibit enhanced performance on tasks requiring cognitive control, indicating that managing two linguistic systems can confer advantages in attentional control, working memory, and task-switching abilities (Antón et al., 2014). For those with DLD, navigating bilingualism involves a complex interplay of cognitive control systems, which can both intensify language management challenges and offer unique cognitive and linguistic enrichment opportunities (Kohnert, Windsor, & Ebert, 2009). Moreover, the interaction between bilingualism and cognitive control is not static but evolves over time, influenced by the quality and quantity of linguistic input and the specific languages involved (Hoff and Core, 2013). This dynamic nature of cognitive development in bilingual children with DLD poses unique challenges but also offers potential cognitive benefits, as suggested by studies indicating that bilingual children with DLD can develop robust language skills, often aided by their bilingual exposure (Kohnert et al., 2020).

To effectively evaluate these dynamic cognitive functions, a variety of measures are utilized, each designed to assess different aspects of executive functioning. Traditional assessments such as the Stroop test (MacLeod & MacDonald, 2000), the Simon task (Hommel, 2011), the flanker task (Eriksen, 1995), and the Attention Network Test (ANT; Rueda et al., 2004) provide insights into how bilingualism impacts cognitive control. Specifically, the ANT, designed for children as young as four years old, measures the ability to focus on task-relevant information amidst distractors and is sensitive to developmental differences in executive function in children from different linguistic backgrounds, including those with language disorders (Ebert et al., 2019). Despite the presumed benefits of enhanced inhibition control in bilinguals over time (Green & Abutalebi, 2013; Kałamała et al., 2021), children with DLD often face challenges in these areas. Underperformance in inhibition control measures may impact their ability to focus on relevant information during language acquisition, affecting the processing and acquisition of subtle grammatical features and leading to comprehension issues (Leonard, 2014; Montgomery et al., 2008). Ebert et al. (2019) found that differences in attention skills between children with and without DLD are comparable across bilingual and monolingual contexts, indicating that bilingualism does not exacerbate or ameliorate subtle deficits in non-linguistic attention skills associated with DLD. This evidence supports the notion that cognitive processes in DLD children are consistent across language contexts, emphasizing the need for nuanced approaches in educational and therapeutic settings.

In summary, the interplay between cognitive control, executive functions, and language development in bilingual children, particularly those with DLD, paints a complex and multifaceted picture. The challenges in inhibitory control, evident across various modalities, underline the intricate nature of cognitive processes in the context of bilingualism and language disorders. Understanding these relationships is crucial for developing targeted interventions that effectively support the unique needs of bilingual children with DLD.

### 4.2.4 ERP, Bilingualism and Language Disorders

The analysis of neural activity through Event-Related Potentials (ERPs) provides valuable insights into the multidimensional aspects of language processing, offering a departure from traditional behavioural measures focused on accuracy and reaction times (RTs) (Kutas & Federmeier, 2000). ERP studies, particularly those centered around the N400 component, have been instrumental in understanding lexical-semantic processing, revealing a distinctive electrical brain response pattern approximately 400 milliseconds post-stimulus presentation (Kutas & Hillyard, 1983). Language development encompasses various facets—phonological, lexical, and morphosyntactic—whose maturation may not align simultaneously in children with Developmental Language Disorder (DLD), differing from typically developing (TD) children.

However, the specific implications of bilingualism combined with DLD on lexical processing remain an underexplored area. While ERP studies have explored lexical processing and executive functions, research specifically addressing bilingual children with DLD is limited. Recognizing the intricate relationship between bilingualism and language disorders is crucial, given that these children navigate the complexities of language development in multiple languages. Comparisons with studies involving monolingual participants highlight the need for understanding neural correlates across diverse linguistic contexts. Studies exploring lexical processing in children with DLD have yielded insights. Cummings and Čeponienė (2010) presented audio-visual stimuli to 16 children with DLD aged 7-15 years. Using visual-auditory presentation of images ***(e.g., ROOSTER)*** with verbs (the lexical condition, e.g., ***Crowing***) or environmental sounds ***(e.g., a Rooster Crowing),*** they observed that children with DLD show longer latencies on the N400 to lexical incongruencies (picture-word difference) as compared to controls, whereas both groups show similar latencies on environmental sound N400s.

Building on this insight, studies by Evans et al. (2022) and Kornilov et al. (2015) extended the exploration of lexical processing in adolescents and younger children with DLD, respectively. Evans et al. (2022) delved into the neural correlates of lexical-phonological and lexical-semantic processing in adolescents with DLD and procedural memory impairment, alongside their TD peers. Notably, an N400 component was elicited in response to semantic incongruency (***Giraffes have long SCISSORS***) in both groups, suggesting a shared mechanism in this aspect of language processing. However, disparities emerged, in the localisation of the N400. For the TD groups, this was distributed predominantly over the right hemisphere whereas the adolescents with DLD exhibited a more bilaterally distributed pattern of activation. This could be an indication of qualitative differences in the underlying representations of words in the lexicons of adolescents with DLD. Kornilov et al. (2014) examined event-related potential indices using a picture–word matching paradigm in younger children with DLD, revealing markedly reduced N400 amplitudes in response to auditorily presented words with initial phonological overlap with the name of the pictured object. This reduction was linked to behavioural indices of phonological and lexical development, showcasing the interconnectedness of neural responses and language abilities in children with DLD.

Several studies, including Li et al. (2019) and Archibald and Joanisse (2012), explored the N400 in the context of cognitive conflict monitoring. Results indicated that N400 responses differed between TD and DLD groups, suggesting limited cognitive resources for monitoring conflict information and compromised inhibition during conflict detection in DLD children. Pijnacker et al. (2017) observed N400 onset delays in Dutch children with DLD, correlating with lower scores on tasks assessing various language and cognitive abilities. The broader scalp distribution of N400 responses in the DLD group emphasized the nuanced nature of lexical-semantic processing in developmental language disorder.

While ERP studies have significantly advanced our understanding of the complex interactions between neural processes, lexical-semantic development, executive functions, and N400 responses in children with DLD, a crucial gap remains in the research landscape. This gap pertains to the specific implications of bilingualism combined with DLD for Lexical processing, Executive Functions (EF), and N400 responses in ERPs. Future research must explore how bilingualism affects the neural processing patterns of lexical-semantic information and executive functions in children with DLD, shedding light on the distinctive challenges faced by bilingual children with DLD in a multilingual environment.

### 4.3 The Study

In this study, we aimed to investigate the lexical processing and cognitive control of bilingual children with Developmental Language Disorder (DLD) compared to their typically developing (TD) peers, all of whom have English as their second language. Our primary focus is to understand how language disorders interact with bilingualism. To achieve this, we administered two tasks: a Lexical Decision task and a Stroop task. The Lexical Decision task assessed participants' efficiency in recognizing and accessing words from their mental lexicon. Slower reaction times in individuals with DLD and bilingualism may indicate difficulties in lexical access. The Stroop task helped us assess cognitive control abilities and determine if bilingualism had an impact on performance. Additionally, we examined event-related potentials (ERPs) during these tasks to gain insights into their neural response. By comparing responses between bilingual children with DLD and their TD peers, we aim to explore the relationship between language disorders, bilingualism, cognitive control, and lexical processing. This study will evaluate whether bilingualism exacerbates or mitigates the linguistic and cognitive complexities inherent in DLD, contributing to a deeper understanding of how bilingualism interacts with language disorders.

## 4.4 Methods

### 4.4.1 Participants

This study involved 68 Chilean children aged 7-10 (mean = 8.3, SD = 1.11), categorized into Bilingual Developmental Language Disorder (Bilingual DLD) and Bilingual Typically Developing (Bilingual TD) groups. All participants were native Spanish speakers with English as their second language. Detailed demographic data, including educational backgrounds and primary languages spoken at home, are summarized in Table 1 and provided in Appendix 1. Ethical approval was secured from the University of Essex Social Sciences Ethics Sub-Committee, with all necessary parental consents obtained prior to participation. For a description participant selection, refer to Section 2.1.

Testing occurred from May to August 2021, following the national COVID-19 lockdown in Chile. By this time, all children had returned to full-time education, providing a stable context for assessing the impacts of bilingualism on linguistic challenges associated with DLD. The study controlled for several covariates, including socioeconomic status (SES), derived from the educational levels of parents or guardians, nonverbal IQ, and English proficiency.

### 4.4.2 Bilingual TD group

This group included 32 participants (18 girls, 14 boys) from three diverse bilingual schools across Chile. These children received English instruction from the start of their schooling, beginning as early as kindergarten. Their extensive exposure to a bilingual environment aimed to enhance both Spanish and English linguistic skills, with English being taught for about 30-35 hours per week. The educational background of their parents, predominantly holding university degrees, supports a culturally rich and academically focused upbringing, fostering an environment conducive to advanced bilingual acquisition. Further details about the participants and their familial backgrounds are described in Section 2.1.1.

### 4.4.3. Bilingual DLD group

The Bilingual DLD group comprised 36 participants (21 girls, 15 boys). This group was selected from the same bilingual schools as the Bilingual TD group and shared similar early educational experiences. Unlike their TD peers, these children faced unique linguistic challenges due to their developmental language disorder, necessitating tailored educational and therapeutic interventions. They benefited from additional support, including frequent sessions with bilingual speech and language therapists, which were crucial for addressing their specific language needs. More information about the participants' backgrounds can be found in Section 2.1.2.

**Table 1: Participants demographic information**

SES (parental education) information was coded following the International Standard Classification of Education (ISCED; UNESCO Institute for Statistics, 2012). This ranged from 0 (less than primary education) to 8 (doctoral or equivalent)

| Group/Variable | Bilingual TD | Bilingual DLD |
|---|---|---|
| **Participants** | 32 | 36 |
| **Age (Years)** | M=8.31, SD=1.07 | M=8.30 SD=1.15 |
| **Sex** | 18Girls, 14 Boys | 21Girls, 15Boys |
| **SES (Parental Education)** | M=6.13, SD=0.49 | M=6.11, SD=0.57 |
| **Non-verbal IQ** | M=91.73, SD=4.35 | M=89.39, SD=4.76 |
| **L2 Proficiency** | M=3.59, SD=0.79 | M=3.50, SD=0.84 |

## 4.5 Materials and Stimuli

### 4.5.1 Lexical decision task

The Lexical Decision Task (LDT) assesses the ability of children to distinguish between words and nonwords, reflecting their capacity to access and process lexical items within their mental lexicon. This task is crucial for understanding lexical access and semantic processing, particularly among children with DLD and those who are bilingual. For detailed task design and stimulus information, refer to Section 2.2 and Appendix 2 for the stimulus list.

### 4.5.2 Nonwords

Nonwords for the LDT were created using the SCOPE Lab Nonword Generator to ensure they did not resemble real words in either English or Spanish. This tool allowed for detailed customization of phoneme choices, orthographic patterns, and character lengths, ensuring the nonwords were challenging yet comprehensible. Examples include “AALKN” and “FWNOL,” designed to eliminate recognition bias from familiarity with linguistic characteristics of participants' native languages. For a detailed description of the nonword generation process see Section 2.2.2

### 4.5.3 Bilingual Lexical Decision

In the bilingual Lexical Decision Task, participants were presented with 80 stimuli, composed of 40 nonwords and 40 words, equally divided between Spanish and English. Spanish words excluded special characters to avoid visual indications of language origin. The English words were selected from the “English Syllabus for primary schools” used in Chile, with the Spanish versions adapted accordingly. The stimuli, including nonwords, ranged from 5 to 7 characters in length (mean = 6.12, SD = 0.74). Direct translations were avoided to eliminate potential biases from recognizing the same concept in both languages. This ensured that each lexical decision was based on the participant's ability to process each word as a unique lexical item, providing a more accurate measure of bilingual lexical access and semantic processing abilities. For additional details on stimulus selection, please refer to Section 2.2.3

### 4.6.1. Stroop Task

Introduced by John Ridley Stroop in 1935, the Stroop Task has become a cornerstone in the study of cognitive flexibility and inhibitory control. These cognitive functions are essential components of executive function, assessing an individual's ability to manage cognitive interference effectively. In this study, the Stroop Task was employed to explore these cognitive processes, with a focus on identifying differences in how they manifest among children, both with and without Developmental Language Disorder (DLD).

### 4.6.2Bilingual Stroop Task

The bilingual Stroop Task presented colour names in both Spanish and English, adding a layer of cognitive complexity by requiring participants to suppress the automated response to read the word and navigate between two languages. This task utilized a nonverbal response format, where participants indicated their answers by pressing keys on a colour-coded keyboard corresponding to the colour of the text, rather than articulating their responses. This format focused on cognitive control, eliminating the confounding factor of language production, making it suitable for children with DLD. The task comprised 90 trials, equally divided between congruent (e.g., the word "RED" printed in red) and incongruent (e.g., the word "GREEN" printed in red) conditions, using the colours RED, GREEN, YELLOW, and BLUE, and their corresponding translations in Spanish. For detailed procedural descriptions and experimental settings, please refer to Section 2.3.2.

## 4.7 Procedure Lexical decision and Stroop Task.

### 4.7.1 Experiment Procedure

The Lexical Decision Task (LDT) and Stroop task were conducted in a quiet, unoccupied classroom to minimize distractions and optimize concentration. To reduce electrical interference, the room's lighting was turned off during the session. Stimuli were displayed using PsychoPy software on an ASUS ZenBook laptop positioned in front of the participants. For the LDT, visual stimuli consisted of words and nonwords shown on a black background in a clear, white 20-point Arial font (see Figure 1 for a visual depiction). For the Stroop task, stimuli were presented on a black background in various colours (green, red, yellow, and blue) using a 20-point Arial font. Participants responded using the laptop keyboard, with both oral and written instructions provided in Spanish to ensure clarity and comprehension. The entire session typically lasted about 45 minutes. This setup maintained a uniform testing environment for reliable data collection. For more detailed descriptions, refer to sections 2.4.1.

### 4.7.2 Lexical Decision Task

Participants categorized stimuli as words or nonwords, starting with practice trials (four words and four nonwords) to familiarize themselves with the task. If necessary, instructions and practice trials were repeated. The experimental task was divided into two blocks of 40 stimuli each, with 10 English words, 10 Spanish words, and 20 nonwords per block, presented in a randomized sequence. A short break was allowed between blocks. Each trial began with a 1000 ms fixation cross, followed by a 3000 ms stimulus. Participants pressed 'A' for words and 'L' for nonwords, with the response screen visible for up to 3000 ms. Participants were instructed to respond as quickly and accurately as possible. For detailed procedures, see section 2.4.2

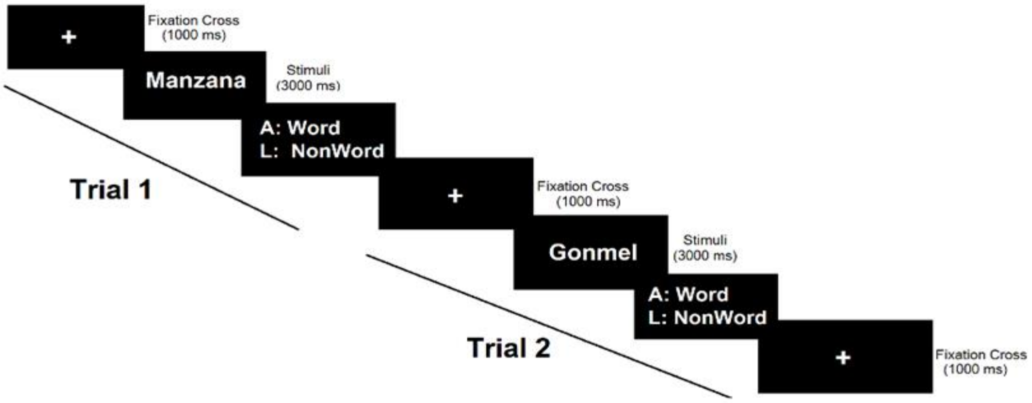



Figure 1: Lexical decision task layout

### 4.7.3 Stroop Task

Following the lexical decision task, participants engaged in the Stroop task, starting with an 8-stimuli practice trial consisting of 4 congruent and 4 incongruent items. If participants did not fully understand the task, further instructions were provided, and the practice session was repeated. The Stroop task consisted of 90 trials divided into three blocks of 30 trials each, balanced with an equal number of congruent and incongruent conditions. Participants used a color-coded keyboard setup to press the key matching the colour of the text displayed. Each trial began with a fixation cross for one second, followed by a priming condition lasting 2.5 seconds, and the main Stroop stimulus displayed for three seconds. Participants were prompted to respond as quickly and accurately as possible. For detailed procedural descriptions and settings, please refer to Section 2.4.3 in the General Methods.

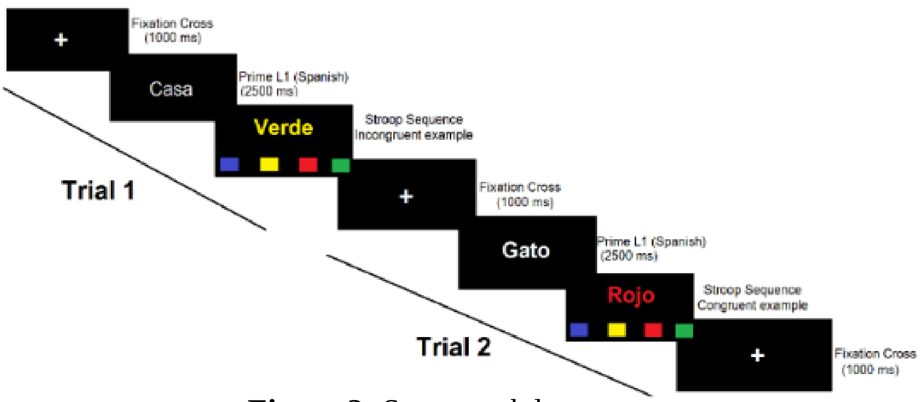



**Figure 2:** Stroop task layout

#### 4.7.4 Priming

This study incorporated a priming phase before the Stroop task to examine the impact of linguistic activation on cognitive control. Participants were shown Spanish words for 2.5 seconds to stimulate relevant linguistic networks. Spanish was chosen to ensure consistent activation across all participants. Although the priming phase aimed to understand how pre-activated linguistic networks affect cognitive control strategies in individuals with DLD, its effects were not included in the primary analysis to maintain focus on the Stroop task's core cognitive processes. However, the potential influence of priming on task performance remains a valuable topic for future research. For detailed priming methodology, refer to section 2.4.4.

#### 4.7.5 EEG Procedure

The EEG procedure for both the lexical decision and Stroop tasks followed a consistent protocol for all participants. EEG signals were acquired using a BioSemi system with 32 Ag-AgCl scalp electrodes placed according to the 10-20 positioning system. The two mastoid electrodes served as references, and ocular movements were recorded using three additional electrodes. EEG data was transmitted to a BioSemi ActiveTwo amplifier box, and ERP triggers were coded using PsychoPy3 software (Peirce et al., 2019). Continuous monitoring of outputs was maintained in BioSemi Actiview. If electrode adjustments were necessary, they were made during designated breaks. This standardized procedure ensured consistent data collection, contributing to the reliability and comparability of neural responses during the tasks.

### 4.8 Data Analysis

#### 4.8.1 Behavioural Analysis

Using RStudio version 4.1.2 and Linear Mixed-Effects Models (LMERs), behavioural and ERP data were analysed. Three participants, (1 TD and 2 DLD) were excluded from the analysis due to poor-quality brain data and consistent movement during the task. For the behavioural data, Reaction times (RTs) were log-transformed to achieve a normal distribution. Only correct responses were included in the analysis to ensure the accuracy of the data. No additional trimming of outlier RTs was performed beyond this. Type of Words and Group were considered as fixed factors, with additional covariates including age, sex, SES, non-verbal IQ, and notably, English proficiency, to acknowledge its potential influence on bilingual processing.

The Stroop Task analysis added language (English vs. Spanish) as a fixed factor alongside congruency and group, offering a detailed exploration of bilingual cognitive control mechanisms. English proficiency alongside SES non-verbal IQ, age, and sex, were added as covariates. English conditions from both tasks were analysed, providing a comprehensive view of bilingual executive functions. Interaction analyses in both tasks examined the

### 4.8.2 ERP Analysis

In this study, we processed EEG recordings from bilingual TD and bilingual DLD children during the Lexical Decision and Stroop tasks, utilizing EEGlab (v2021.1) and ERPlab (v8.10) tools. All EEG data underwent filtering at a 256Hz sampling rate with a 0.1Hz high pass and a 30Hz low pass filter. Artifact identification and removal were systematically conducted using Independent Component Analysis (ICA), targeting predominantly blink-related artifacts. On average, we extracted 4 artifacts per child, thereby enhancing the data quality for subsequent ERP analysis. After ICA, the datasets were re-referenced to mastoid electrodes, and segmented into epochs from -200 to 1000 ms. This epoch window was specifically chosen to capture the anticipated ERP components spanning from initial sensory responses to complex cognitive events like the N400. Artifact rejection proceeded in two stages, employing a peak-to-peak threshold method that first addressed eye-channel artifacts and subsequently those from all scalp channels. Across the tasks, data retention varied: In the Lexical Decision Task, we observed a rejection rate of 5.1%, resulting in roughly 76 trials retained (95.5%) for TD children. For DLD children, the rejection rate was 5.4%, resulting in approximately 76 trials retained (94.5%). The Stroop task showed a similar pattern, with Bilingual TD having a rejection rate of 5.5%, resulting in approximately 85 trials retained (94.5% of 90 trials). For the DLD group, the rejection rate was 5.9%, resulting in approximately 85 trials retained (94.4% of 90 trials).

The N400 component's mean amplitude was explored within a 350-550 ms window. Centro-parietal electrodes (CZ, C3, C4, CP5, CP1, CP2, CP6, P7, P3, PZ, P4, P8) were selected for our region of interest based on their documented sensitivity to the N400 component in semantic tasks (Kutas & Federmeier, 2011; Moreno & Kutas, 2005). These regions are critical for linguistic and executive processing. Linear Mixed-Effects Modeling (LMER) was used for statistical analyses, treating each electrode as a random effect within the ROI. This approach allowed us to capture the unique contributions and variability of each electrode's response across different conditions and participant groups.

In Study 2, we focused on the N400 component to reveal insights into cognitive and lexical processing abilities between bilingual children with and without DLD. Early ERP components like P1 and N1, which reflect sensory processing and attentional mechanisms (Luck, 2014; Woodhead et al., 2014), were not the central focus of our research. We observed some variability in waveforms during the early stages (0-200 ms post-stimulus), but our emphasis was on the 350-550 ms window due to its relevance to semantic processing (Kaan et al., 2000). Our decision to focus on the N400 component is supported by its responsiveness to linguistic variables in bilingual populations (Hahne, Eckstein, & Friederici, 2004). This may explain the reduced prominence of early components in our findings. However, the early visual word recognition components could still provide valuable information. Research by Maurer, Brandeis, & McCandliss (2005) indicates that early sensory processing is informative for understanding language development disorders. Future research should include these early components to offer a more comprehensive view of neurocognitive processing in bilingual children with and without DLD.

## 4.9 Results

### 4.9.1 Lexical Decision Task: DLD and TD differences

**Table 2:** Reaction Time (RTs)

| Group | Spanish | English | Nonword |
|---|---|---|---|
| Bilingual TD | 6.91 (0.44) | 6.93 (0.41) | 7.07 (0.42) |
| Bilingual DLD | 6.94 (0.40) | 6.97 (0.44) | 7.25 (0.40) |

**Table 3:** Accuracy

| Group | Spanish | English | NonWords |
|---|---|---|---|
| Bilingual TD | 99.3 | 94.0 | 92.0 |
| Bilingual DLD | 98.2 | 93.0 | 88.6 |

Results from the Lexical Decision Task are summarized in Table 4. Significant results were found for type ($F$ (2, 80.2) = 74.74, $p<.001$), and group, ($F$ (1, 488) = 50.43, $p<.001$). Additionally, the interaction between type and group was also significant, ($F$ (2, 525) = 25.21, $p<.001$). Non-significant results were observed for age, ($F$ (1,414) = 2.60, $p$ = .107); sex ($F$ (1, 506) = 0.60, $p$ = .436); NVIQ, ($F$ (1, 427) = 0.17, $p$ =.674); SES, ($F$ (1,13) = 0.45, $p$ = .831); and L2 proficiency ($F$ (1, 480) = 0.34, $p$ =.560).

**Table 4:** Model results for Lexical Decision reaction time analysis

| **Parameter** | *DF* | MeanSq | F | p |
|---|---|---|---|---|
| Type | 2 | 10.60 | 74.74 | <.001 |
| Group | 1 | 2.96 | 20.88 | <.001 |
| Age | 1 | .367 | 2.60 | .107 |
| Sex | 1 | .086 | .606 | .436 |
| NVIQ | 1 | .025 | .176 | 674 |
| SES | 1 | .006 | .055 | .831 |
| L2 Proficiency | 1 | .048 | .340 | .560 |
| Group*Type | 2 | 3.57 | 25.21 | <.001 |

To further investigate these results, a post hoc test was conducted. A summary of the results can be seen in Table 4. Bilingual DLD children show longer RTs for NonWords compared to their TD peers. On the other hand, no significant difference was observed in RTs for English and Spanish words across group.

**Table 5:** Post hoc analysis

| **Type: Spanish** | Estimate | SE | *t* | *p* |
|---|---|---|---|---|
| Bilingual DLD – Bilingual TD | .027 | .020 | 1.32 | .186 |
| **Type: Non-Words** | | | | |
| Bilingual DLD – Bilingual TD | .178 | .015 | 11.89 | <.001 |
| **Type: English** | | | | |
| Bilingual DLD – Bilingual TD | .033 | .020 | 1.61 | .105 |

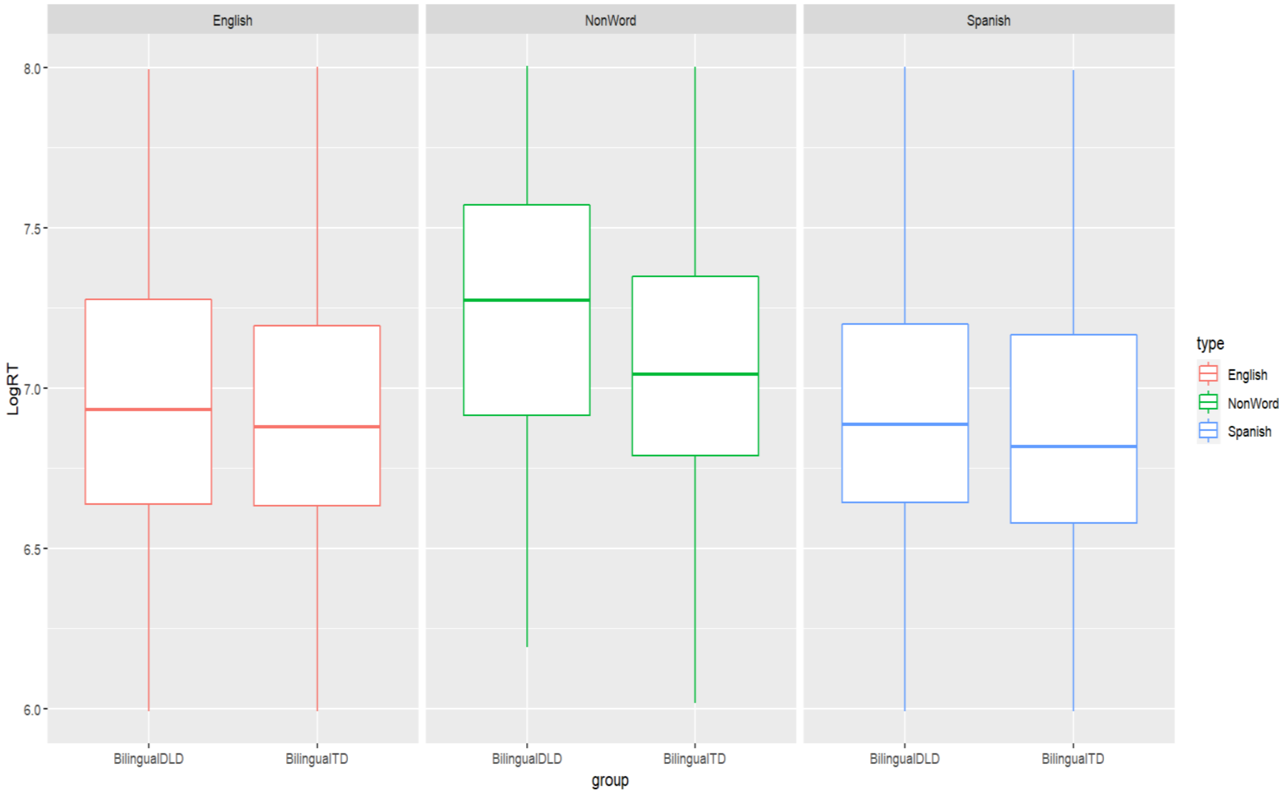



**Figure 3:** Bilingual DLD children exhibited significantly longer response times for NonWords compared to English and Spanish words, DLD group showed a similar performance as their TD peers in Spanish and English words.

### 4.9.2 Lexical decision: ERP analysis

The analysis concentrated solely on electrodes within the region of interest (ROI). This strategic electrode selection ensured a focused examination of the N400 component. Data analysis shows a significant effect of group (F (1, 59.4) = 3.04, p <.001), type (F (2, 345) = 8.94, p <.001) and interaction between group and type (F (2, 345) = 14.20 p <.001). These results indicate that the impact of the group on N400 amplitudes varies depending on the specific word categories.

**Table 6:** Model results for lexical decision ERP analysis

| **Parameter** | *DF* | MeanSq | F | p |
|---|---|---|---|---|
| Group | 1 | 11.28 | 3.04 | <.001 |
| Type | 2 | 87.68 | 8.94 | <.001 |
| Group*Type | 2 | 139.24 | 14.20 | <.001 |

To better understand these results, a post hoc test was done, to see if there were differences in ERP response between both groups and also if these differences varied according to the type of word presented. For English and Spanish words, no differences in amplitude emerged between DLD and TD groups. In contrast, for NonWords, a significant N400 amplitude difference was observed, with DLD children showing significantly more negative N400 amplitudes compared to their TD peers.

**Table 7:** Post hoc analysis

| **Type: Spanish** | Estimate | SE | *t* | *p* |
|---|---|---|---|---|
| Bilingual DLD – Bilingual TD | .090 | .510 | .175 | .861 |
| **Type: Nonword** | | | | |
| Bilingual DLD – Bilingual TD | -1.36 | .509 | -2.68 | <.001 |
| **Type: English** | | | | |
| Bilingual DLD – Bilingual TD | .263 | .516 | .512 | .610 |

**Figure 4: LDT Spanish waves, electrodes CZ, PZ, CP1, CP2**

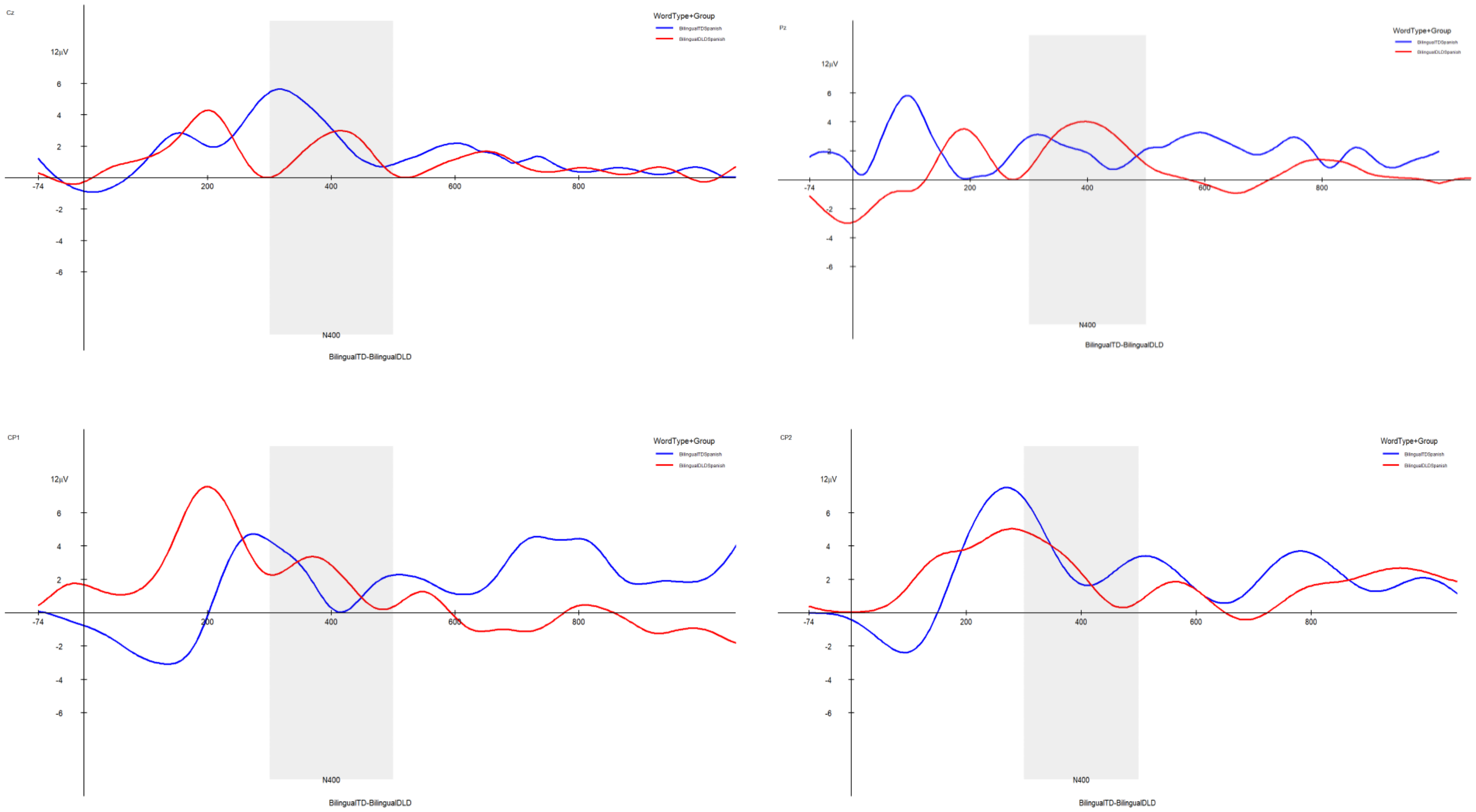



**Figure 5: LDT Nonword waves, electrodes CZ, PZ, CP1, CP2**

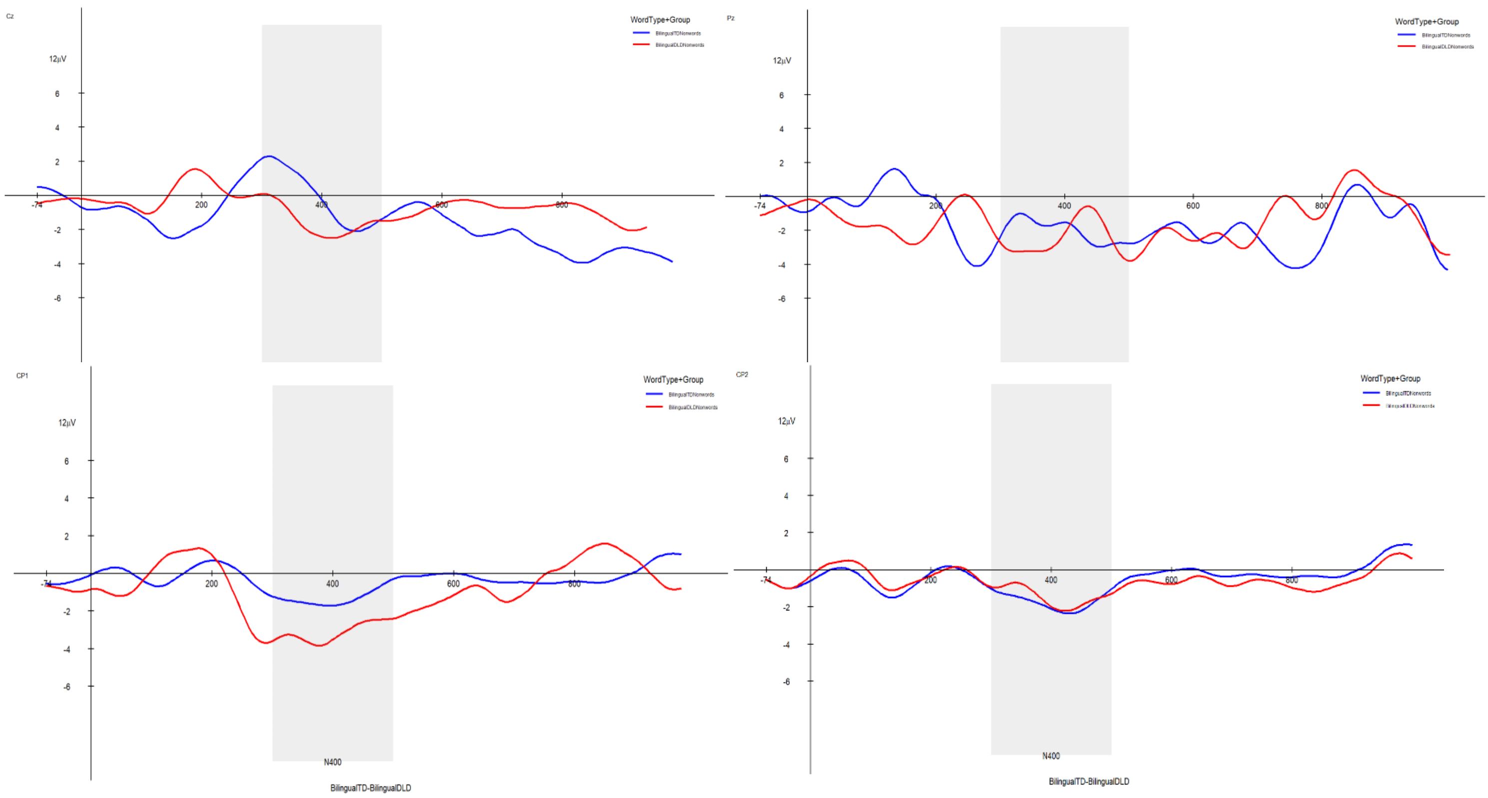
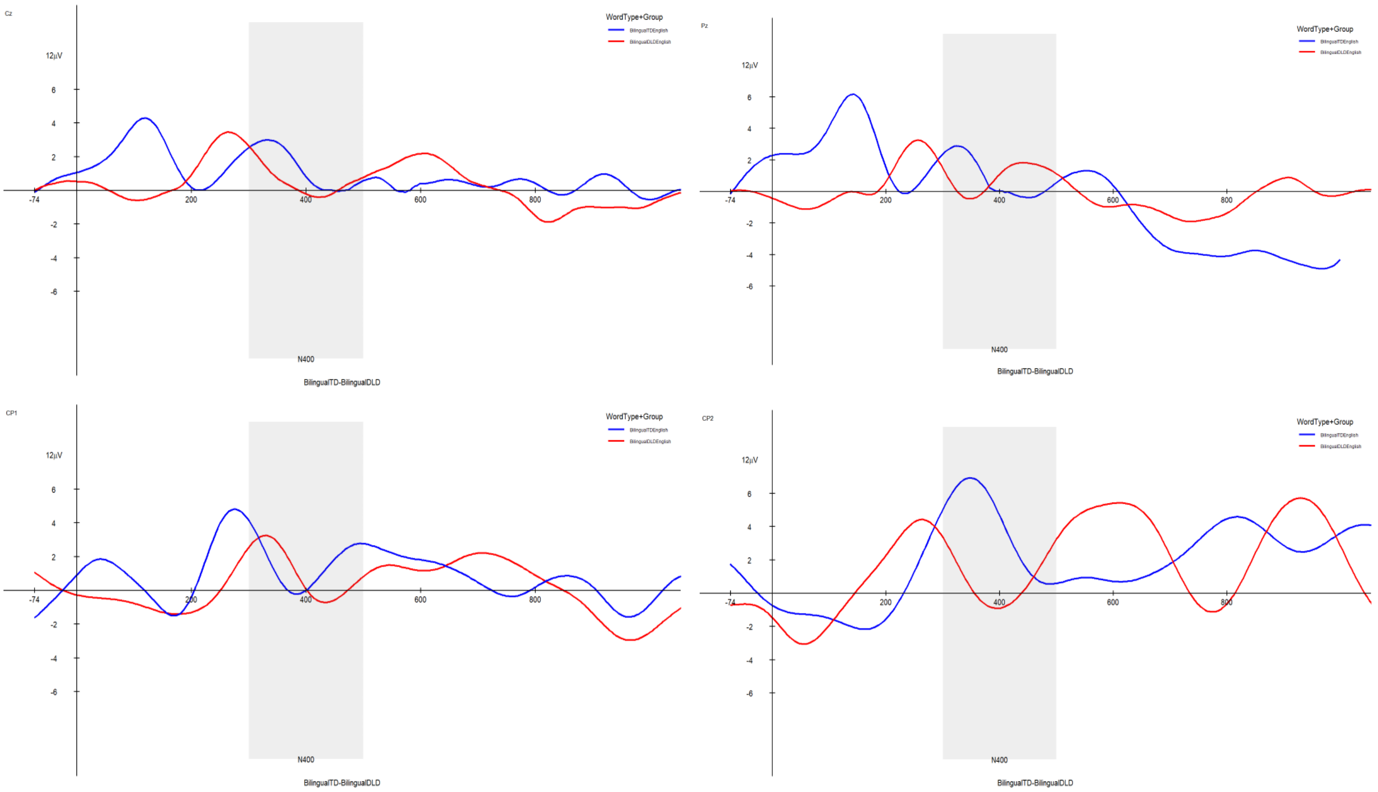


**Figure 6: LDT English words waves, electrodes CZ, PZ, CP1, CP2**



### 4.9.3 Stroop Task: Bilingual TD and DLD

**Table 8:** Reaction Time (RTs)

| Group + Language | Congruent | Incongruent |
|---|---|---|
| Bilingual TD | | |
| English | 6.99 (0.43) | 7.07 (0.40) |
| Spanish | 6.97 (0.40) | 7.01 (0.40) |
| Bilingual DLD | | |
| English | 7.01 (0.40) | 7.11 (0.37) |
| Spanish | 6.99 (0.41) | 7.04 (0.41) |

**Table 9:** Accuracy

| Group + Language | Congruent | Incongruent |
|---|---|---|
| Bilingual TD English | 1 | 76.0 |
| Spanish | 1 | 95.2 |
| Bilingual DLD English | 96.2 | 88.6 |
| Spanish | 98.1 | 91.6 |

Results in Table 10 revealed statistically significant effects of group, (F (1, 418) = 13.04, p<.001); congruency, (F (1, 641) = 54.36, p <.001); and language, (F (1, 7.3) = 7.32, p<.001). Additionally, the interaction between congruency and language also reached statistical significance, (F (1, 641) = 3.92, p<.001). On the other hand, covariates age, sex, NVIQ, SES, L2Proficiency, and interaction between group and congruency and group and language, did not reach significant results.

**Table 10** Model results for Stroop Task reaction time analysis

| **Parameter** | *DF* | MeanSq | F | p |
|---|---|---|---|---|
| Congruency | 1 | 8.25 | 54.35 | <.001 |
| Group | 1 | 1.98 | 13.04 | <.001 |
| Language | 1 | 1.11 | 7.3 | <.001 |
| Congruency*Language | 1 | .595 | 3.91 | <.001 |
| Age | 1 | .182 | 1.20 | .272 |
| Sex | 1 | .053 | .349 | .554 |
| NVIQ | 1 | .001 | .009 | .921 |
| SES | 1 | .164 | 1.08 | .301 |
| L2 Proficiency | 1 | .294 | 1.93 | .173 |
| Congruency*Group | 1 | .105 | 1.93 | .403 |
| Group*Language | 1 | .003 | .021 | .884 |
| Group*Language*Congruency | 1 | .001 | .004 | .983 |

As detailed in Table 11, the results unveiled distinctive patterns. In congruent trials, the post-hoc analysis did not reveal any significant differences between English and Spanish language conditions. Conversely, in incongruent trials, a statistically significant difference emerged between English and Spanish conditions. Specifically, participants displayed prolonged response times in the incongruent condition when responding to stimuli presented in English compared to those presented in Spanish. This discrepancy highlights the influence of language in situations requiring conflict resolution, where incongruent stimuli pose a challenge to cognitive processing.

**Table 11:** Post Hoc analysis

| **Congruency: Congruent** | Estimate | SE | *t* | *p* |
|---|---|---|---|---|
| English - Spanish | .018 | .017 | 1.10 | .286 |
| **Congruency: Incongruent** | | | | |
| English - Spanish | .057 | .017 | 3.35 | <.001 |

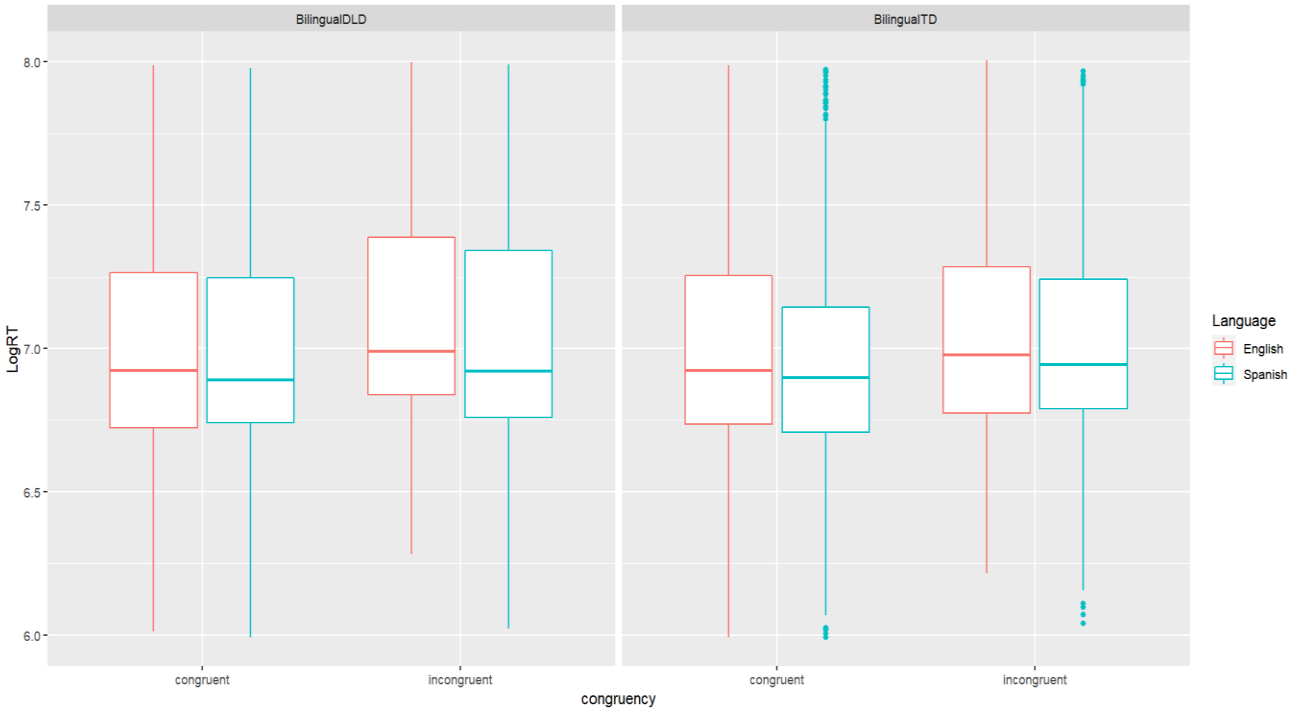



**Figure 5:** Longer RTs in the incongruent condition when responding to stimuli presented in English compared to those presented in Spanish.

### 4.9.4 Stroop Task: ERP Results

ERP results, summarized in Table 12, were analysed using electrodes selected from our region of interest (ROI). The analysis revealed the significance of congruency ($F(1, 736) = 7.33$, $p < .001$), language ($F(1, 735) = 6.68$, $p < .001$), and group ($F(1, 735) = 5.51$, $p < .001$), indicating discernible differences in ERP amplitudes between DLD and TD groups. Further exploration involved interactions, with congruency and language showing a significant result ($F(1, 736) = 5.92$, $p < .001$), suggesting that the impact of congruency on ERP amplitudes was contingent on the language condition. Conversely, the interactions between congruency and group, language and group, and the three-way interaction (congruency x language x group) were not found to be significant.

**Table 12**: Stroop ERP

| **Parameter** | $DF$ | MeanSq | F | p |
|---|---|---|---|---|
| Congruency | 1 | 170.53 | 7.33 | <.001 |
| Language | 1 | 148.41 | 6.68 | <.001 |
| Group | 1 | 128.16 | 5.51 | <.001 |
| Congruency*Language | 1 | 137.57 | 5.92 | <.001 |
| Congruency*Group | 1 | 56.36 | 2.42 | .119 |
| Group*Language | 1 | .912 | .039 | .842 |
| Group*Language*Congruency | 1 | 2.72 | .117 | .732 |

The post hoc analysis demonstrates that significant differences in ERP responses were observed between English and Spanish in the incongruent condition, with English showing a more negative N400 response. However, no significant differences were found in the congruent condition between the two language groups.

**Table 13:** Post Hoc analysis

| **Congruency: Congruent** | Estimate | SE | *t* | *p* |
|---|---|---|---|---|
| English – Spanish | .040 | .186 | .219 | .827 |
| **Congruency: Incongruent** | | | | |
| English – Spanish | -.534 | .181 | -2.95 | <.001 |

**Figure 7: Stroop Task Congruent-Spanish condition electrodes CZ, PZ, CP1, CP2**

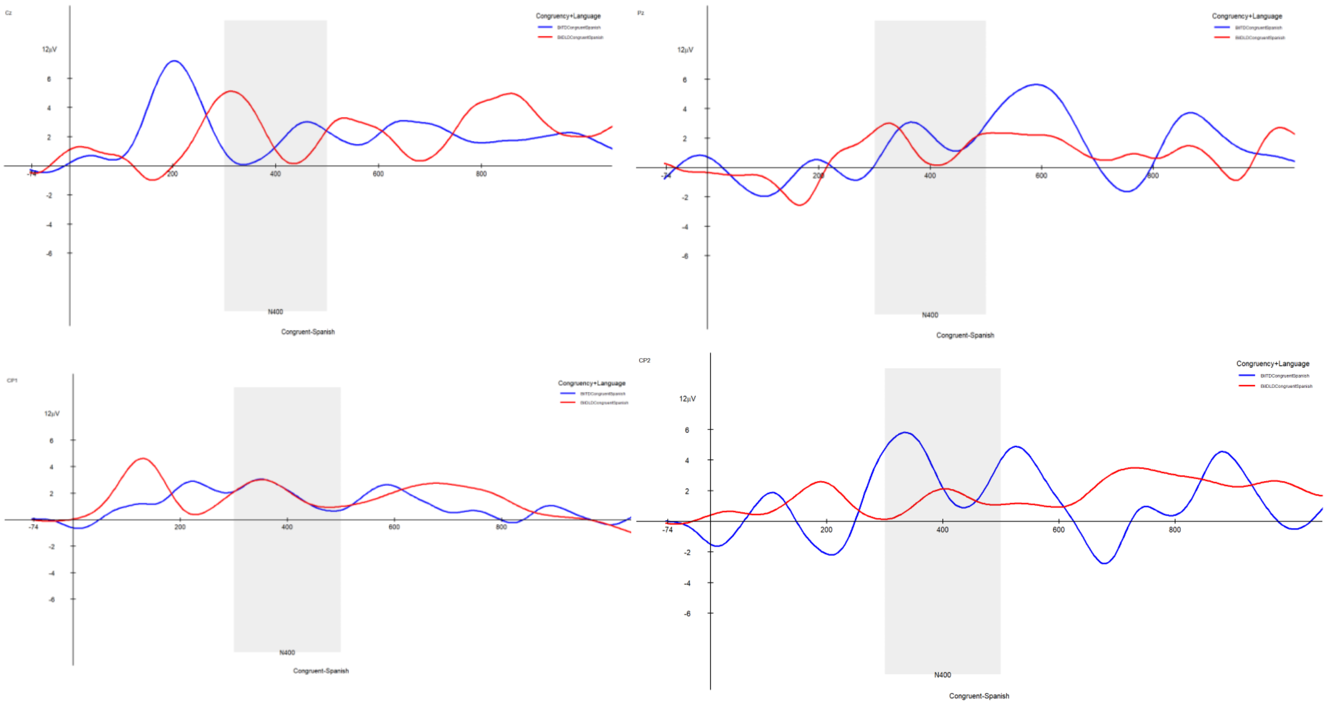



**Figure 8: Stroop Task Congruent – English condition electrodes CZ, PZ, CP1, CP2**

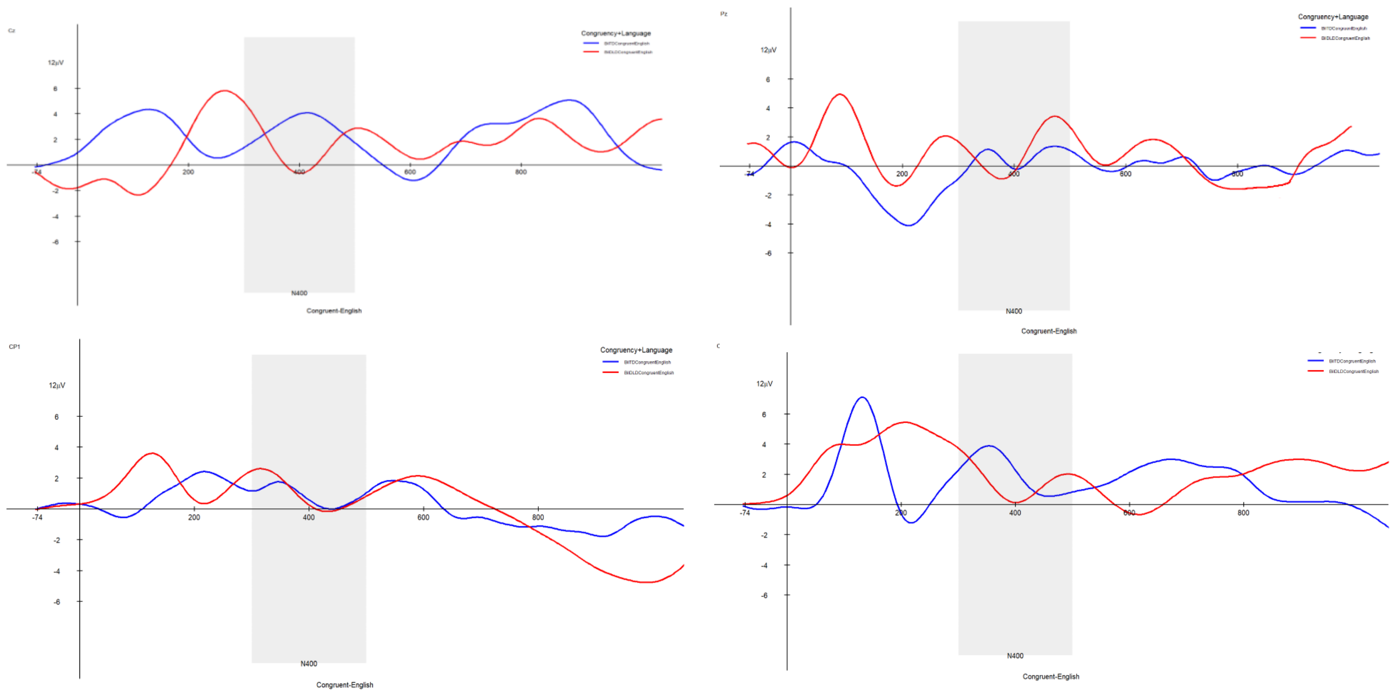


**Figure 9: Stroop Task Incongruent-Spanish condition electrodes CZ, PZ, CP1, CP2**

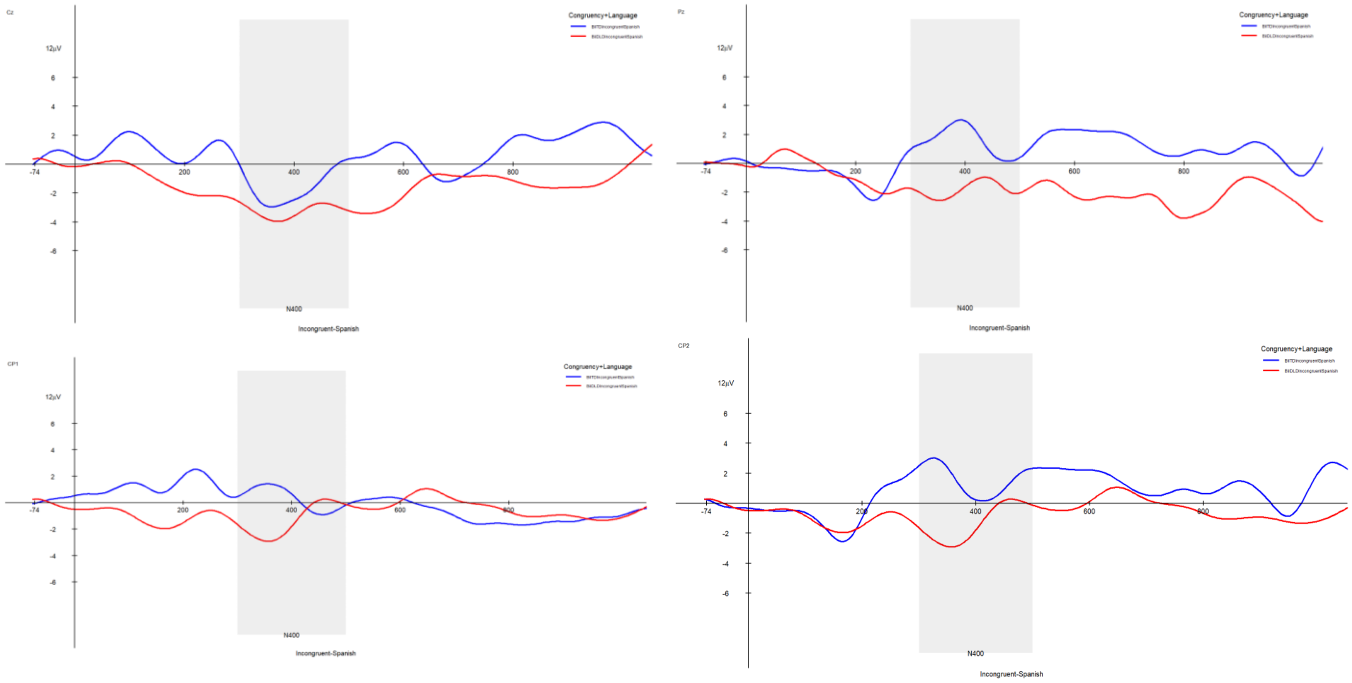
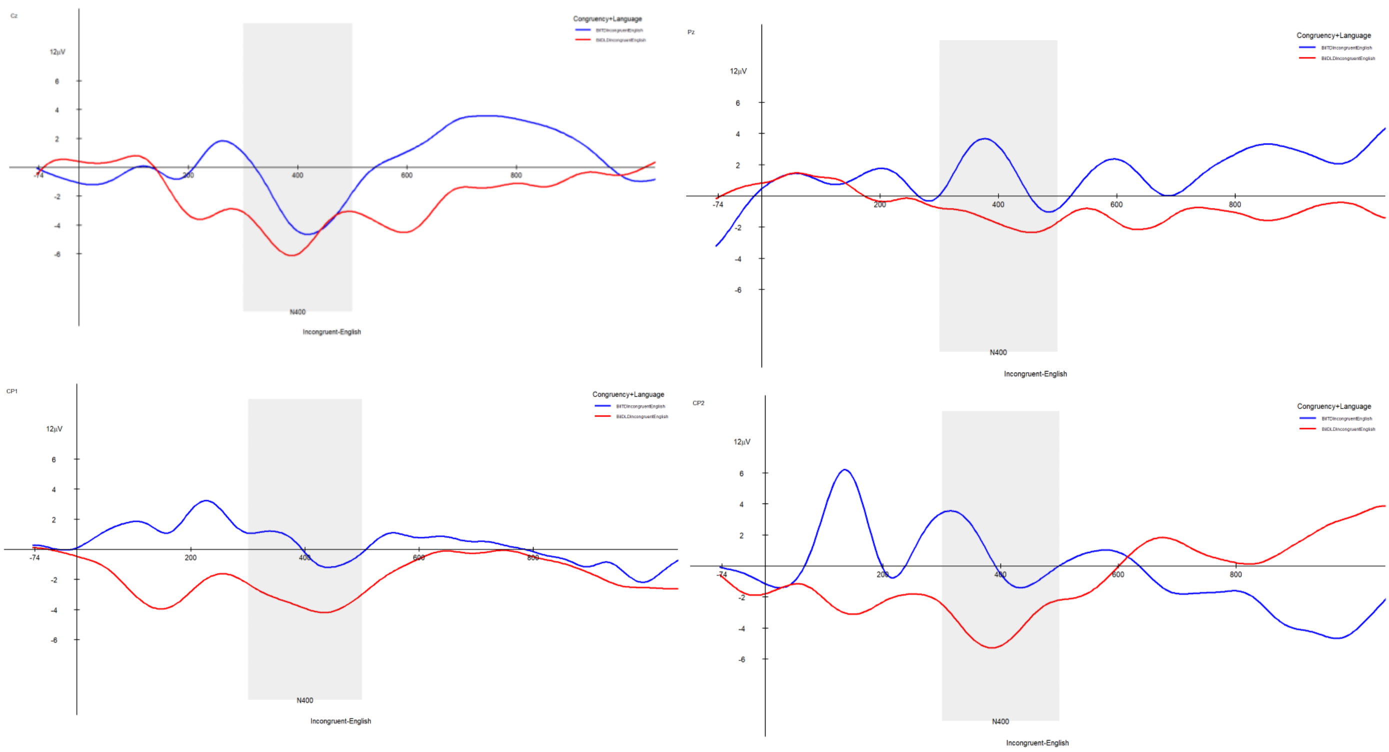



**Figure 10: Stroop Task Incongruent-English condition electrodes CZ, PZ, CP1, CP2**



### 4.10 Discussion

In recent years, research on individuals with Developmental Language Disorder (DLD) has predominantly centred around tasks such as picture naming, lexical retrieval, word association, and oral sentence processing. However, there remains a gap in the literature concerning the use of lexical decision tasks and colour-word Stroop tasks, especially when measuring behavioural data alongside EEG responses. Additionally, the assessment of bilingual children with DLD has primarily focused on their first (L1) or second language (L2) across different tasks, without integrating both languages within a single task. Understanding the distinctions between monolingual and bilingual tasks and how these choices impact study outcomes is crucial. This study aims to bridge this gap by investigating the performance of bilingual children with DLD and their typically developing (TD) peers in both lexical decision and Stroop tasks, offering insights into their lexical processing abilities and cognitive mechanisms across languages.

#### 4.10.1 Lexical Processing in Bilingual DLD Children: Comprehensive Insights from Lexical Decision Tasks

Our results indicate pronounced reaction times (RTs) and more negative N400 amplitudes in nonwords among bilingual DLD children. This suggests that the cognitive challenges associated with DLD are augmented in a bilingual setting when managing unfamiliar lexical items. Children with DLD inherently exhibit slower processing speeds, particularly in phonological processing and lexical access (Leonard, 2017). This is likely due to sparse semantic networks and immature word associations, making it harder for them to categorise unfamiliar items like nonwords. With no established semantic or phonological connections, nonwords are more challenging to classify, resulting in longer RTs and enhanced N400 amplitudes. The prolonged RTs and more negative N400 responses align with the broader cognitive and linguistic challenges highlighted by Alt et al. (2013). They observed that children with DLD often have difficulty providing accurate word definitions due to sparse semantic representations, leading to challenges categorizing unfamiliar words. Our findings corroborate this, emphasizing the distinct neural processing approaches required for challenging stimuli in bilingual children with DLD.

Drawing parallels to recent work by Evans et al. (2022), which examined lexical-phonological and lexical-semantic processing in adolescents with DLD, both studies showed N400 responses to semantic congruency. However, only typically developing (TD) children exhibited N400 sensitivity to word frequency. Our study shows a similar pattern, that bilingual children with DLD had distinctive N400 responses to nonwords, suggesting shared challenges in processing unfamiliar lexical items. This connection emphasizes the multifaceted nature of lexical processing deficits in DLD, highlighting the importance of both behavioural and neural data for a comprehensive understanding. Kornilov et al. (2014) showed atypical ERPs in children with DLD at multiple processing stages, indicating difficulties in early phonological analysis and lexical access. This aligns with our findings, reinforcing the challenges faced by children with DLD in lexical processing, particularly in bilingual settings.

Ebbels et al. (2012) provide a compelling perspective on the potential benefits of ambiguity within the bilingual lexicon for aiding children with DLD during lexical retrieval. This could explain their unexpected efficiency in certain tasks, demonstrating the complex dynamics in bilingual DLD. Windsor et al. (2010) and Verhoeven et al. (2012) reinforce the concept of shared processing mechanisms across languages, and our findings further affirm this idea by demonstrating that bilingual children with DLD can leverage knowledge from one language to facilitate processing in the other.

Contrary to the common belief that bilingualism may exacerbate difficulties for children with language disorders, our results indicate that bilingualism often alleviates linguistic challenges. The absence of significant differences between bilingual DLD and TD children in processing familiar Spanish and English words highlights these mitigating effects. Positive associations across various language tasks reported by Verhoeven et al. (2012) underscore the potential for bilingual children with DLD to use their knowledge from one language to improve performance in the other. This is consistent with our results, which reveal that challenges in lexical processing for bilingual children with DLD are more closely tied to the presence of DLD itself than to bilingualism.

This aligns with Marini et al. (2017) and Paradis et al. (2011) who emphasize that early and sustained exposure to two languages enhances metalinguistic awareness and cognitive flexibility, helping children with DLD compensate for their linguistic deficits. Our findings align with this, as we observed that familiar words presented in both languages yielded similar reaction times (RTs) and accuracy for bilingual children with DLD and their TD peers. Chéileachair et al. (2020) add that bilingual children with DLD often perform better in accuracy and RTs when processing frequent words across both languages, which aligns with our study's results showing that word familiarity plays a crucial role in performance.

Kohnert et al. (2020) note that children with DLD can effectively acquire and use two languages without worsening their symptoms. Our study echoes this, as bilingual children with DLD showed similar proficiency to their TD peers when processing familiar words due to early and consistent exposure to both languages. Regular exposure to English (L2) and early language learning align with Castillo et al. (2020), who found a positive relationship between the number of years children are exposed to a second language and their performance on linguistic tasks. Our data corroborate this pattern in bilingual children with DLD. Moreover, Thordardottir and Brandeker (2013) found comparable RTs and accuracy among simultaneous bilinguals with DLD and TD peers, emphasizing the significance of consistent language exposure. Our study aligns with this perspective, as evidenced by parallel RTs and comparable

N400 responses to familiar words in both groups. These findings underscore the importance of early and consistent exposure to both languages in shaping lexical processing outcomes for bilingual children with DLD.

Our comprehensive analysis reveals that the primary challenges in lexical processing among bilingual children with DLD are intricately linked to DLD, rather than bilingualism per se. While bilingualism adds complexity, it doesn't inherently impede linguistic capabilities in familiar contexts and may even offer cognitive benefits. These findings significantly contribute to the discourse on bilingualism and language disorder, underscoring the importance of considering individual linguistic backgrounds and cognitive profiles in research.

**4.10.2 Executive Function Differences in Bilingual DLD Children**

Our study on bilingual children with Developmental Language Disorder (DLD) using the Stroop task offers significant insights into the interplay between DLD and bilingualism. We found significant main effects in reaction times (RTs) and event-related potentials (ERPs) under both congruent and incongruent conditions. An interaction between congruency and language revealed that incongruent English stimuli led to slower RTs compared to Spanish, highlighting the nuanced relationship between linguistic factors and cognitive processing. No significant interactions were found between group and congruency or group and language, suggesting that congruency and language (English vs. Spanish) are the primary factors influencing cognitive processing.

This interaction between congruency and language underscores the challenges posed by tasks in an L2 due to the additional cognitive load imposed by dual-language processing. Brauer's (1998) research supports this, noting that bilingual teenagers with DLD might experience increased Stroop interference in their second language (L2). Our study further sheds light on processing capacity differences between children with DLD and their TD peers, which may arise from challenges in resource allocation and heightened cognitive demands.

The observed Stroop interference aligns with previous research by Kuntz (2012) and Ladánya and Lukás (2019), highlighting the interplay between controlled and automatic processing in tasks requiring inhibitory control and cognitive flexibility. In our study, prolonged reaction times in incongruent conditions suggest an increased reliance on controlled processing, indicating difficulties faced by bilingual children with DLD in managing conflicting information. The congruency effect's alignment with ERP patterns, particularly the N400, provides a comprehensive understanding of how language and cognitive demands intersect in bilingual children with DLD.

These insights are supported by studies like Markela-Lerenc et al. (2004) and Liotti et al. (2000), further illuminating the complex cognitive landscape in bilingual DLD. The significant interaction between congruency and language reveals a language-specific modulation of the N400 effect in bilingual participants, both TD and DLD, during incongruent trials. This unique contribution underscores the specific challenges faced by these individuals, surpassing inconsistencies noted in previous studies (Shen et al., 2021; Haebig et al., 2018). Archibald and Joanisse's (2012) work also emphasized a typical N400 effect for semantic mismatches in children with DLD.

Previous studies (Lukács et al., 2016; Gray et al., 2019) underscore the importance of task and language choices in EEG assessments of executive functions like the Stroop and Flanker tasks. Our Stroop results align with those studies, showing a robust congruency effect and conflict during incongruent conditions. The longer RTs for English words in incongruent conditions emphasize the practical relevance of language-specific modulation in executive function assessments. Furthermore, previous studies have shown that the N400 is sensitive to cognitive conflict monitoring (Xue et al., 2016; Zhao et al., 2017), representing the conflict indexes elicited during the Stroop task.

Our exploration into the cognitive underpinnings revealed processing capacity disparities in children with DLD, characterized by constrained cognitive resources. This limitation adds complexity to interpreting reaction time differences, particularly in situations requiring heightened inhibitory control. Children with DLD, as our findings suggest, exhibit a constrained processing capacity, possibly due to challenges in resource allocation, aligning with previous research (Adams 2000). This constrained processing capacity contributes to discernible differences in RTs between children with DLD and their typically developing counterparts, especially in conditions demanding greater inhibitory control.

In comparing our findings with studies conducted by Ladányi (2018) and Reichenbach et al. (2016), intriguing parallels emerge. Ladányi´s work suggested that individuals with DLD might not exhibit increased Stroop effects, possibly due to weaker automaticity in reading, resulting in a lesser impact of conflicting word meanings. Similarly, Reichenbach et al. (2016), found that young children, despite being unable to read (participants were 4 and 5 years old), could efficiently resolve interference in a modified Stroop task. Aligning with these insights, our bilingual DLD group demonstrated a better performance in accuracy comparable to their TD peers in incongruent conditions in English, indicating a potential strategy emphasizing colour over conflicting word meanings. This observation supports the notion that individuals with language disorders might adopt alternative cognitive strategies, such as prioritizing colour information, to navigate tasks successfully. Our results highlight the need to consider varied cognitive mechanisms and adaptive strategies employed by bilingual DLD individuals, emphasizing accuracy in incongruent conditions rather than reaction times.

In a bilingual context, deficits in inhibitory control are anticipated in congruent and incongruent conditions in both the first (L1) and second (L2) languages. However, this depends on proficiency and language similarity (Ebert et al., 2019). Despite the heightened cognitive demands of bilingualism and dual-language testing, our observed ability to resolve interference in congruent conditions challenges prevailing assumptions. This similarity between bilingual DLD and TD children prompts a reassessment of the perceived difficulties in inhibition and cognitive control among children with DLD when exposed to two languages. Genesee et al. (2004) suggest that bilingual exposure enhances executive functions, potentially offsetting linguistic disadvantages in children with DLD.

The language environment influences the development of children's cognitive systems (Goldin-Meadow et al., 2014). Thus, attending a bilingual school in early childhood may influence their cognitive and linguistic skills. Consequently, cognitive processes are affected by the particularities of each language and do not manifest uniformly across bilingual populations (Lallier & Carreiras, 2018b). Overall, these findings indicate that the Stroop effect is more pronounced when processing stimuli in the second language (English) than in the dominant language (Spanish). This pattern aligns with how language proficiency influences the Stroop task. Our study on bilingual children with DLD using the Stroop task emphasizes that executive function challenges are primarily linked to DLD characteristics. Although bilingualism adds complexity, it is not the primary cause of difficulties in inhibitory control and conflict resolution tasks. These findings challenge assumptions of uniform struggles in bilingual DLD individuals, emphasizing the need for tailored assessment and support approaches.

### 4.10.3 Conclusion

Our comprehensive investigation into lexical processing and cognitive control among bilingual children with Developmental Language Disorder (DLD) highlights specific processing differences in this group, especially in response to nonwords. Our findings from both the Lexical Decision Task and the Stroop Task reveal that while challenges are present in dealing with unfamiliar lexical items, bilingual children with DLD display competent executive functioning skills. Notably, our study contradicts the notion that bilingualism exacerbates linguistic difficulties for children with language disorder. In fact, we find that bilingualism does not impede, and may even facilitate, cognitive processing in familiar contexts compared to their typically developing (TD) peers.

Our research illustrates that the primary struggles in bilingual DLD children are concentrated in processing unfamiliar words, as evidenced by prolonged reaction times and distinctive ERP patterns. However, their performance in tasks demanding cognitive control, particularly in executive function measures, is remarkably adept. This suggests that while bilingual DLD children may encounter specific challenges in certain aspects of linguistic and cognitive tasks, they do not exhibit a generalized impairment that hinders processing two languages. These insights contribute significantly to our understanding of DLD, offering a nuanced perspective on the capabilities and challenges faced by bilingual children with this condition.

# 5- Study 3: Lexical processing and Cognitive control in Bilingual and Monolingual children with Developmental language disorder

## 5.1 Abstract

This study explores lexical processing and cognitive control in bilingual and monolingual children with Developmental Language Disorder (DLD), focusing on children aged 7-10. Our findings highlight that bilingual DLD children encounter longer reaction times (RTs) when processing NonWords compared to their monolingual counterparts. This phenomenon underscores specific challenges related to bilingualism in processing unfamiliar lexical items. Contrastingly, for familiar Spanish words, both groups exhibited similar RTs, suggesting comparable levels of language processing. These behavioural patterns are mirrored in the event-related potentials (ERPs) data, where distinctive neural responses to Nonwords were observed in the bilingual DLD children. For familiar words, ERP responses did not differ significantly between the groups, indicating a uniform neural challenge posed by DLD across both bilingual and monolingual children.

In terms of cognitive control, while significant main effects for congruency and group were observed, the lack of a significant interaction between congruency and group indicates that DLD, irrespective of bilingual or monolingual status, similarly affects children's ability to resolve cognitive conflicts. This is corroborated by the ERP data, which further supports the notion that additional challenges in processing unfamiliar words in bilingualism do not exacerbate difficulties in cognitive control tasks or processing familiar words. Moreover, socioeconomic status (SES) was found to influence performance in both tasks, with bilingual children generally having higher SES levels. However, this did not fully account for the longer RTs observed among bilingual children, suggesting that cognitive and linguistic challenges are not solely linked to SES disparities.

## 5.2 Introduction

An essential aspect of language comprehension and production lies in lexical knowledge. From early infancy, children start developing their word knowledge, enabling them to comprehend and utilize a vast vocabulary creatively to interact with others (Nation, 2014). Considering the significance of words in comprehension, it's not surprising that children facing language difficulties during their development often struggle with words. However, for effective comprehension, one must recognize that it's not just about knowing a specific word, but also about understanding the interplay between words and their contextual surroundings (Ralph, 2014).

According to this perspective, having a vocabulary knowledge of a word is not a simple "all or nothing" matter, solely based on whether a child knows the dictionary definition of the word. Equally important is the ability to quickly retrieve the correct word and its meaning in a specific context while processing real-time speech (Woollams, 2015). Common laboratory tests, like picture naming, word-to-picture matching, providing definitions, word associations, or recalling semantic attributes, may claim to assess a child's ability to identify, recognize, or understand words, however, these tasks are not purely isolated processes (Nation, 2014). Setting aside non-linguistic factors that can influence performance, such as memory or executive control processes, language is a dynamic and interactive system. It cannot be neatly divided into distinct components labelled as identification, recognition, and understanding.

### 5.2.1 Developmental Language Disorder (DLD) in Children

Developmental Language Disorder (DLD) represents a significant deviation in language abilities, characterized by difficulties in acquiring and using language across both spoken and written forms. Affecting approximately 7% of the general population, DLD is not linked to auditory deficits, global developmental delays, or neurological conditions. The CATALISE project has broadened the definition of DLD to include a diverse range of intellectual abilities, moving beyond the constraints of specific language impairment (SLI) to encompass those with varied language deficits (Bishop et al., 2016, 2017; Leonard, 2014).

DLD manifests through difficulties in several aspects of language processing and use, such as limited vocabulary, challenges in constructing coherent narratives, difficulties understanding complex language, and problems with grammar and syntax. These issues affect both expressive and receptive language tasks, impacting academic performance and social interactions. Recognizing these symptoms as part of a broader language learning difficulty is crucial, as they are not just isolated issues but integral parts of the child's communication capabilities (Bishop, Snowling, Thompson, & Greenhalgh, 2017).

Children with DLD exhibit significant cognitive challenges, particularly in working memory and executive functions that are crucial for language processing. These deficits often necessitate targeted interventions designed to address their specific educational needs. Moreover, recent neuroimaging advancements have revealed specific structural brain differences in individuals with DLD, identifying alterations in critical language processing regions such as the inferior frontal gyrus and posterior superior temporal gyrus. Changes in the white matter pathways, notably the arcuate fasciculus, highlight a spectrum of neurobiological diversity within the DLD population. This diversity impacts how linguistic information is processed and transmitted across the brain, underscoring the need for tailored intervention strategies that reflect the complex interplay between neuroanatomy and linguistic function (Verhoeven et al., 2012).

School-age children with DLD encounter significant hurdles in word learning due to deficits in semantic knowledge, morphosyntax, lexicon, pragmatics, and phonology. These areas, particularly morphosyntactic deficits, require specialized language instruction and intervention strategies (Claessen et al., 2013; Leonard, 2017). Additionally, the interaction between bilingualism and DLD adds complexity. While managing two languages can enhance executive control and cognitive flexibility, it may also exacerbate language system strains for some children with DLD. However, bilingualism also presents unique cognitive and linguistic enrichment opportunities, which can mitigate some DLD-associated challenges (Kohnert, 2010; Bialystok et al., 2009).

The interaction between bilingualism and DLD presents a complex dynamic. Managing two languages can enhance cognitive functions such as executive control and flexibility; however, this benefit is not uniform across all individuals with DLD. While some studies suggest that bilingualism may exacerbate challenges within an already taxed language system, it also provides unique cognitive and linguistic enrichment opportunities that can mitigate some of the adverse effects associated with DLD (Kohnert, 2010; Bialystok et al., 2009). The differential impact of bilingualism on children with DLD underscores the need for tailored intervention approaches. These should be sensitive to the distinct cognitive and linguistic landscapes navigated by monolingual and bilingual individuals, emphasizing that bilingualism, with appropriate support, can serve as a valuable resource for enhancing linguistic and cognitive outcomes. This approach recognizes the potential of bilingualism to contribute positively to cognitive and linguistic development, particularly when interventions are adjusted to accommodate factors such as the age of second language acquisition and overall language proficiency (Antón et al., 2014).

Understanding the distinctions between bilingual and monolingual children with DLD is imperative for devising effective strategies tailored to their unique needs. Ongoing research into DLD’s neurobiological foundations and the efficacy of various interventions will be crucial in optimizing outcomes for these children, ensuring they achieve their full linguistic and cognitive potential.

**5.2.2 Lexical Processing in Bilingual and Monolingual Children with DLD**

Bilingualism is broadly defined as the acquisition of two or more languages during the dynamic period of communication development, from birth to adolescence (Kroll, Dussias, Biece, and Perroti, 2015). This encompassing definition includes individuals who acquire two languages from birth and those who add a second language (L2) in childhood. Within a bilingual speaker, both languages remain active during speech perception, reading, or speech planning in either language, resulting in influences even from the non-dominant language production (Marian & Spivey, 2003; Kroll, Bobb & Wodniecka, 2006). This parallel activation of both languages means that there are influences of the language, which is not in use, even when bilinguals are unaware of those influences. Importantly, it is now uncontroversial that both languages of a bilingual are jointly activated during all linguistic processing, even in strongly monolingual contexts.

Children with DLD show a heightened susceptibility to lexical-semantic priming (Pizzioli & Schelstraete, 2011), indicating a reliance on lexical semantics as a compensatory strategy when facing grammatical challenges. Ramus et al. (2013) further elucidates that phonological skills in children with DLD and reading disabilities remain somewhat independent of non-phonological language skills, like lexical and morphosyntactic abilities. This distinction contributes to our understanding of the interplay between phonological and non-phonological skills, highlighting overlapping features of DLD and reading disabilities. Barak, Degani, and Novogrodsky (2022) explored word learning and recall in Hebrew-speaking monolingual and Russian-Hebrew bilingual children with and without DLD. Their findings suggest that bilingualism does not inherently hinder word learning in typically developing children or exacerbate difficulties in children with DLD. However, it's noteworthy that even typically developing bilingual children exhibited lower word retrieval skills than their monolingual counterparts, pointing to the impact of reduced word exposure in bilingual contexts. Notably, even bilingual children with typical development displayed lower word retrieval skills compared to their monolingual counterparts with typical development. This suggests that bilingualism does not impede the mechanisms involved in language learning, even for children with DLD. Instead, the reduced exposure to words in bilingual contexts appears to contribute to the lower performance in word retrieval. Balanced bilingual children with DLD, seem to exhibit similar language abilities in each language when compared to monolingual children with DLD who speak the same languages (Paradis et al., 2003).

This challenges the assumption that children with pre-existing language difficulties in one language would inevitably struggle when learning a second language. Longitudinal studies indicate that the effects of bilingualism on language development in children with DLD may evolve over time, suggesting that these children may adopt different strategies in language processing tasks. For example, in nonword repetition tasks, L2 learners may not differentiate between word-like and non-word-like items as distinctly as monolingual children with DLD do (Thordardottir & Gudrun Juliusdottir, 2012).

In conclusion, while bilingual children with DLD face unique challenges, the interaction between bilingualism and DLD does not necessarily exacerbate language difficulties. Instead, it underscores the need for nuanced understanding and approaches in language learning and assessment for these children. Future research should continue exploring the specific issues and strategies employed by bilingual children with DLD to further enhance our understanding of their linguistic development.

### 5.2.3 Lexical Processing and ERP

Event-related potentials (ERP) studies investigating lexical-semantic processing primarily centre around the N400 component. The N400 is an electrical brain response pattern that typically arises approximately 400 milliseconds after stimulus presentation, with its most prominent activity observed in the centro-parietal region of the scalp. In 2008, Fonteneau and Van der Lely conducted a study exploring neural responses in children with grammatical Developmental Language Disorder (DLD), examining both syntactic and semantic violations. They found that auditorily presented sentences containing semantic violations, especially cases where a noun violated the verb's semantic selection restrictions, consistently elicited an N400. Remarkably, this response was observed in both children with DLD and typically developing (TD) children.

However, the story took a different turn when syntactic violations were introduced. Typically developing (TD) children exhibited a robust early left anterior negativity (ELAN) component in response to structural syntactic dependencies, thought to signify the early automatic processing of such dependencies. In contrast, children with Developmental Language Disorder (DLD) displayed a delayed N400 response to these violations, with the absence of the ELAN component serving as a distinctive marker for identifying individual children with DLD. Fonteneau and Van der Lely's findings suggest the presence of selective grammatical deficits in children with grammatical DLD, with the N400's appearance hinting at a relative strength in semantic processing. This perspective suggests that the morphosyntactic deficits in these children are functionally separated from their proficiency in other language areas, such as lexical processing.

Furthermore, the emergence of the N400 in response to syntactic violations in children with DLD may signify neuroplastic changes in the language processing system associated with DLD. This perspective posits that the N400 reflects alterations in the language processing system in DLD, potentially in addition to its role in normal lexical-semantic processing. To date, only a limited number of studies have explored lexical–semantic processing in DLD using neurophysiological methods, apart from Fonteneau and Van der Lely's study mentioned above. Neville, Coffey, Holcomb, and Tallal (1993) investigated visually presented sentences varying in semantic appropriateness of the final word (anomalous vs. non-anomalous). They found that children with both DLD and reading disabilities exhibited a larger N400 response to both anomalous and non-anomalous sentence-final words, with the amplitude of the difference waveform (anomalous–non-anomalous) being greater in children with DLD compared to TD children. These findings suggested that children with DLD invested greater compensatory effort in integrating words with context successfully.

Malins et al. (2013) examined ERP responses in a cross-modal picture-word task involving monolingual children with and without DLD. They manipulated both the degree of semantic congruence and phonological overlap between spoken words and visually presented pictures. Both groups of children exhibited notable N400 responses when presented with words that were semantically and phonologically unrelated to the target word. Moreover, both groups displayed a similar early phonological mapping negativity (PMN) effect, indicating that children with DLD could form online phonological expectations and detect deviations from these expectations. However, only typically developing children showed a significant reduction in the N400 effect when presented with rhyming words. The absence of this rhyme-based reduction in the DLD children led the authors to propose that these children might either be less sensitive to rhyming compared to typically developing children (possibly due to difficulties in establishing robust phonological representations) or less effective in suppressing lexical alternatives during spoken-word recognition.

Pijnacker et al. (2017) observed N400 onset delays in a group of Dutch children with DLD compared to typically developing children of the same age. In their study, children listened to simple sentences with semantically incongruent final nouns while watching unrelated silent short video clips. The N400 onset for the control group ranged between 300–500 msec, while for the group with DLD, it extended from 500–800 msec. Notably, the N400 response had a broader scalp distribution in the DLD group, in contrast to the more posterior distribution observed in typical children. Furthermore, the study revealed that smaller N400 amplitudes in the DLD group correlated with lower scores on tasks assessing various language and cognitive abilities, including grammar, vocabulary, language comprehension, and nonverbal IQ.

ERP studies of lexical and semantic processing in children with DLD have resulted in a complex landscape of findings that suggests, at the minimum, atypical organization of lexical–semantic processing in DLD. The insights from Neville et al. (1993) and Pijnacker et al. (2017) emphasize the broader scope of language processing difficulties faced by children with DLD. These studies highlight the intricate neural responses that underlie language processing in children with DLD, both in terms of semantic and syntactic processing.

### 5.2.4 Cognitive abilities, Stroop task and ERP

During the last couple of years, linguists have begun to investigate the advantages and disadvantages of bilingualism in relation to cognitive performance. This includes how cross-language similarity, in terms of phonological and/or orthographic overlap, influences the bilingual/multilingual language processing system. A task that is well-suited to investigate issues of cognitive control and cross-language similarity in bilingual processing is the Stroop task (Stroop, 1935). The Stroop task has been widely used in cognition research as a paradigm for investigating executive control functions, particularly the interference resolution between stimulus dimensions, response inhibition and response selection.

The Stroop task, where participants must name the ink colour of printed words and ignore the word itself, creates cognitive conflicts particularly in incongruent trials. For example, when 'red' is printed in blue ink, the correct response—'blue'—leads to prolonged reaction times. Conversely, congruent trials where the word and colour match facilitate quicker responses. This paradigm illustrates the active engagement of bilinguals' dual lexicons during comprehension and production, as seen in foundational studies (Marian & Spivey, 2003; Kroll, Bobb & Wodniecka, 2006). These studies underscore the cognitive complexity managed by bilinguals compared to monolinguals, a factor that contributes significantly to discussions about bilingual cognitive advantages.

The hypothesis of a bilingual advantage suggests that managing two languages can enhance executive functions like inhibitory control and cognitive flexibility. This is supported by studies such as those by Bialystok et al. (2012) and Costa et al. (2009). However, this advantage varies significantly across individuals, influenced by factors like language proficiency, age of acquisition, and task complexity (Kefi et al., 2004). For bilingual children with DLD, these factors might complicate cognitive and linguistic development further, necessitating tailored interventions. Critically, not all researchers agree on the presence of a bilingual advantage. Critics like Paap and his colleagues argue that when confounding factors like socioeconomic status and educational background are controlled, the alleged cognitive benefits often diminish (Paap & Greenberg, 2013; Paap, Johnson, & Sawi, 2014; Paap, 2019). This ongoing debate highlights the need for meticulous research designs that account for these variables.

Bilinguals, with their simultaneously active language systems, must navigate complex cognitive landscapes. They need to pay attention to the linguistic environment, select the appropriate language, inhibit the inappropriate one, and manage conflicts between the two. This contrasts with monolinguals who are not typically subject to these constant conflicting lexical choices and generally perform better in lexical retrieval tasks. For bilinguals, especially those with DLD, this dual-language management can be particularly challenging, as they must marshal considerable cognitive resources to manage two languages—resources that are already taxed by their difficulties in areas like working memory and cognitive flexibility (Leonard, 2014; Kapa et al., 2017).

Empirical evidence, however, suggests that despite these challenges, there can be cognitive and linguistic benefits from bilingual exposure in children with DLD (Kohnert et al., 2020; Chéileachair et al., 2020). These benefits, however, are not uniformly distributed and tend to manifest primarily in individuals with high proficiency in both languages and those at their cognitive peak (Bialystok, 2012).

Results from the study made by Kuntz (2012), showed that when performing an auditory and visual Stroop task, monolingual TD and DLD pre-teens, exhibited more errors and longer RTs while presented with the incongruent condition (word blue in red ink or male voice saying women); however, this error and longer RTs were more pronounced in the DLD group. Similar to this, Lukács et al. (2016) used a large battery of executive function tasks (simple and complex span, fluency, N-back, and Stroop tasks) to explore verbal and nonverbal executive function abilities. Results from the Stroop tasks showed deficits in the performance of the monolingual DLD children, in both congruent and incongruent conditions. Longitudinal studies offer additional insights into the dynamic nature of bilingual advantages. For example, Tran et al. (2015) observed that bilingual benefits in executive tasks like the Attention Network Task were not consistently present across all testing intervals, suggesting that such advantages might vary with developmental stages (Blom et al., 2014). This underscores the complex interplay between age, language exposure, and cognitive development, suggesting that bilingualism might influence different components of executive function at various points in development.

Recent linguistic research has delved into the cognitive advantages and challenges of bilingualism, particularly how cross-language similarities influence bilingual language processing. The Stroop task, a well-established paradigm in cognitive research, has been pivotal in this exploration. It assesses executive control functions like interference resolution, response inhibition, and response selection. When bilinguals engage in this task, they demonstrate unique cognitive control skills necessitated by the parallel activation of their two language systems, even in monolingual settings. This is evident in studies like the one conducted by Naylor, Stanley, and Whicha (2015), where Spanish–English bilinguals showed that the N450 component, typically associated with semantic processing, was sensitive to color congruence in the Stroop task. This ERP response was consistent across different languages, underscoring its utility in bilingual research and indicating an insensitivity to language context in cognitive control processes.

Additionally, Liu et al. (2014) showed a similar pattern with a numeric Stroop task. Monolingual pre-teens and their TD peers were presented with three conditions, congruent (the larger valued number was presented with the large font), incongruent (the larger valued number was presented with the small font), and a neutral condition, where the two numbers were presented with the same size font, with half of the trials using the large font and the other half using the small font. Both groups showed larger amplitude responses in the incongruent condition, in this case reported as an N450. More interestingly, the DLD showed a different distribution as well, with more negative amplitudes in the frontal region and more positive amplitudes in the occipital region than their TD peers. These different ERP signal patterns of the DLD group may indicate compensatory functions of their brain—they recruited extra cognitive resources to cope with their insufficient ability in interference control.

The Stroop task has proven to be a valuable tool in assessing cognitive control functions, in both bilingual and DLD populations. Studies utilizing ERP have shed light on the underlying neural processes during Stroop tasks, revealing differences in neural responses between individuals with and without language disorders. These findings contribute to our understanding of the complex relationship between language, cognitive control, and neural processing. In the following sections, we will explore additional cognitive tasks and neurophysiological methods to further examine the intricate nature of language disorders and their impact on cognitive functions.

**5.3 The Study**

In this study, we aimed to investigate the lexical processing and cognitive abilities of children with Developmental Language Disorder (DLD) in both monolingual and bilingual contexts, focusing on children aged 7-10. Our primary focus was to understand how language disorders interact with bilingualism and cognitive control. To achieve this, we administered two distinct tasks: the Lexical Decision Task and the Stroop Task. The Lexical Decision Task allowed us to explore how these children recognize and process words, both familiar and unfamiliar, in their respective languages. Additionally, we examined event-related potentials (ERPs) during this task to gain insights into their neural responses, particularly the N400 component, which is crucial for understanding lexical-semantic processing. In the Stroop Task, we delved into their cognitive control abilities, aiming to discern any influences of bilingualism on their performance. This task is particularly valuable for assessing executive functions such as cognitive flexibility and inhibitory control, which are hypothesized to be differentially affected by bilingualism in children with DLD.

By comparing the responses of bilingual and monolingual children with DLD, we aimed to understand the complex relationship between language disorders, language background, cognitive control, and lexical processing. We hypothesized that bilingualism adds complexity to cognitive processing in children with DLD, particularly with unfamiliar words, leading to longer reaction times and distinct neural responses. In the Stroop task, we expected bilingual children with DLD to show greater difficulty managing cognitive conflicts, as evidenced by increased reaction times and error rates during incongruent conditions

## 5.4 Methods

### 5.4.1 Participants

Paper 3 included 69 Chilean children aged 7-10 (mean = 8.3, SD = 1.11), divided into two groups: Bilingual Developmental Language Disorder (Bilingual DLD) and Monolingual Developmental Language Disorder (Monolingual DLD). All participants were native Spanish speakers, with those in the bilingual group also having English as a second language. Informed consent was obtained from their parents or guardians, followed by a detailed questionnaire that collected background information such as parental education levels and home language use (detailed in Appendix 1). Ethical approval was provided by the University of Essex Social Sciences Ethics Sub-Committee, ensuring adherence to all relevant ethical standards.

Testing took place from May to August 2021, following the national COVID-19 lockdown in Chile. By this time, all participants had resumed full-time education, offering a stable basis for assessing the differential impacts of bilingual and monolingual environments on DLD. Children in both the Bilingual DLD and Monolingual DLD groups were assessed by SLTs based on the guidelines from the Chilean Ministry of Education (Decree-Law N170, 2010), aligning with international standards for clinical diagnoses (more details are provided in Section 2.1 and table 1). The research rigorously controlled for variables such as socioeconomic status (SES), nonverbal IQ, age, and sex to ensure a robust analysis of the effects under study

### 5.4.2 Monolingual DLD group

This group consisted of 33 participants (20 girls, 13 boys) drawn from various public schools across Chile. Starting their education at around age 4, these children typically received six hours of English instruction weekly, reflecting standard public-school curricula. They received substantial developmental support in line with Chile's "inclusion law," including regular sessions with school based SLTs. Detailed descriptions of the support mechanisms and family dynamics affecting these participants are available in Section 2.1.4 of the general methods.

### 5.4.3 Bilingual DLD group

The Bilingual DLD group included 36 children (21 girls, 15 boys), who were enrolled in bilingual schools also attended by the Bilingual TD group from previous studies. Their educational journey began in kindergarten, where they were immersed in both Spanish and English. These children received consistent educational and therapeutic support, crucial for their development. For more details on their educational environment, see Section 2.1.2 of the general methods.

**Table 1: Participants demographic information.**

SES (parental education) information was coded following the International Standard Classification of Education (ISCED; UNESCO Institute for Statistics, 2012). This ranged from 0 (less than primary education) to 8 (doctoral or equivalent).

| Group/Variable | Bilingual DLD | Monolingual DLD |
|---|---|---|
| **Participants** | 36 | 33 |
| **Age (Years)** | M=8.30 SD=1.15 | M=8.30, SD=1.10 |
| **Sex** | 21Girls, 15Boys | 20 Girls, 13 Boys |
| **SES (Parental Education)** | M=6.11, SD=0.57 | M=4.24, SD=0.65 |
| **Non-verbal IQ** | M=89.39, SD=4.76 | M=85.03, SD=3.64 |
| **L2 Proficiency** | M=3.50, SD=0.84 | N/A |

## 5.5 Materials and Stimuli

### 5.5.1 Lexical Decision

The Lexical Decision Task (LDT) evaluates lexical processing abilities, particularly the ability of children to distinguish between words and nonwords. This task highlights differences in lexical access and semantic processing among bilingual and monolingual children, focusing on the impact of bilingualism and DLD. Two versions of the task were designed, one for the bilingual group and one for the monolingual group. For detailed task design and stimulus information, refer to Section 2.2.1 in the General Methods and Appendix 2 for the stimulus list.

### 5.5.2 Nonwords

Nonwords for the LDT were created using the SCOPE Lab Nonword Generator. This tool was instrumental in producing stimuli that did not resemble real words in either English or Spanish, both phonologically and orthographically. Customization features allowed precise control over phoneme selection, orthographic patterns, and character length. Examples include “AALKN” and “FWNOL,” designed to eliminate recognition bias from familiarity with linguistic characteristics of participants' native languages. For a detailed description of the nonword see Section 2.2.2

### 5.5.3 Bilingual Lexical decision task

For the bilingual version, participants were presented with 80 stimuli, consisting of 40 nonwords, 20 Spanish words, and 20 English words. Spanish words excluded items with special characters such as <ñ> or accents to avoid visual cues indicating the language used. English words were selected from the "English Syllabus for primary schools" used in Chile, with Spanish versions adapted accordingly. Stimuli ranged from 5 to 7 characters in length (mean = 6.12, SD = 0.74). Direct translations were excluded to prevent biases from recognizing the same concept in both languages, ensuring each lexical decision was based on processing each word as a unique lexical item. For additional details on stimulus selection, refer to section 2.2.3.

### 5.5.4 Monolingual Lexical decision task

The monolingual version adapted the bilingual structure for participants who speak only Spanish, maintaining the total stimulus count at 80, with 40 Spanish words and 40 nonwords.

This parallel structure ensured a fair comparison of lexical decision-making abilities across groups, with a comparable lexical challenge within their linguistic capabilities. The selection of Spanish words matched the bilingual task's criteria for word length and familiarity, ensuring participants faced a comparable lexical challenge. For detailed information, refer to section 2.2.3.

### 5.6.1 Stroop task

Introduced by John Ridley Stroop in 1935, the Stroop Task has become a cornerstone in the study of cognitive flexibility and inhibitory control. These cognitive functions are essential components of executive function, assessing an individual's ability to manage cognitive interference effectively. In this study, the Stroop Task was employed to explore these cognitive processes, with a focus on identifying differences in how they manifest among bilingual and monolingual children, both with and without Developmental Language Disorder (DLD).

### 5.6.2 Bilingual Stroop

The bilingual version presented colour names in both Spanish and English, requiring participants to suppress the automated response to read the word and navigate between two languages. This task used a nonverbal response format, where participants pressed keys on a color-coded keyboard corresponding to the text colour, rather than articulating responses. This format focused on cognitive control, eliminating the confounding factor of language production, making the task suitable for children with DLD. The task comprised 90 trials, divided equally between congruent and incongruent conditions, using the colours RED, GREEN, YELLOW, and BLUE, and their Spanish translations. For detailed procedural descriptions and settings, refer to section 2.3.2.

### 5.6.3 Monolingual Stroop

The monolingual version was conducted entirely in Spanish, allowing for a direct assessment of inhibitory control and cognitive flexibility within a monolingual framework, isolating these cognitive processes from the complexities of bilingualism. This task also utilized a nonverbal response format to ensure differences in executive function were attributed to cognitive processes rather than language production abilities. The monolingual task also consisted of 90 trials, maintaining a balanced measure of cognitive control abilities across participant groups. For detailed information, refer to section 2.3.3.

## 5.7 Procedure Lexical Decision Task (LDT) and Stroop Task

### 5.7.1 Experiment Procedure

The Lexical Decision Task (LDT) and Stroop task were conducted in a quiet, empty classroom to minimize distractions and enhance concentration. To avoid electrical interference, the room's lighting was turned off during the sessions. Stimuli were presented using PsychoPy software on an ASUS ZenBook laptop placed in front of the participants. For the LDT, words and nonwords were displayed on a black background in a 20-point white Arial font (see Figure 1 for a visual depiction). Participants responded using the laptop keyboard, with oral and written instructions provided in Spanish. The Stroop task followed the procedures outlined in the general methods. Stimuli were displayed on a black background, featuring colours such as green, red, yellow, and blue in a 20-point Arial font. Participants responded using the laptop keyboard. Both tasks were designed to ensure a consistent testing environment for reliable data collection, with sessions lasting about 45 minutes.

### 5.7.2 Lexical Decision Task

Participants categorized stimuli as words or nonwords, starting with practice trials (four words and four nonwords) to familiarize themselves with the task. If necessary, instructions and practice trials were repeated. The experimental task was divided into two blocks of 40 stimuli each, with 10 English words, 10 Spanish words, and 20 nonwords per block for the bilingual version, and 20 Spanish words and 20 nonwords per block for the monolingual version. Each trial began with a 1000 ms fixation cross, followed by a 3000 ms stimulus. Participants pressed 'A' for words and 'L' for nonwords, with the response screen visible for up to 3000 ms. Participants were instructed to respond as quickly and accurately as possible. For detailed procedures, see section 2.4.2.

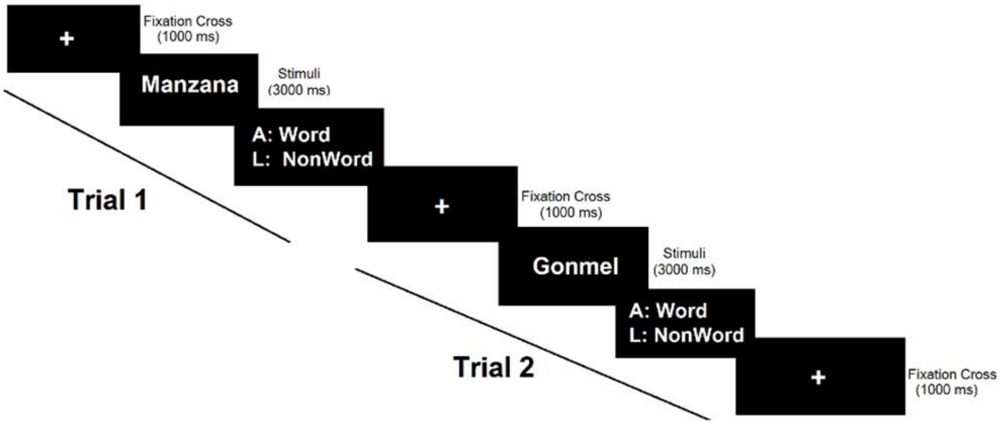



**Figure 1:** Lexical decision task layout

### 5.7.3 Stroop Task

Following the lexical decision task, participants engaged in the Stroop task, starting with an 8-stimuli practice trial consisting of 4 congruent and 4 incongruent items. If participants did not fully understand the task, additional instructions were provided, and the practice session was repeated. The Stroop task consisted of 90 trials, divided into three blocks of 30 trials each, balanced with an equal number of congruent and incongruent conditions. Participants used a color-coded keyboard setup to press the key matching the text colour. Each trial began with a fixation cross for one second, followed by a priming condition lasting 2.5 seconds, and the main Stroop stimulus displayed for three seconds. Participants were instructed to respond as quickly and accurately as possible. For detailed procedural descriptions and settings, refer to section 2.4.3.

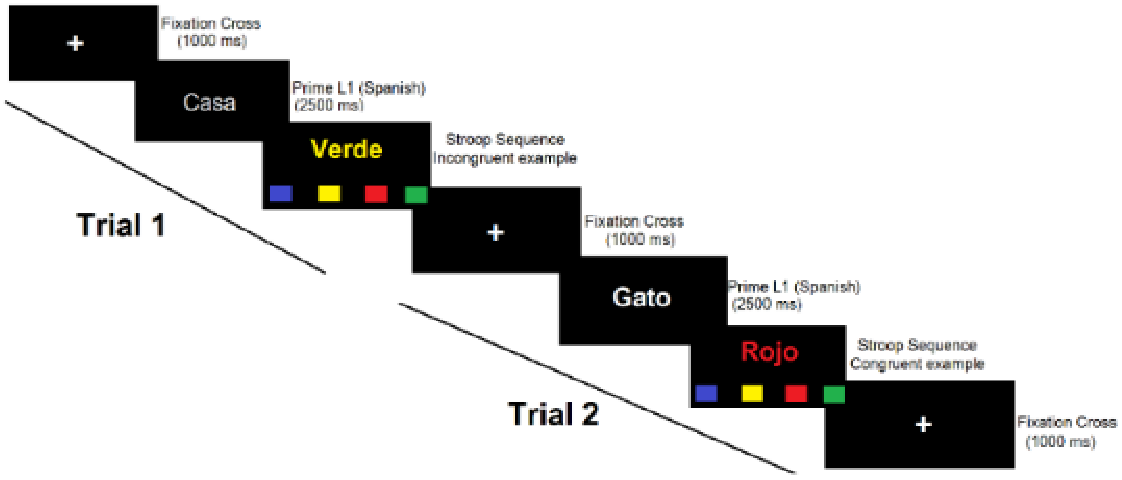



**Figure 2**: Stroop task layout

### 5.7.4 Priming

The Stroop task included a priming phase where participants were exposed to Spanish words for 2.5 seconds. This aimed to stimulate linguistic networks relevant to subsequent cognitive tasks, with Spanish chosen for consistent activation across participants. Although the priming phase aimed to understand the impact on cognitive control strategies, its effects were not included in the primary analysis to focus on the Stroop task's core cognitive processes. The potential influence of priming on task performance remains a valuable topic for future research.

### 5.7.5 EEG Procedure

The EEG procedure for both the lexical decision and Stroop tasks followed a consistent protocol for all participants. EEG signals were acquired using the BioSemi system with 32 Ag-AgCl scalp electrodes placed according to the 10-20 positioning system. The two mastoid electrodes served as references, and ocular movements were recorded using three additional electrodes. EEG data was transmitted to a BioSemi ActiveTwo amplifier box, and ERP triggers were coded using PsychoPy3 software (Peirce et al., 2019). Continuous monitoring of outputs was maintained in BioSemi Actiview. If electrode adjustments were necessary, they were made during designated breaks. This standardized procedure ensured consistent data collection, contributing to the reliability and comparability of neural responses during the tasks.

## 5.8 Data analysis

### 5.8.1 Behavioural analysis

Employing RStudio for linear mixed effects models for behavioural and ERP data, this paper closely examines the effects of DLD within bilingual and monolingual contexts, specifically focusing on Spanish language tasks. The statistical approach, including log transformation of RTs and the inclusion of relevant covariates, is consistent with the methodology applied across studies. Five participants, (2 Bilinguals and 3 Monolinguals) were excluded from the analysis due to poor-quality brain data and consistent movement during the task.

In the Lexical Decision Task, fixed factors included the type of word and group, with age, sex, SES and Nonverbal-IQ considered as a covariate. Participants and words were used as random effects. For the Stroop Task, fixed factors encompassed Congruency and Group, and covariates for the Stroop were the same used in the LDT, with participants and words considered as random effects. Interaction analyses were conducted to explore nuanced relationships between groups and the type of word, including a 2x2 interaction for the Lexical Decision Task and a 2x2 interaction with congruency and group for the Stroop Task. English conditions were excluded from the analysis for both tasks, concentrating on the Spanish language to directly compare the cognitive and linguistic functions of bilingual and monolingual DLD participants.

### 5.8.2 ERP Analysis

EEG processing for the Lexical Decision and Stroop tasks was done using EEGlab (v2021.1) and ERPlab (v8.10). EEG signals were filtered at a 256Hz sampling rate with 0.1Hz high pass and 30Hz low pass settings to delineate the neural correlates of cognitive tasks accurately. This filtering, as mentioned by Luck (2014), was essential for isolating task-relevant neural activity.

The process of Independent Component Analysis (ICA) played a pivotal role in artifact management, with an average of 4 artifacts, predominantly due to eye movements, being meticulously rejected from each participant's data. Post-ICA, we re-referenced the EEG data to mastoid sites and selected an epoch window from -200 to 1000 ms to embrace the breadth of expected ERP components, capturing the continuum from early sensory to later cognitive events, including the N400. Artifact rejection was systematically executed in a two-stage procedure employing a moving window peak-to-peak threshold, with specific attention first to ocular channels and then to all scalp channels. Trial retention post-artifact rejection showed variability reflective of the cognitive demands of the tasks and the specificities of the participant groups.

Within the Lexical Decision Task, we commenced with 80 trials per child and noted distinct rejection rates, leading to an approximate 5.0 % of rejection, resulting on 76 trials retained, which correspond to 95%, for Monolingual DLD group, and for Bilingual DLD children, the rejection rate was 5.4%, resulting in approximately 76 trials retained (94.5%). For the Stroop Task, which began with 90 trials, a slightly elevated rejection rate resulted in 5.7% of trials rejected for the Monolingual DLD group, with 85 trials retained (94.4%), and the Bilingual group had 5.9% of trials rejected, resulting in approximately 85 trials retained (94.4%).

The mean amplitude for the N400 component was measured within the 350-550 ms interval, chosen to align with the developmental trajectory of language processing in children, including those with DLD. Centro-parietal electrodes (CZ, C3, C4, CP5, CP1, CP2, CP6, P7, P3, PZ, P4, P8) were selected for our region of interest (ROI) based on their documented sensitivity to the N400 component in semantic tasks, as supported by Kutas and Federmeier (2011) and Moreno and Kutas (2005). Linear Mixed-Effects Modeling (LMER) was employed, treating each electrode as an individual random effect within the ROI. This approach allowed us to capture the unique contributions and variability of each electrode's readings, providing a nuanced analysis of the effects of task conditions on ERP amplitudes.

While our primary focus was on the N400 component, we also observed early ERP activity potentially corresponding to the visual word recognition components P1 and N1. These components were less pronounced in the bilingual DLD group, suggesting additional cognitive load from managing multiple languages alongside DLD (Paradis et al., 2003; Hirosh and Degani, 2021). The P1 and N1 components are crucial markers of visual and attentional processing (Luck, 2014), serving as initial stages in language comprehension. The diminished prominence of these components in the bilingual DLD group indicates potential differences in early sensory encoding, which may influence subsequent semantic processing observed in the N400 window.

## 5.9 Results

### 5.9.1 Behavioural Analysis: Lexical Decision Task

**Table 2:** Reaction Time (RTs)

| Group | Spanish | Nonword |
|---|---|---|
| Monolingual DLD | 6.90 (0.41) | 7.12 (0.43) |
| Bilingual DLD | 6.94 (0.40) | 7.25 (0.40) |

**Table3:** Accuracy

| Group | Spanish | NonWord |
|---|---|---|
| Monolingual DLD | 1 | 95.1 |
| Bilingual DLD | 98.2 | 88.6 |

Results from the Lexical Decision can be seen in Table 4. Results indicated significant effects for several variables, like type ($F(1,57) = 148.25$, $p<.001$) and group ($F(1, 212) = 12.70$, $p<.001$). Additionally, the interaction between type and group was also significant (F (1, 432)

=27.71, p<.001), similarly SES also showed significant values (F (1, 168) = 29.97, P<.001). The covariates age, sex and NVIQ were not significant.

**Table 4:** Lexical decision Bilingual and Monolingual DLD

| **Parameter** | $DF$ | MeanSq | F | p |
|---|---|---|---|---|
| Type | 1 | 20.38 | 148.24 | <.001 |
| Group | 1 | 1.72 | 12.70 | <.001 |
| Age | 1 | .075 | .551 | .462 |
| Sex | 1 | .009 | .010 | .937 |
| NVIQ | 1 | .153 | 1.11 | .298 |
| SES | 1 | 4.12 | 29.97 | <.001 |
| Group*Type | 1 | 3.81 | 27.71 | <.001 |

A post hoc analysis was conducted to further investigate the differences between Bilingual DLD and Monolingual DLD children in their response times (RTs) for different types of stimuli. For Non-Words, a significant difference was found when comparing both groups. This means that Bilingual DLD performed significantly more slowly in comparison to their Monolingual peers (p < .001). Contrary to this, Spanish words did not show a significant difference (p = 0.1581). This lack of statistical significance indicates that the observed difference in RTs between the two groups when processing Spanish words is likely attributable to random variability. Therefore, we cannot conclude that there is a meaningful difference in reaction times between the Bilingual DLD and Monolingual DLD groups for Spanish stimuli.

**Table 5:** Post hoc analysis

| **Type: Spanish** | Estimate | SE | *t* | *p* |
|---|---|---|---|---|
| Bilingual DLD – Monolingual DLD | .025 | .017 | 1.38 | .158 |
| **Type: Non-Words** | | | | |
| Bilingual DLD – Monolingual DLD | .150 | .015 | 9.56 | <.001 |

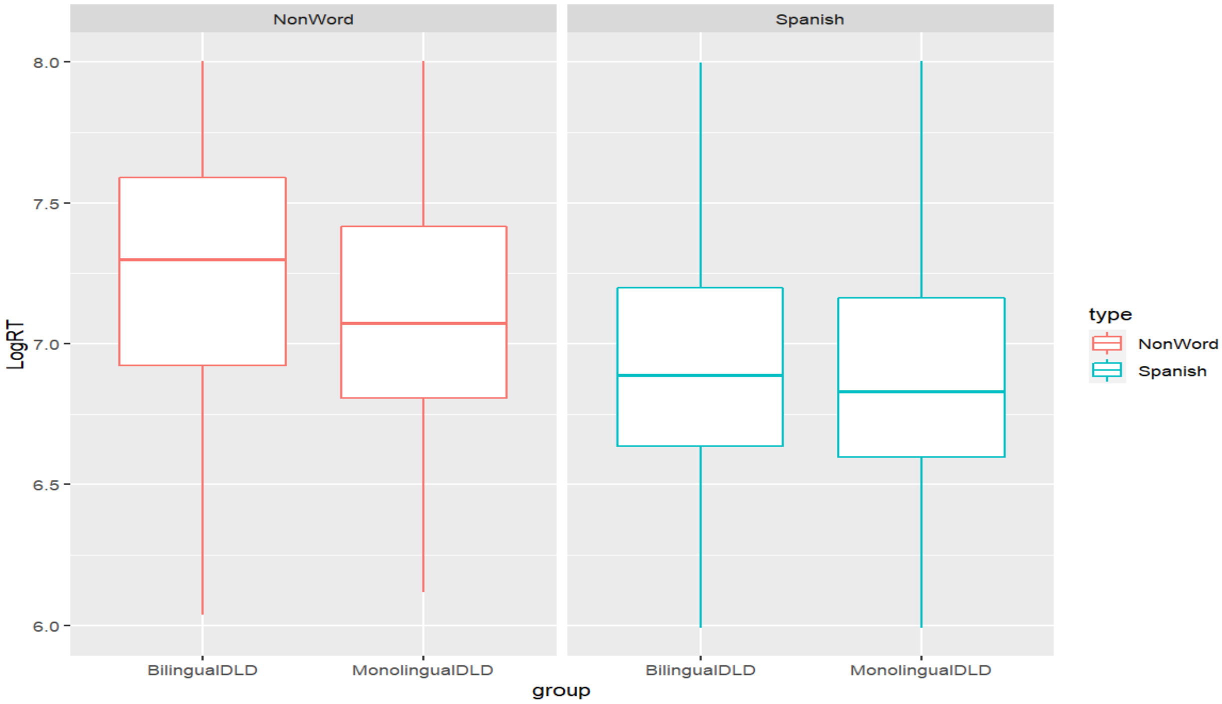



**Figure 3:** Reaction time between Bilingual DLD and Monolingual DLD. This shows a difference in RTs when comparing Spanish Words and Non-Words.

### 5.9.2 ERP analysis: Lexical Decision

As expected, we observed a significant N400 effect, with larger amplitudes in response to Non-Words compared to Spanish words, reflecting differences in the lexico-semantic processing of these words. The time window of 350-550 msec was chosen for analysis based on participant age and the presence of developmental language disorder (DLD). This window is known to capture the N400 component, and our ROI-based electrode selection focused on regions associated with semantic processing. Data analysis unveiled several important findings. Firstly, there was a significant main effect of the Type of Word ($F(1,32) = 29.15$, $p < .001$), indicating that N400 amplitudes differed significantly between Non-Words and Spanish words across both groups.

Secondly, a main effect of Group was also observed ($F(1,50) = 4.84$, $p < .001$). Finally, there was a significant interaction effect between Group and Type ($F(1,80) = 7.20$, $p < .001$). This interaction suggests that the differences in responses between the two groups vary depending on the type of stimulus presented. In other words, the N400 amplitude differs not only between Non-Words and Spanish words but also between the Bilingual DLD and Monolingual DLD groups, suggesting a complex interplay between linguistic processing and bilingualism. Table 6 summarizes the results.

**Table 6:** ERP Bilingual and Monolingual DLD group.

| **Parameter** | $DF$ | MeanSq | F | p |
|---|---|---|---|---|
| Group | 1 | 50.47 | 4.84 | <.001 |
| Type | 1 | 326.96 | 29.15 | <.001 |
| Group*Type | 1 | 80.82 | 7.20 | <.001 |

A post hoc analysis was done to further examine the differences in ERP responses between the two groups for Spanish words and Non-Words. For Non-Word stimuli, a significant difference in N400 amplitudes emerged between the Bilingual DLD and Monolingual DLD groups, with Bilingual DLD children exhibiting more negative amplitudes (estimate = -.956, $p < .001$). In contrast, for Spanish stimuli, there was no significant difference in N400 amplitudes between the two groups (estimate = 0.018, p = .972). These findings indicate that the differences in N400 amplitudes between the two groups were more pronounced when processing Non-Words.

**Table 7:** Post Hoc analysis

| **Type: Spanish** | Estimate | SE | *t* | *p* |
|---|---|---|---|---|
| Bilingual DLD – Monolingual DLD | .018 | .542 | .035 | .972 |
| **Type: Non-Words** | | | | |
| Bilingual DLD – Monolingual DLD | -.956 | .173 | -5.54 | <.001 |

These results underscore the impact of being bilingual or monolingual with DLD on neural processing during language tasks, particularly evident in the distinctive N400 responses between the two groups when processing Non-Words.

**Figure 4: LDT Spanish waves, electrodes CZ, PZ, CP1, CP2**

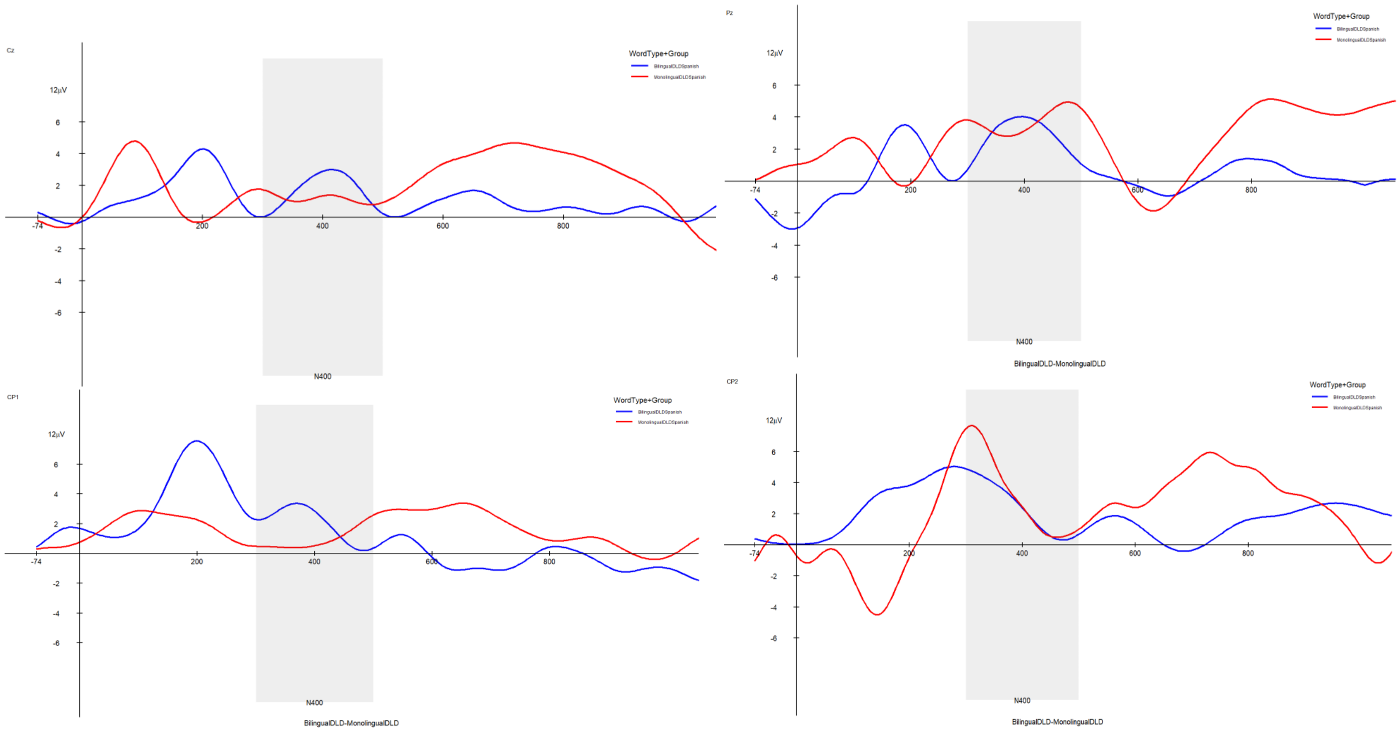
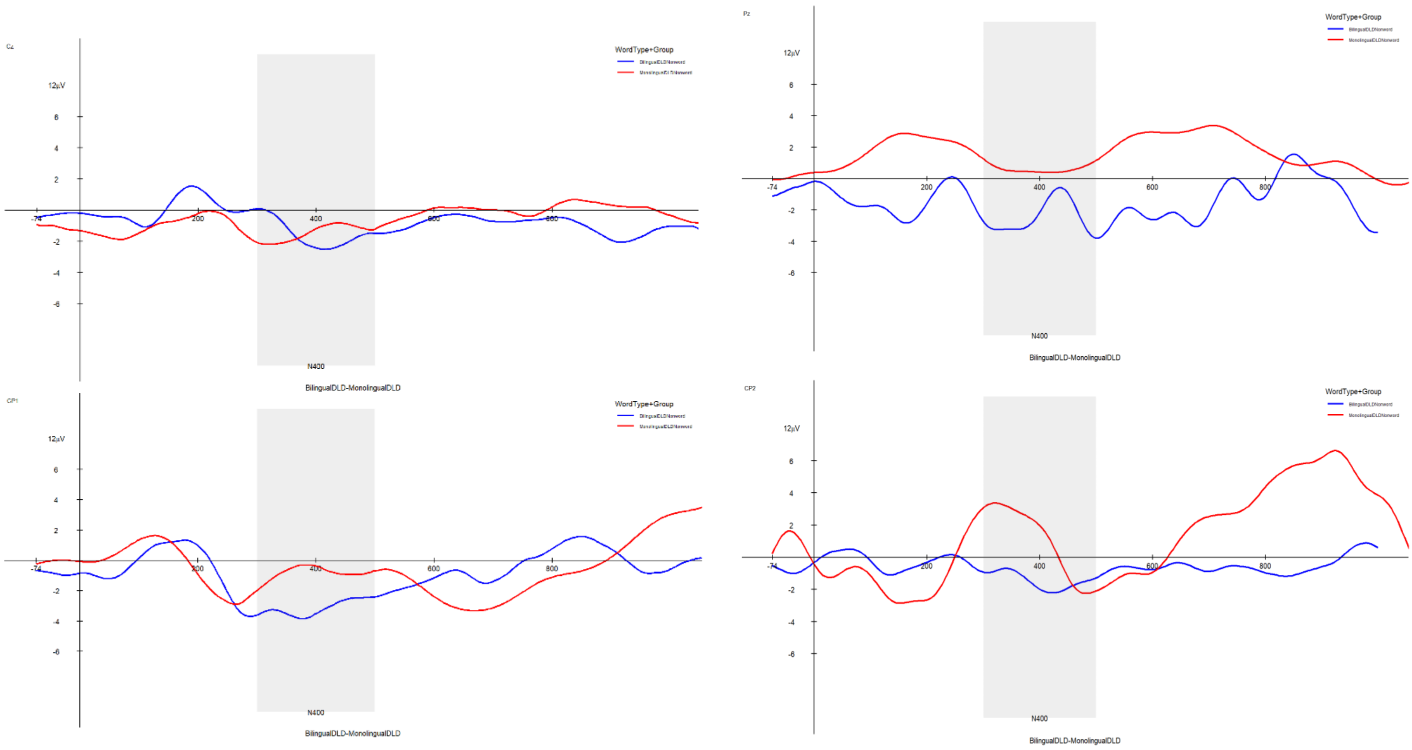



**Figure 5: LDT Nonword waves, electrodes CZ, PZ, CP1, CP2**



### 5.9.3 Behavioural Analysis: Stroop Task

**Table 8:** Reaction Time (RTs)

| Group | Congruent | Incongruent |
|---|---|---|
| Monolingual DLD | 6.95 (0.39) | 7.00 (0.38) |
| Bilingual DLD | 6.99 (0.41) | 7.04 (0.41) |

**Table 9:** Accuracy

| Group | Congruent | Incongruent |
|---|---|---|
| Monolingual DLD Spanish | 1 | 94.2 |
| Bilingual DLD Spanish | 98.1 | 91.6 |

Results can be seen in Table 10. The main effect of Congruency was statistically significant, (F (1, 641) = 54.04, p<.001), same as group (F (1, 435) = 13,39, p<.001), Additionally, SES was also significant (F (1, 416) = 3.94, p<.001). However, covariates of Age, Sex and NVIQ, did not exhibit significant effects, as well as the congruency and group interaction.

**Table 10:** Stroop Task Bilingual-Monolingual DLD group

| **Parameter** | *DF* | MeanSq | F | p |
|---|---|---|---|---|
| Congruency | 1 | 8.21 | 13,39 | <.001 |
| Group | 1 | 2.03 | 54.04 | <.001 |
| Age | 1 | .179 | 1.18 | .276 |
| Sex | 1 | .057 | .379 | .537 |
| NVIQ | 1 | .004 | .031 | .849 |
| SES | 1 | .599 | 3.94 | <.001 |
| Congruency*Group | 1 | .102 | .673 | .411 |

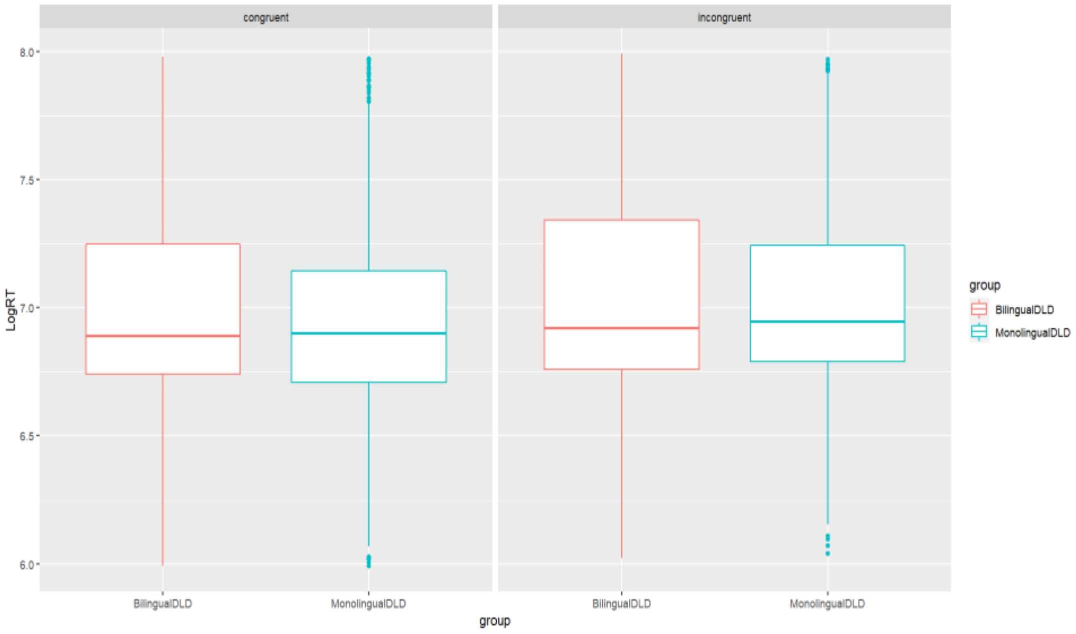



**Figure 5:** Reaction times in Bilingual DLD and Monolingual DLD groups performing a Stroop task. Both groups exhibited longer RTs in the incongruent condition, which was slower in the Bilingual DLD group.

### 5.9.4 ERP analysis: Stroop Task

A robust Stroop effect was found when analysing the data. Results on Table 11, show that Congruency significantly predicts N400 amplitude (F (1,35) = 3.34, p<.001), Group was also significant (F (1,35) = 4.03, p<.001), meaning that there are significant differences in ERP measurements between these two groups. Finally, the interaction between group and congruency did not reach a significant level meaning that the impact of congruency on ERP measurements is not significantly different between the Bilingual DLD group and the Monolingual DLD group.

**Table 11:** ERP Bilingual and Monolingual DLD group

| **Parameter** | DF | MeanSq | F | p |
|---|---|---|---|---|
| Group | 1 | 86.4 | 4.03 | <.001 |
| Congruency | 1 | 71.8 | 3.34 | <.001 |
| Group*Congruency | 1 | 6.29 | .029 | .588 |

**Figure 6: Stroop Task Congruent Condition electrodes CZ, PZ, CP1, CP2**

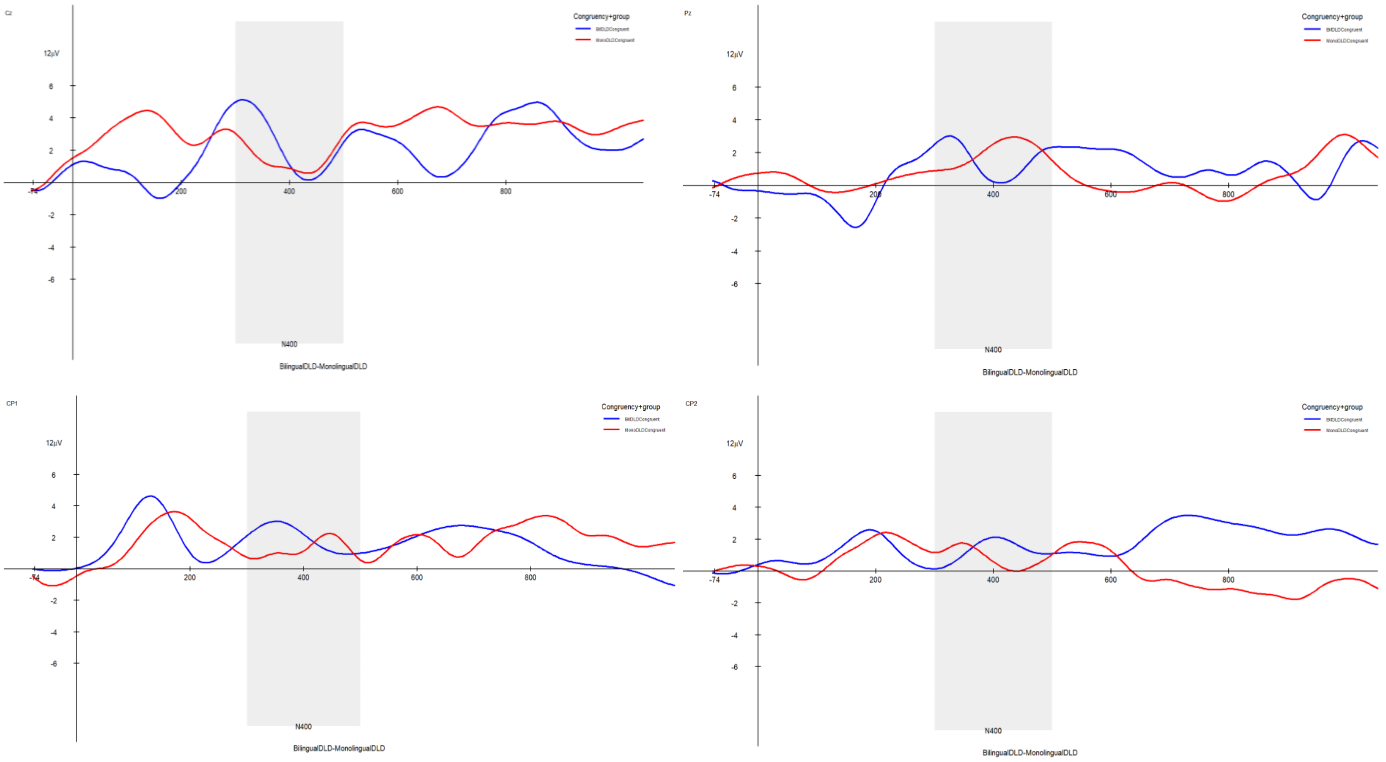
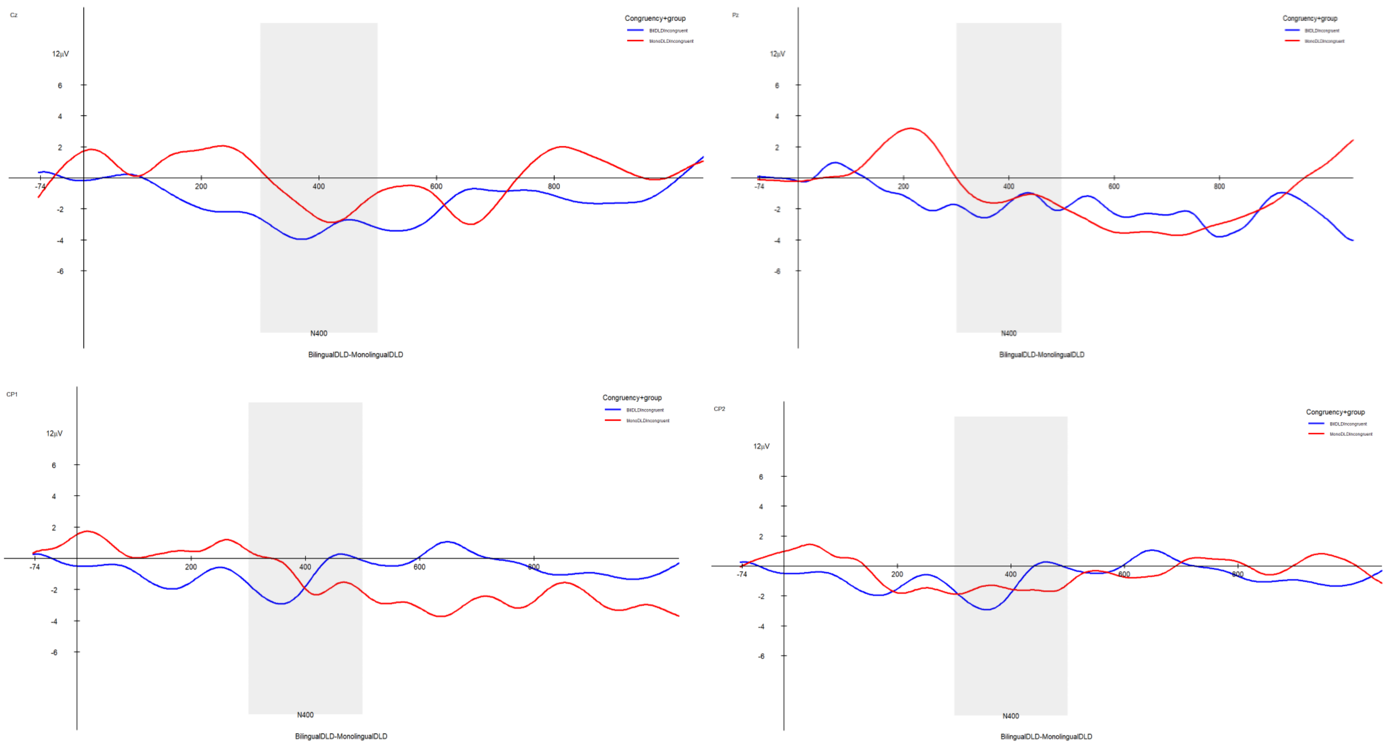



**Figure 7: Stroop Task Incongruent Condition electrodes CZ, PZ, CP1, CP2**



## 5.10 Discussion

In recent years, research examining individuals with Developmental Language Disorder (DLD) has primarily employed various linguistic tasks such as picture naming, lexical retrieval, word association, and oral sentence processing, among others. However, there is still a gap in the literature regarding the use of lexical decision tasks, for lexical processing, and colour word Stroop task, and even less is available when measuring behavioural data in conjunction with EEG. Furthermore, when assessing bilingual children with DLD, most of the tests conducted have been done in the child´s first language (L1) or second language (L2), in different tasks. This means that most of the tasks don't use both languages within a single task.

### 5.10.1 Lexical processing in Bilingual DLD and Monolingual DLD children

In our data analysis, we observed intriguing patterns in lexical processing between bilingual and monolingual children with Developmental Language Disorder (DLD). Notably, both groups processed familiar Spanish words similarly, with no significant differences in reaction times (RTs). This finding suggests that both bilingual and monolingual children with DLD can navigate familiar words within their respective L1s. However, bilingual children demonstrated significantly longer RTs and more negative N400 amplitudes when processing NonWords than their monolingual counterparts. This aligns with prior findings linking immature word associations in children with DLD to poor lexical-semantic organization (Sheng & McGregor, 2010).

The significant interaction between type and group underscores that bilingual children with DLD are particularly disadvantaged in processing NonWords compared to monolingual children with DLD. The added complexity of managing two language systems may exacerbate the phonological and lexical processing difficulties inherent in DLD. Leonard (2017) notes that children with DLD inherently exhibit slower processing speeds in phonological and lexical tasks. However, the lack of significant differences in processing familiar Spanish words suggests that the additional cognitive load associated with bilingualism does not further impair processing when linguistic demands are reduced. DLD manifests in several aspects of language processing, such as limited vocabulary, difficulty constructing coherent narratives, understanding complex language, and grammar and syntax issues. These affect expressive and receptive tasks, impacting academic and social interactions (Bishop, Snowling, Thompson, & Greenhalgh, 2017). Thus, recognizing these issues as a broader learning challenge is essential.

The N400 component, observed more prominently in the bilingual group during nonword processing, corroborates the increased cognitive load due to unfamiliar lexical items. This aligns with the behavioural data indicating prolonged reaction times. Contrastingly, the similarity in N400 responses for familiar Spanish words between the groups shows that lexical familiarity mediates processing efficiency, regardless of bilingualism or DLD presence. This insight aligns with Hirosh and Degani's (2021) findings on how learning and testing language impact bilingual language processing. Bilingual learners with DLD may exhibit varied proficiency in their L1 and L2 that shifts with age and experience, often changing across different linguistic measures. For instance, a bilingual learner may show greater skill in Spanish at age six but later shift to English dominance at age eight (Bird, Genesee, & Verhoeven, 2016).

Our study also contributes to filling a significant gap in the current research on bilingual children with DLD, especially in the context of lexical decision tasks. Thordardottir and Brandeker's (2013) work, while differing in methodology, parallels our findings, indicating no pronounced deficit in bilingual DLD children compared to their monolingual counterparts. This suggests that the challenges posed by bilingualism in lexical processing might not necessarily exacerbate the difficulties inherent to DLD. Such an understanding is crucial, especially when considering intervention and educational strategies for bilingual children with DLD, emphasizing the need for approaches that acknowledge the dual language context.

Considering the unique bilingual context of our study, it is important to highlight the lack of previous research addressing lexical processing in bilingual children with DLD in both of their languages within a single task. It was expected for the bilingual group to perform worse than their monolingual peers, not only in Non-Words but also in Spanish words. Bilinguals must learn to connect words both within and across languages, but also, they must be able to organize known words, newly learned or acquired and categorize them into their existing lexical system (Royle & Courteau, 2014). With this, it is known that for children with DLD, the overall processing of language may take place at a slightly slower or less efficient rate. This additional layer of complexity introduced by the bilingual context may have contributed to the distinct ERP patterns we observed in the task.

Furthermore, our findings indicate that the primary challenges in processing Non-Words in Bilingual DLD children can be attributed more to the bilingual context than DLD itself. This conclusion is drawn from the more pronounced difficulty observed in processing Non-Words in the bilingual group compared to the monolingual group. The bilingual context introduces additional cognitive demands, as evidenced by the distinct N400 response patterns, a finding that resonates with studies by Carreiras, Vergara, and Barber (2005), and Kornilov et al. (2014). These studies highlight the intricacies of lexical processing challenges in children with DLD, especially when compounded by bilingualism.

In summary, our study sheds light on the intricacies of lexical processing in children with DLD in bilingual and monolingual contexts. Both behavioural and ERP data indicate that while differences exist between Bilingual DLD and Monolingual DLD groups, these differences primarily stem from the Bilingual. The distinct N400 response patterns observed in the bilingual group when processing Non-Words highlight the specific challenges faced by bilingual children with DLD, suggesting that bilingualism, introduces additional complexities, in children with DLD.

**5.10.2 Colour-Word Stroop Task, ERP and Cognitive processing in DLD children**

In our analysis of the Colour-Word Stroop Task involving children with Developmental Language Disorder (DLD), both the behavioural and ERP data revealed notable patterns. While some studies suggest that DLD may pose particular challenges in tasks like the Stroop task, our findings indicate nuanced insights, especially concerning the impact of bilingualism.

Our findings align with prior research, emphasizing that individuals with DLD may exhibit altered performance on tasks involving cognitive control and language processing. For instance, a study by Kuntz (2012) found that English monolingual pre-teens with DLD performed poorly in incongruent conditions compared to both neutral (congruent) and age-matched typical control peers (Monolingual TD). Notably, bilingual teenagers with DLD may experience more Stroop interference in their second language (L2) than their first language (L1), depending on proficiency and language similarity (Brauer, 1998). The format of the Stroop task can also influence performance. Our colour-word Stroop task required key presses, while other versions, such as the one used by Spaulding (2010), involve oral responses, potentially increasing the cognitive load for children with DLD in incongruent conditions.

Our behavioural and ERP analysis did not show significant differences between the Bilingual DLD and Monolingual DLD groups in the Stroop task. Both groups exhibited similar patterns when comparing congruent and incongruent conditions, indicating that inhibitory control challenges affect both groups similarly. The absence of a significant group-congruency interaction implies that the Stroop interference effect occurs uniformly across both bilingual and monolingual children with DLD. This suggests that heightened cognitive processing demands during incongruent trials are not exclusive to either group.

Both groups exhibited more negative ERP amplitudes in incongruent conditions compared to congruent conditions, indicating that cognitive conflict leads to a heightened neural response in children with DLD, regardless of linguistic background. This aligns with previous studies highlighting that the 350-550 msec time window is sensitive to cognitive interference during the Stroop task (Markela-Lerenc et al., 2004; Liotti et al., 2000). The consistent ERP pattern across both bilingual and monolingual children with DLD reinforces that inhibitory control challenges are a shared experience.

While bilingualism may positively influence executive functions (van den Noort et al., 2019; Ware et al., 2020), bilingual children with DLD confront heightened cognitive demands, particularly when transitioning from congruent to incongruent conditions. Moreover, our findings underscore the importance of considering specific language contexts and linguistic abilities when assessing cognitive functions in individuals with DLD. Interestingly, our results did not reveal significant differences between bilingual and monolingual DLD children in congruent conditions. This observation is pivotal, as it indicates that while bilingualism exacerbates cognitive challenges in conflicting situations, it does not affect performance in tasks where language interference is minimal. Such findings are in line with recent research that posits the benefits and drawbacks of bilingualism are context-dependent (Green et al., 2019; Lukács et al., 2016).

In summary, our study highlights differences in cognitive control and language processing between children with Bilingual DLD and Monolingual DLD during the Stroop task. Both ERP and behavioural data support the presence of these differences, particularly in incongruent conditions, where the Bilingual DLD group exhibited longer RTs and more negative ERP amplitudes. These findings contribute to our understanding of the interplay between language disorders and cognitive control.

**5.10.3: Socioeconomic Status (SES)**

Research suggests that SES disparities between bilingual and monolingual groups can complicate direct comparisons of cognitive outcomes. Higher SES correlates with better educational resources and cognitive outcomes, which is crucial to consider when evaluating the influence of SES on bilingualism. Although the Stroop task did not reveal significant differences between bilingual and monolingual children with DLD, SES may play a role in cognitive outcomes. Studies by Paap et al. (2015) and Morton & Harper (2007) suggest that the bilingual advantage in executive functioning could be influenced by SES rather than bilingualism alone.

Our results indicate that cognitive advantages related to bilingualism were not universally observed. Both bilingual and monolingual DLD children showed similar performance in the Stroop task. This suggests that SES and other cultural factors may have a more nuanced role in cognitive processing. The bilingual advantage may depend on task-specific demands, requiring careful interpretation in studies where SES disparities exist between groups.

Additionally, research indicates that SES and cultural differences intertwine with bilingualism, influencing cognitive outcomes and requiring careful methodological consideration (Antoniou et al., 2016; Blom et al., 2017). Future research should consider within-group comparisons or carefully matched participants to minimize confounding effects and recognize the role of SES in cognitive development. Nuanced approaches are essential to studying bilingual cognitive processing. Longer reaction times in the Stroop task suggest that bilingual children with DLD face more significant challenges, partly due to broader linguistic search spaces. However, SES disparities between groups highlight the need for valid comparisons to account for educational resource influence on cognitive performance.

### 5.10.4 Conclusion

In our study, we delved into the complex dynamics of language processing and cognitive control in children with Developmental Language Disorder (DLD) across bilingual and monolingual settings. Utilizing the Lexical Decision Task and the Stroop Task, we sought to unravel how DLD, and bilingualism interact and influence these cognitive abilities.

Our findings in the Lexical Decision Task suggest that bilingualism adds a layer of complexity to lexical processing in children with DLD. Bilingual children with DLD demonstrated greater difficulty with unfamiliar Non-Words, likely due to the cognitive load of managing two languages. This was evidenced by the distinct negative N400 response observed in bilingual children, highlighting the unique lexical processing challenges they face. However, in processing familiar Spanish words, both bilingual and monolingual groups displayed similar capabilities, indicating that lexical processing for familiar words remains relatively intact regardless of language background. In contrast, the Stroop Task revealed that the impact of bilingualism on cognitive control was not as pronounced as initially anticipated. While the Bilingual DLD group did show some differences in the incongruent condition, suggesting greater challenges in handling cognitive conflicts, both groups demonstrated similar overall patterns in task performance. This finding implies that DLD, rather than bilingualism, is a more significant factor in shaping cognitive control abilities in these children. The notable challenges in the incongruent conditions for both groups further underscore the influence of DLD on cognitive processing.

Our results contribute to the ongoing dialogue on how language disorders intersect with bilingualism. They highlight the need for nuanced understanding and assessment approaches, particularly in bilingual contexts. While our findings reveal that DLD plays a central role in cognitive and lexical processing challenges, the influence of bilingualism, especially in tasks involving unfamiliar words or cognitive conflicts, is an important consideration. This study offers valuable insights into the interplay between language disorders, bilingualism, cognitive control, and lexical processing in children. It underscores the significant influence of DLD in shaping how children process language and manage cognitive tasks, regardless of their language background. The findings emphasize the importance of considering both language proficiency and the presence of developmental disorders in understanding the unique challenges faced by bilingual children with DLD.

## 6.0 General Discussion

This project investigated the differences in lexical processing and executive function in Bilingual and Monolingual children with and without language disorder. Study 1 challenged the assumption of a consistent bilingual advantage in children, whereas study 2 and 3, focused on how bilingualism and/or language disorder may affect lexical processing and cognitive control in children. Furthermore, the integration of behavioural (RTs) and ERP analysis helped us to unravel the intricate relationship between language disorders, language background, cognitive control, and lexical processing.

## 6.1 Summary of the findings

### 6.1.1 Study 1

In the Lexical Decision Task, significant differences emerged between bilingual and monolingual participants. Behaviourally, bilinguals demonstrated prolonged reaction times (RTs) in processing NonWords compared to monolinguals, highlighting challenges in dealing with unfamiliar lexical stimuli. However, for Spanish words, this disparity was not observed, indicating proficiency in handling familiar language stimuli. The Electrophysiological (ERP) data mirrored these behavioural trends. Bilinguals exhibited more pronounced neural responses to NonWords, as evidenced by the negative amplitude differences in the ERP signals, suggesting that bilinguals experienced greater difficulty rejecting items, especially when confronted with linguistically challenging stimuli.

The Stroop Task results further illuminated the impact of bilingualism on cognitive processing. Behaviourally, bilingual participants showed longer reaction times in both congruent and incongruent conditions compared to their monolingual counterparts, indicating that bilinguals experienced increased cognitive load or difficulty in tasks requiring higher executive control, regardless of the congruency of the stimuli. The ERP results corroborated these findings. In incongruent conditions, bilinguals demonstrated a significantly larger negative response than monolinguals, suggesting heightened cognitive effort or enhanced conflict resolution processes. This response pattern was less evident in congruent conditions, indicating that the cognitive challenge for bilinguals predominantly lies in managing conflicting information.

Study 1's findings revealed that bilingualism significantly affected both lexical decision-making and cognitive control abilities. Bilingual individuals exhibited unique challenges and processing patterns, particularly in managing unfamiliar words and tasks requiring complex cognitive control. These results suggested a nuanced landscape of cognitive processing in bilinguals, characterized by heightened neural activity and extended reaction times in specific contexts. Socioeconomic status (SES) was considered as a covariate, indicating its substantial influence on cognitive performance outcomes. The analyses showed that higher SES was often associated with better educational resources, yet it did not straightforwardly mitigate the cognitive complexities associated with bilingualism.

### 6.1.2 Study 2

In this study, we presented a detailed examination of bilingual children with Developmental Language Disorder (DLD) and their performance in lexical decision and Stroop tasks. In the Lexical Decision Task, the results indicated that Bilingual DLD children faced notable challenges when processing NonWords, as evidenced by their prolonged reaction times (RTs) compared to typically developing (TD) bilingual peers without DLD. This contrasted with their performance with familiar English and Spanish words, where they demonstrated comparable RTs to their Bilingual TD peers. This pattern suggests that while Bilingual DLD children can proficiently process familiar linguistic content, they encounter specific difficulties with unfamiliar lexical stimuli. ERP data supported these behavioural findings. In the Lexical Decision Task, ERP data revealed that Bilingual DLD children, when processing NonWords, exhibited unique neural responses, especially in the N400 component. These responses underscore the distinct cognitive and neural approaches these children use to handle challenging linguistic stimuli, particularly unfamiliar words. These differences in ERP responses were less pronounced for familiar words, indicating a more aligned neural processing pattern with bilingual TD children for known linguistic content.

In the Stroop Task, we observed significant differences in both reaction times (RTs) and event-related potential (ERP) patterns between congruent and incongruent conditions. These differences were evident within each group, reflecting how cognitive processing in tasks requiring conflict resolution varies significantly depending on the congruency of the stimuli. While the main effects of group and language were significant, suggesting variations in cognitive processing among different groups and in different language conditions, our data did not reveal a significant interaction between group and congruency, nor between language and congruency. However, the interaction of congruency and language, showed that the language of the task influences how participants respond to congruent and incongruent stimuli. These findings underscore the complexity of cognitive processing in relation to bilingualism and Developmental Language Disorder (DLD). They indicate that while both groups of children exhibit differences in processing congruent and incongruent stimuli, the impact of language on these processes is a critical factor to consider.

### 6.1.3 Study 3

In this study, our investigation into Bilingual and Monolingual children with DLD presented insightful findings on their lexical processing, cognitive control, and the role of socioeconomic status (SES). In the lexical decision task, Bilingual DLD children displayed significantly longer reaction times (RTs) compared to their Monolingual counterparts, particularly when processing NonWords. This suggests that bilingualism introduces specific challenges in processing unfamiliar lexical items. Conversely, when processing familiar Spanish words, the RTs differences between Bilingual and Monolingual DLD groups were not significant, indicating a comparable level of proficiency with familiar words. These behavioural findings were mirrored in the ERP data, where Bilingual DLD children showed distinct neural responses to NonWords, indicative of an increased cognitive load. However, for familiar Spanish words, the ERP responses did not significantly differ between the Bilingual and Monolingual DLD groups, suggesting similar neural processing for known words.

In terms of cognitive control, as assessed by the Stroop Task, the behavioural data showed significant main effects for congruency and group, but no significant interaction between congruency and group was found. This indicates that both Bilingual and Monolingual DLD children faced similar challenges in resolving cognitive conflicts, irrespective of their bilingual status. The ERP results corroborated this, further emphasizing that bilingualism does not distinctly alter cognitive control challenges in children with DLD. Notably, SES was found to significantly influence performance in both tasks, with bilingual children generally having higher SES levels but still showing longer RTs compared to monolingual peers. This suggests that SES alone may not account for the differences in cognitive and linguistic processing between the groups.

These findings from study 3 emphasize the complexity of bilingualism's impact on cognitive and linguistic processing in children with DLD. While bilingualism poses additional challenges in processing unfamiliar words, it does not appear to exacerbate difficulties in cognitive control tasks or the processing of familiar words. This nuanced understanding is crucial in acknowledging the specific influence of bilingualism on children with DLD, highlighting the importance of tailored approaches in both linguistic and cognitive assessments for this group, while also considering the potential role of socioeconomic factors in shaping these outcome

**6.2 Lexical Processing - A Critical Reassessment in Bilingual and Monolingual Contexts**

Our investigation into lexical processing unveils compelling insights, prompting a critical reassessment of bilingual cognitive and lexical processing. We observed notable differences in reaction times (RTs) and N400 components during the Lexical Decision Task across Bilingual TD and Bilingual DLD, when compared to their Monolingual peers. These findings challenge prevailing notions about bilingual lexical efficiency and raise a critical question: Why do bilingual children, irrespective of developmental language status, encounter more challenges with unfamiliar lexical items compared to their monolingual peers?

Drawing from the insights of Bird, Genesee, and Verhoeven (2016), we understand that the evolving proficiency levels in L1 and L2 among bilingual children could significantly impact their performance, particularly with nonwords. The fluctuating proficiency leads to greater cognitive demands when processing nonwords, as bilinguals must navigate and suppress interference from their less dominant language (Gollan et al., 2014; Vihman, 2014). Jones and Brandt (2018) further contribute to this understanding, highlighting that the difficulty in classifying nonwords for bilinguals might stem from the intricate task manipulation and the inherent complexity of the Lexical Decision Task. The need to suppress interference from their less dominant language, combined with the unfamiliarity of nonwords, leads to prolonged reaction times for bilingual children in categorization tasks.

Furthermore, the complexities in bilingual processing, which arise from navigating two linguistic systems, are notably pronounced when bilinguals encounter nonwords. The distinct N400 responses observed in our study for nonwords among bilingual children could be indicative of these complexities. This heightened cognitive load and potential cross-language interference, a perspective supported by Lallier & Carreiras (2018), suggest that bilinguals must engage in more effortful semantic processing when the linguistic stimulus does not correspond to established lexical items in either of their languages. The challenge lies in the absence of a clear linguistic anchor for nonwords, requiring bilinguals to engage more deeply in semantic analysis and decision-making, which could be less demanding for familiar words. This increased cognitive load and interference result in prolonged reaction times, likely due to the need to navigate a larger cognitive search space. This need for increased semantic processing for nonwords could be a factor in the development of unique neural processing pathways in bilinguals, especially evident in the way they handle nonwords.

Despite the significant influence of socioeconomic status (SES), with bilingual groups generally having higher SES than monolinguals, the prolonged RTs in bilingual children highlight that SES alone does not fully account for differences in lexical processing. The larger cognitive search space and cross-linguistic interference still play a significant role in influencing cognitive performance. Thus, SES should be carefully considered in research and practice but not used as a sole explanatory factor (Paap et al., 2015).

The significant SES differences observed between our bilingual and monolingual groups underscore the complex role SES plays in cognitive performance. Despite bilingual children often having higher SES, which generally correlates with better educational resources and richer linguistic environments, they exhibited longer reaction times for non-words. Research has shown that higher SES is typically linked to improved educational resources, linguistic environments, and cognitive stimulation, which enhances cognitive performance (Hart & Risley, 1995; Fernald et al., 2013). However, the challenges inherent in managing two linguistic systems outweigh these advantages, resulting in prolonged reaction times in non-word tasks. This discrepancy between SES benefits and the challenge of bilingualism is supported by Calvo and Bialystok (2014), who emphasize that while higher SES might offer foundational cognitive and linguistic resources, it does not fully mitigate bilingual children's specific challenges. These include extensive phonological processing and lexical retrieval, particularly in tasks involving novel linguistic stimuli.

In contrast to these challenges, we observe a different pattern in the processing of familiar words by bilingual children. Both Bilingual TD and DLD groups demonstrated proficiency in recognizing and processing familiar lexical items in English and Spanish, comparable to monolingual peers. This proficiency, indicative of the cognitive flexibility highlighted by Barac et al. (2014), contradicts the narrative of bilingual inefficiency in lexical processing. It reveals a nuanced capability in bilinguals to efficiently manage familiar linguistic content—a skill-less pronounced in monolinguals. These differences highlight how familiarity with linguistic stimuli affects processing proficiency across groups and underscores the importance of considering the diverse cognitive challenges that bilingual TD and DLD children face

Acknowledging insights from Paper 2, we note the unique perspective offered by the performance of bilingual children with DLD. Their comparable proficiency in processing English and Spanish words challenges the assumption of inherent bilingual disadvantages in the context of language disorders. This observation not only calls for a re-evaluation of bilingual advantages but also highlights the resilience and adaptability within bilingual cognition, particularly in the face of language disorders. This discussion will be expanded further in subsequent sections.

Reflecting on these findings, I draw from my bilingual experiences and the diverse language environments encountered by children. The variability in language exposure among our bilingual participants underscores the intricate relationship between language environment and cognitive development. These personal and research insights, aligned with Castillo et al. (2020), emphasize the significance of considering individual linguistic histories in understanding bilingual cognitive processing. To further enrich our understanding of bilingual cognitive processing, future research could benefit from the introduction of additional qualitative methodologies. This approach would provide a more integrated view of the individual linguistic experiences and cognitive strategies employed by bilingual individuals, allowing for a more personalized interpretation of bilingualism's impact on cognitive and lexical processing.

In summary, our study contributes to a broader understanding of bilingualism, advocating for a differentiated approach in evaluating bilingual lexical processing. This approach respects the diversity and complexity of bilingual experiences, recognizing the need to consider various factors, including task complexity, linguistic familiarity, and individual differences. In line with Royle and Courteau (2014), our findings demonstrate the adeptness of bilingual individuals in word recognition tasks, challenging the notion of a consistent bilingual disadvantage. Our research enriches the discourse on bilingual cognitive processing, emphasizing the importance of context, individual differences, and the evolving nature of bilingual cognition.

### 6.3 Bilingualism's Complex Role in Cognitive Control and Executive Functions

Our investigation into bilingualism, cognitive control, and executive function, spanning three distinct studies, reveals intricate complexities and nuances. These findings invite a re-evaluation of conventional perceptions of bilingual cognitive processing and illuminate the multifaceted interplay between bilingualism and executive functions.

In Study 1, we observed extended reaction times (RTs) in bilingual children during both congruent and incongruent Stroop Task conditions. This finding challenges the commonly held belief in the cognitive edge of bilingualism and suggests a more complex reality. The extended RTs indicate that the cognitive control benefits often attributed to bilingualism are not uniformly distributed but are influenced by the nature of cognitive tasks and the child's developmental stage. These observations resonate with Marian et al. (2013) and Oliveira et al. (2016), who highlighted the evolving nature of language proficiency and its impact on cognitive control. Specifically, our findings suggest that younger bilingual participants, aged 7 to 10, may still be in the developmental phase where the full benefits of bilingualism on cognitive control have not yet been realized, reflecting a gradual maturation process of bilingual cognitive processing.

The hypothesis of a bilingual advantage posits that bilingual individuals exhibit superior executive function skills compared to monolinguals, attributed to the cognitive demands of managing two languages. This advantage is suggested to manifest in areas such as inhibitory control, cognitive flexibility, and attention management (Bialystok et al., 2012; Costa et al., 2009). However, critics like Paap and colleagues (Paap & Greenberg, 2013; Paap, Johnson, & Sawi, 2014; Paap, 2019) argue that the evidence supporting a bilingual advantage is inconsistent and often fails to account for confounding variables like socioeconomic status (SES). They emphasize that SES, educational background, cultural influences, and individual differences in language proficiency significantly affect research outcomes. When these variables are rigorously controlled, the purported advantages often diminish or disappear (Paap et al., 2015). Furthermore, Kousaie and Phillips (2012) note that bilingual advantage findings are sensitive to proficiency, age of acquisition (AoA), and the task's difficulty.

Despite the significant influence of SES, where bilingual groups generally had higher SES than their monolingual peers, the prolonged RTs in bilingual children highlight that SES alone does not fully account for differences in cognitive processing. Paap et al. (2015) criticized the use of SES as a covariate in studies on bilingual advantage, noting that SES might not fully account for the nuanced effects of bilingualism on cognitive performance. Antoniou et al. (2016) and Blom et al. (2017) emphasized that SES should be carefully controlled to understand bilingual advantage fully. Factors like proficiency, task type, and linguistic background all influence outcomes beyond SES.

Interestingly, Study 1's findings contrast with those from Study 3, where no significant differences in cognitive performance were noted between bilingual and monolingual children with Developmental Language Disorder (DLD). This raises pivotal questions about the adaptive cognitive strategies that bilinguals with DLD might utilize, potentially offsetting the cognitive demands of managing two languages. The lack of significant differences prompts us to consider whether the presence of DLD alters how bilingualism impacts cognitive control. This nuanced view requires us to rethink our understanding of bilingual advantages and the role of language proficiency in cognitive control mechanisms.

Study 3 introduces a contrasting scenario in the context of Developmental Language Disorder (DLD). The absence of significant cognitive performance differences between bilingual and monolingual children with DLD suggests that bilingualism's impact on cognitive control is not straightforward in the presence of language disorders. This finding is particularly intriguing as it contradicts the expectation of exacerbated cognitive challenges due to bilingualism in DLD. Instead, it highlights an interplay where bilingualism's effects on cognitive processing depend on the child's specific cognitive and linguistic context.

Paper 2 expands the scope of our inquiry by demonstrating that the implications of bilingualism in cognitive processing extend beyond language development status. It highlights a complex interaction between bilingualism and other cognitive and linguistic factors, such as DLD. This study contributes significantly to our comprehension of the broader cognitive ramifications of bilingualism, extending the dialogue beyond comparisons of bilinguals and monolinguals. It brings to light the varied contexts in which bilingualism operates, particularly in scenarios involving language disorders, thereby enriching our understanding of bilingual cognitive processing in diverse environments.

Collectively, these studies underscore that the influence of bilingualism on cognitive control is not straightforward but is shaped by a myriad of factors, including age, task complexity, language proficiency, and the presence of language disorders. This multifaceted perspective is reinforced by Gangopadhyay et al. (2019) and Wang, Fan, Liu, and G. Cai (2016), who highlight the context-dependent nature of bilingual advantages and their sensitivity to task-specific demands.

To advance our understanding, future research in bilingualism and language disorders should adopt more nuanced approaches, integrating qualitative methods alongside traditional quantitative analyses. This approach would provide a richer understanding of individual experiences and cognitive strategies in bilingual individuals. It is imperative to develop methodologies capturing the dynamic nature of bilingualism, especially regarding cognitive control. This exploration through these studies advocates for context-sensitive and multifaceted research approaches in the future. Embracing both quantitative and qualitative methodologies will offer a more comprehensive view of bilingual cognitive processing. Our findings underscore the need to consider individual differences, developmental trajectories, and the dynamic nature of bilingual cognition, paving the way for studies that contribute to a nuanced understanding of the complex role bilingualism plays in cognitive development.

### 6.4 Does DLD Affect Bilingualism or Vice Versa?

The exploration of bilingualism's interaction with DLD in our studies unravels a narrative that is far from straightforward. The nuanced relationship we uncovered challenges us to rethink the traditional views on this subject, prompting a re-evaluation of the roles these two factors play in cognitive and linguistic development. Our exploration of Study 2 revealed unexpected insights. Bilingual children with DLD demonstrated a level of proficiency in processing familiar words in both English and Spanish that matched that of their TD peers. This finding contradicts the long-held belief that bilingualism exacerbates language disorders, as discussed by Leonard (2017). Instead, it points towards a scenario where bilingualism, in certain contexts, could act as a beneficial scaffold rather than a hindrance for children with DLD. This revelation compels us to consider a more dynamic interaction between bilingualism and DLD, where the added complexity of managing two languages might, in some cases, offer cognitive and linguistic advantages.

The beneficial scaffolding effect of bilingualism for children with DLD can be understood in terms of enhanced cognitive flexibility. Regularly navigating two linguistic systems could enhance their ability to process language in diverse contexts, thereby aiding their linguistic development. This increased cognitive flexibility is a key component of bilingualism's scaffolding effect. For instance, the ability to switch between languages may enhance executive function skills, which in turn could aid in language processing tasks. Additionally, exposure to diverse linguistic structures and vocabularies could enrich the linguistic repertoire of bilingual children, providing them with a broader linguistic base to draw upon when confronted with language processing tasks.

Supporting this perspective, the work of Hirosh and Degani (2021) suggests that bilingual exposure may not necessarily intensify language difficulties in children with DLD, and in certain situations, might even aid their linguistic processing. This aligns with the idea that bilingualism, by offering varied linguistic experiences, may contribute positively to the cognitive and linguistic development of children with DLD, particularly in familiar language contexts.

In Study 3, we found that bilingualism appeared to have a more pronounced influence than DLD in shaping cognitive processing, especially in tasks involving familiar Spanish words. This finding, aligning with the research by Paradis et al. (2003), challenges the notion that bilingualism invariably adds to the cognitive load in children with DLD. It suggests that bilingualism, in familiar language contexts, does not inherently impair language processing, but might level the playing field for children with DLD.

However, the studies also highlight the complexities in cognitive processing among bilingual DLD children. The most striking observation from Study 2 was the accuracy of bilingual DLD children in incongruent conditions, especially in English. This performance was not only better than that of their bilingual TD peers but also showcased a potential adaptive strategy emphasizing colour over conflicting words This outcome, showing better accuracy than their bilingual TD peers, suggests a different cognitive processing strategy. It is possible that the bilingual DLD group was not engaging in compulsive reading behaviour, which typically sets up the Stroop conflict. This interpretation aligns with broader research on bilingual cognitive control, where bilinguals are known to activate both languages even in monolingual settings, necessitating constant language selection mechanisms to avoid interference (Abutalebi & Green 2013). This constant linguistic juggling might enhance their ability to ignore irrelevant information, leading to more efficient executive control across cognitive domains.

Furthermore, the variability in results across different cognitive control studies might stem from the limited understanding of conflict resolution processes. One possible source of discrepancies between the results of our study is the fact that research about cognitive control in general is limited and it is not clear whether different tasks measuring representational conflict resolution abilities require the same type of conflict resolution process or whether there are different processes for the different situations/stimuli. Therefore, the higher accuracy of bilingual DLD children in incongruent conditions may not just highlight an alternative strategy but could also indicate different underlying conflict resolution processes at play in these children.

Our findings collectively indicate a bidirectional relationship between bilingualism and DLD. While DLD significantly impacts linguistic processing in bilingual contexts, bilingualism concurrently introduces its own set of challenges and advantages. This necessitates a differentiated approach in both cognitive and linguistic assessments for bilingual children with DLD, acknowledging the complexities introduced by their bilingualism and language disorder. In light of these novel findings, future research should adopt approaches that more fully account for the intricacies of bilingualism and DLD. Incorporating qualitative methodologies alongside quantitative analyses could provide a deeper understanding of individual linguistic experiences and cognitive strategies, as suggested by Smolander et al. (2020) and Thordardottir & Brandeker (2013).

In summary, this investigation into bilingualism and DLD not only contributes to the academic discourse but also establishes an exciting new direction for future research in this field. It emphasizes the need for a nuanced understanding of bilingualism's role in the context of language disorders, urging researchers and practitioners alike to consider bilingualism not just as an added challenge but potentially as a facilitative factor in the linguistic and cognitive development of children with DLD.

**6.5 Implications and Further studies**

The series of studies conducted have unearthed several pivotal insights into bilingualism and its interplay with Developmental Language Disorder (DLD). These findings not only offer a deeper understanding of the current landscape but also pave the way for numerous prospective research avenues. As indicated by Gangopadhyay et al. (2019), bilingual children may align with their monolingual counterparts in lexical processing over time. A longitudinal approach, revisiting our participants in a year or two, would be instrumental in understanding the evolution of bilingual proficiency and its impact on DLD. Particularly, tracking the developmental trajectory in children with DLD, as discussed by Bird, Genesee, and Verhoeven

(2016), would illuminate changes in language proficiency over time and provide insights into the relative strengths and preferences of bilingual learners with DLD.

Another intriguing aspect highlighted by our research, especially in Study 2, is the accuracy of bilingual children with DLD in incongruent conditions. This raises questions about potential alternative cognitive strategies or nuances in cognitive control impacted by DLD. Future studies should delve into various cognitive control paradigms, particularly focusing on younger participants, to understand the specific challenges faced by children with DLD and the strategies they employ to navigate these tasks. Such research, incorporating methods accessible to younger participants who may not yet read proficiently, will broaden our understanding from an earlier developmental stage.

**Implications of Group Differences:** The observed differences between bilingual and monolingual children, with and without DLD, highlight unique cognitive strategies that can inform differentiated educational and therapeutic approaches. By understanding how these groups approach language tasks differently, practitioners can develop interventions that emphasize the strengths of each group, whether it's the cognitive flexibility of bilingual children or the consistency of monolingual learners.

**Practical Implications:** Translating these findings into practical applications is crucial for designing interventions tailored to the needs of bilingual and monolingual children with DLD. For instance, the distinct cognitive strategies observed in bilingual children with DLD suggest that educational plans should focus on enhancing dual-language exposure, which leverages their ability to manage interference between languages. These tailored strategies can help children improve their cognitive flexibility and executive function skills, supporting better linguistic outcomes.

**Dual-Language Programs:** Implement educational programs that provide balanced exposure to both languages. These programs should support children in managing language interference and improving executive functions.

**Cognitive Flexibility Training:** Develop activities that specifically target cognitive flexibility. Examples include switching tasks that require children to alternate between languages or focus on different aspects of a problem.

**Parental Involvement:** Encourage parental involvement in dual-language exposure by providing resources and training for parents to support language development at home.

**Therapeutic Techniques:** Introduce therapeutic techniques that leverage the strengths of bilingual children. Use bilingualism to enhance cognitive control and problem-solving skills.

By implementing these strategies, practitioners can better support the linguistic and cognitive development of bilingual children with DLD, leading to more effective educational and therapeutic outcomes.

**Methodological Suggestions:** Methodologically, integrating eye-tracking with EEG measures, particularly focusing on the N400 component, could offer more nuanced insights into cognitive processing in bilingual children with DLD. This approach would build on the research by Liu et al. (2014), providing deeper insights into neural mechanisms underpinning cognitive control. Investigating how the N400 component and other cognitive processes manifest across different age groups will offer insights into the developmental aspects of cognitive control in bilingualism, aligning with the findings of Verhagen et al. (2017), which emphasize the influence of early dual-language exposure on executive functions. Combining eye-tracking with EEG measures allows for a more nuanced analysis of how cognitive processes unfold over time and in response to different types of stimuli. This integrated approach can provide a dynamic picture of the interplay between visual attention and neural processing. For instance, correlating gaze patterns with N400 amplitudes during a Stroop task can reveal how visual attention to different aspects of stimuli (like colour versus text in the Stroop task) aligns with neural markers of cognitive control and conflict resolution.

Future studies should use larger sample sizes to identify potential subgroups within the DLD population, allowing for variability in cognitive control abilities to be better understood. Including both younger and older participants will shed light on how cognitive and linguistic trajectories evolve over time. Considering the suggestion by Bialystok et al. (2012) about bilingual advantages manifesting in individuals with high proficiency at their cognitive peak, examining how DLD and bilingual advantages evolve or persist over time is crucial. Additionally, reevaluating diagnostic criteria, especially in bilingual populations, is essential for developing effective intervention strategies. This aligns with the work of Acosta Rodríguez et al. (2014) and underscores the importance of accurate and early identification of DLD.

Exploring a broader range of linguistic and cognitive domains in future studies is vital. This approach, in line with the multifaceted nature of bilingualism and DLD highlighted by Marini et al. (2017) and Ebbels et al. (2012), would allow for a more comprehensive understanding of bilingualism's role in language disorders, particularly considering the potential scaffolding effect in the lexical domain. Translating these findings into practical applications, as recommended by Tsimpli et al. (2016), is essential for developing tailored linguistic support in bilingual DLD contexts.

The future of research in this field also calls for interdisciplinary collaborations and cross-cultural studies to explore bilingualism and DLD in different linguistic and cultural environments. Engaging families and communities in future research and understanding the impact of the home language environment will enrich our methodologies and intervention tools. Studies like those by Chéileachair et al. (2020) and Kohnert et al. (2020) underscore the importance of language exposure in bilingual lexical development. Future research should focus on how this exposure influences language processing in bilingual children with DLD.

While our research has provided comprehensive insights, it is essential to recognize and address its limitations in future studies. For instance, the absence of a typically developing comparison group in some studies limits the generalizability of our findings. Future research should ensure a more balanced representation of comparison groups. Moreover, employing diverse task paradigms will provide a more holistic view of the diverse range of cognitive and lexical processes involved in bilingualism and DLD.

Our studies have not only contributed to the existing body of knowledge but have also charted new territories in the realm of bilingualism and Developmental Language Disorder. By challenging traditional assumptions and revealing unexpected patterns, our research invites a re-examination of established theories and calls for innovative approaches in future investigations. The implications of our work extend beyond theoretical insights, influencing practical applications in education and therapy. As we move forward, the integration of diverse methodologies and perspectives will be crucial in unravelling the complexities of bilingual language development and disorders. Our research thus stands as a catalyst for ongoing inquiry, encouraging a multifaceted and dynamic exploration of bilingualism and DLD in the years to come.

# 7 Conclusion

This dissertation represents a pioneering journey into the intricate interplay between bilingualism and Developmental Language Disorder (DLD) in children. Through the lens of three meticulously designed studies, it delves deep into the realms of lexical processing and cognitive control, dissecting how these vital aspects of language development are uniquely shaped in bilingual and monolingual contexts, with a particular focus on children aged 7-10.

At its core, this investigation was propelled by the hypothesis that bilingualism, far from being a mere linguistic variable, introduces distinctive challenges and nuances in cognitive processing, especially in the presence of DLD. It sought to unravel whether bilingualism acts as an exacerbating force in the cognitive complexities inherent in DLD or, conversely, serves as a mitigating or even beneficial factor.

In its pursuit, Study 1 peeled back layers of assumed cognitive advantages in bilingual children, uncovering a landscape where these young bilingual minds encounter distinct challenges in processing nonwords and exhibit unique cognitive control patterns. This revelation challenges the monolithic view of bilingual cognitive advantage, revealing a more nuanced and dynamic interaction between bilingualism and cognitive processes. Study 2 further expanded this exploration to bilingual children with and without DLD. Here, the findings took an unexpected turn, with bilingual children with DLD demonstrating proficiency in processing familiar words, comparable to their typically developing bilingual peers – a finding that upends the conventional narrative of bilingualism exacerbating language disorders. Instead, it suggests a scenario where bilingualism, particularly in familiar linguistic contexts, can offer cognitive and linguistic scaffolds, supporting and enriching language development. Study 3 deepened our understanding by juxtaposing the experiences of bilingual and monolingual children with DLD. The outcomes of this study painted a nuanced picture of bilingualism's role in language disorder. While bilingualism introduced specific challenges in processing unfamiliar words, it did not uniformly exacerbate difficulties in cognitive control tasks or the processing of familiar words. This highlights the intricate and varied impact of bilingualism on children with DLD, underscoring the necessity of a tailored, nuanced approach in both linguistic and cognitive assessments for this group.

Collectively, these studies illuminate the multifaceted relationship between bilingualism and DLD. They reveal a complex narrative where bilingualism presents both challenges and potential advantages, reshaping our understanding of how these two factors interact in the cognitive and linguistic development of children. This research challenges existing paradigms, offering fresh perspectives, and contributing significantly to the discourse on bilingual language development and disorder. As our comprehension of bilingualism and DLD evolves, so too must our strategies for diagnosing, supporting, and educating children navigating these complex cognitive landscapes.

This dissertation does more than enrich theoretical understanding; it charts a new course for future research in bilingualism and language disorder. It underscores the importance of viewing bilingualism not merely as an added challenge but as a potential facilitative factor in the linguistic and cognitive development of children with DLD. It advocates for a multi-faceted exploration of these phenomena, emphasizing the need for future studies to embrace this dynamic and nuanced perspective. In doing so, the research presented herein sets a precedent for innovative, interdisciplinary approaches that consider the rich tapestry of individual experiences and developmental trajectories.

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## Appendix 1: Questionnaire used for all three studies.

University of Essex

**Name of the project: Lexical Processing and Executive Function in Bilingual Children with and without Language Disorder**

**Name of the researcher:** Stephanie Martin Vega **Email:** sa17132@essex.ac.uk

**Supervisor:** Dr Laurel Lawyer **Email:** l.lawyer@essex.ac.uk

*The following questionnaire needs to be answer only by parents, carer, or legal guardian of the participant.*

**Please answer the following questions:**

1.-Date of birth of the participant: ______________________________

2.- Has the participant been diagnosed with a language disorder? If so, which one is it? When was the diagnose made?

________________________________________________________________________________

________________________________________________________________________________

__________________________________________________________________________

3.- Apart from Developmental language disorders (DLD), has the participant been diagnose with any other condition like Autism spectrum disorder (ASD), Asperger´s, dyslexia etc? Does the participant have any hearing or visual impairment?

________________________________________________________________________________

________________________________________________________________________________

__________________________________________________________________________

4.- Is the participant left or right-handed?

______________________________________________________________________

5.-Does the participant have any siblings?

______________________________________________________________________

6.- Have any immediate family members (brothers, sisters, mother, father) been diagnosed with a language disorder? If so, please provide details below.

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

_____________________________________________________________________

7.- Does the participant attend sessions with a language therapist? If so, for how many hours a week?

________________________________________________________________________________

__________________________________________________________________________

8.- Did the participant attend a language school before starting formal education? If so, for how long?

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

_______________________________________________________________________

9.- If the participant attended a language school, was Spanish the only language taught to him/her?

_______________________________________________________________________________

_______________________________________________________________________________

_________________________________________________________________________

10.- For how long has the participant been in a bilingual school?

_______________________________________________________________________________

_______________________________________________________________________________

_________________________________________________________________________

11.- What is the main language or languages spoken at home?

_______________________________________________________________________

12. Using the chart below, please indicate the number of hours the participant is exposed to English in an average day for each area.

| | 30 min to 1 hour | 2 to 3 hours | 4 to 5 hours | 6 to 7 hours | 8 hours or more |
|---|---|---|---|---|---|
| TV | | | | | |
| School | | | | | |
| Homework | | | | | |
| Internet | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Home | | | | | |
| Extracurricular activities | | | | | |

____________________ _______________________

Researcher signature

Parent or Legal guardian signature

## Appendix 2: List of Stimuli

| Word | Length | Word | Length | Nonwords |
|---|---|---|---|---|
| Adult | 5 | Abajo | 5 | Aforteny |
| Apple | 5 | Arena | 5 | Ansomil |
| Chair | 5 | Brazo | 5 | Atanfo |
| Child | 5 | Bruja | 5 | Biman |
| Clean | 5 | Calle | 5 | Borten |
| Colour | 5 | Cielo | 5 | Corcils |
| Green | 5 | Cisne | 5 | crenta |
| Horse | 5 | Danza | 5 | Cuminon |
| House | 5 | Dedos | 5 | Danomor |
| Lunch | 5 | Falda | 5 | dather |
| Music | 5 | Libro | 5 | Durten |
| Night | 5 | Mosca | 5 | Durtery |
| Smile | 5 | Negro | 5 | Hendor |
| Table | 5 | Perro | 5 | Hufter |
| Water | 5 | Plato | 5 | ilmantu |
| White | 5 | Silla | 5 | jonmel |
| autumn | 6 | Verde | 5 | Komron |
| banana | 6 | Vela | 5 | Krauf |
| Circle | 6 | Alumno | 6 | Lomins |
| father | 6 | Cabeza | 6 | Mesilke |
| monkey | 6 | Cables | 6 | Minton |
| mother | 6 | Cuello | 6 | Mirtons |
| number | 6 | Esfera | 6 | monko |
| orange | 6 | Flores | 6 | mornai |
| potato | 6 | Fresas | 6 | Nedert |
| purple | 6 | Hablar | 6 | niron |
| rabbit | 6 | Helado | 6 | nurmen |
| Sister | 6 | Llegar | 6 | Omlos |
| Spring | 6 | Lluvia | 6 | Ovonel |
| summer | 6 | Pelota | 6 | panery |
| tomato | 6 | Pierna | 6 | pather |
| winter | 6 | Verano | 6 | Pildon |
| animals | 7 | Volver | 6 | Porten |
| brother | 7 | Armario | 7 | rakir |
| chicken | 7 | Bandera | 7 | ramrod |
| example | 7 | Botella | 7 | refigo |
| friends | 7 | Celeste | 7 | Roleti |
| history | 7 | Galleta | 7 | sernal |
| holiday | 7 | Gallina | 7 | shent |
| kitchen | 7 | Hermana | 7 | shough |

| | | | | |
|---|---|---|---|---|
| library | 7 | Invierno | 7 | Sinton |
| monster | 7 | Lechuga | 7 | slamen |
| penguin | 7 | Mochila | 7 | subarto |
| silence | 7 | Naranja | 7 | Sumol |
| stomach | 7 | Rodilla | 7 | Telerone |
| student | 7 | Tostada | 7 | Tipsol |
| uniform | 7 | Ventana | 7 | Unrel |
| volcano | 7 | Violeta | 7 | Vifturt |
| | | | | |
| | | | | |