L1 and L2 lexical form activation during L3 word processing: Do beginner learners translate into Chinese or English when reading Hungarian?

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Abstract

In today's globalized world, multilingualism is increasingly common, presenting unique challenges for language processing and learning. This study investigates cross-language activation in Chinese-English-Hungarian trilinguals, focusing on whether lexical forms of L1 (Chinese) and L2 (English) are activated during L3 (Hungarian) word processing. Utilizing a quantitative approach, 32 Hungarian-major Chinese students participated in a lexical decision task, followed by proficiency tests and questionnaires. The participants were unaware that some of the Hungarian word pairs had concealed repetition if translated into Chinese or English. This study utilized a combination of paired t-tests, correlation analyses, and regression models to analyze the reaction time, error rates, and proficiency test scores collected from the participants. The results indicated significant activation of both L1 and L2, reflected in higher error rates and longer reaction times when Hungarian word pairs had hidden repetitions in their Chinese or English translations compared to control pairs. L1 also seemed to interfere more with L3 processing, resulting in significantly higher error rates than L2. Additionally, higher proficiency in Hungarian showed mitigating effects of L3 proficiency on cross-language interference. The study's findings extend the Bilingual Interactive Activation (BIA) model to a trilingual context, suggesting non-selective access to multilingual lexicons and emphasizing the complexity of managing multiple linguistic systems. These insights have significant theoretical implications for understanding multilingual language processing and practical applications in developing more effective language teaching strategies that account for cross-language interference.

Introduction

In today's globalized world, multilingualism has become increasingly prevalent. Many individuals have to process multiple languages in their everyday lives. Understanding how multilingual individuals process and manage multiple languages is a central question in psycholinguistics (Schwieter, 2015).

Cross-language activation is rarely defined in the literature. Hoshino and Thierry (2011) described cross-language activation as a phenomenon of lexical alternatives from both languages being active in proficient bilinguals' speech planning process. Previous research has extensively explored cross-language activation in bilinguals (e.g., Brysbaert et al., 1999; Colomé, 2001; Hermans et al., 1998). These research have revealed that both target and non-target languages are often activated simultaneously. McClelland and Rumelhart (1981) proposed that bilingual processing involves non-selective access; this suggests that bilingual word recognition involves the simultaneous activation of both languages, with words from both languages competing for selection. This model served as a foundation of bilingual activation research and it has been supported by numerous studies. For example, Thierry and Wu (2007, 2010) used event-related potentials (ERPs) to show that Chinese-English bilinguals activated Chinese translations of English words unconsciously, indicating nonselective access. Likewise, Marian and Spivey (2003) used eye-tracking to reveal that Russian-English bilinguals showed cross-language activation effects during a visual world paradigm task, with participants' eye movements indicating simultaneous activation of both languages. These studies indicate that bilinguals cannot selectively process one language without activating the other.

Phonological and orthographic activation are critical components of cross-language activation. Phonological activation refers to the activation of sound representations of words, while orthographic activation refers to the activation of written or visual representations of words. Bilinguals have been found to activate phonological representations from both their L1 and L2 during language processing tasks, suggesting that phonological processing is nonselective (Jared & Kroll, 2001;

Marian & Spivey, 2003). Similarly, orthographic activation also occurs nonselectively in bilinguals. For instance, studies by Van Heuven et al. (1998) and Dijkstra et al. (1999) found that bilinguals activated orthographic representations from both languages when reading words that were orthographically similar across languages.

While there is substantial literature on bilingual language processing, research on trilingualism and cross-language activation involving three languages remains relatively scarce. Trilingualism introduces additional complexity, as individuals must manage interactions between three linguistic systems instead of two. The cognitive load and potential influence from L1 or L2 are presumably higher in trilinguals, making it crucial to investigate how these individuals navigate multiple language activations. Research on trilingualism, such as studies by De Angelis (2007) and Poarch and Van Hell (2012), suggests that trilinguals experience similar cross-language activation effects as bilinguals but with added complexity. De Angelis (2007) found that trilingual individuals often transfer lexical and syntactic structures from one non-native language to another, indicating that all three languages are active during L3 language processing. Poarch and Van Hell (2012) demonstrated that trilingual children showed cross-language influence in a picture naming task, with the degree of influence varying depending on language proficiency and usage patterns. Specifically, they employed a picture naming task in which the cognate status of the words—whether the words were cognates or non-cognates across the languages—was manipulated. Poarch and Van Hell observed a significant cognate facilitation effect (i.e., cognates are named faster and more accurately than noncognates because of their similar form and meaning across languages) in both L1 and L2 from L3 for the trilingual children. The interference was stronger in the less dominant language (L2), reflecting greater cross-language activation when the language being processed is less proficient or dominant.

Given the unique challenges posed by trilingualism, it is essential to explore how trilingual individuals manage cross-language activation and whether the principles of nonselective access observed in bilinguals extend to trilinguals. Understanding cross-language activation in trilingual individuals has significant implications for both theoretical and practical perspectives. Theoretically, this research contributes to our knowledge of multilingual language processing and the cognitive mechanisms that underlie it. By extending the principles of nonselective access from bilinguals to trilinguals, this study enhances our understanding of how multiple languages are managed simultaneously in the brain.

Practically, the findings of this study can inform language teaching and learning strategies. For educators and language learners, understanding the dynamics of cross-language activation can help develop more effective teaching methods that account for the potential for interference and the need for strategies to manage multiple languages. Additionally, insights from this research can inform clinical practices for diagnosing and treating language-related disorders in multilingual individuals.

By investigating cross-language activation in trilingual individuals, this dissertation aims to contribute to the growing body of knowledge on multilingual language processing and provide insights that can benefit both theoretical understanding and practical applications in education settings. This dissertation aims to investigate cross-language activation in Chinese-English-Hungarian trilinguals. Given the typological distance and script differences between these languages, this study provides a unique opportunity to examine how multilinguals navigate their linguistic repertoire and manage cross-language interference.

This dissertation is organized into several chapters. The current introductory chapter provides an overview of the research background and objectives. Chapter 2 reviews the relevant literature on cross-language influence and activation, highlighting key theories and empirical findings. The subsequent Methodology chapter details the experimental procedures, including participant selection, materials used, experimental design, and norming procedures. Chapter 4 presents the results of the experiment, including detailed analyses of behavioral data. Chapter 5 discusses these findings in the context of the research questions and the existing literature. The next chapter addresses the limitations of the study and suggests directions for future research. The dissertation concludes with the final chapter.

Literature Review

This chapter will first explore the theoretical models and empirical evidence surrounding cross-language activation. The chapter then delves into evidence for cross-language activation and inhibition, examining the dynamic nature of bilingual processing. Subsequent sections discuss evidence of cross-language phonological and form activation, the impact of different scripts, and other variables like proficiency and age of acquisition. Finally, it outlines the research paradigms and outcome measures used in activation studies, setting the stage for the significance and aims of the current research. The chapter concludes by presenting three research questions along with their corresponding predictions.

1 Theoretical Models of Lexical Access

The BIA (Bilingual Interactive Activation) model was first proposed by McClelland and Rumelhart (1981). BIA posits that bilingual word recognition involves simultaneous activation of both languages, with words competing until the correct one is selected (Sunderman & Kroll, 2006). This model supports the idea of nonselective access in bilinguals. According to the BIA model, lexical activation spreads from orthographic and phonological representations to semantic representations in both languages. In other words, the BIA model proposes that during the processing of lexical items, whether in L1 or L2, related sounds and forms in both languages will be activated. For example, for English-German bilinguals, seeing the word “cat” would activate *Katze*, which is “cat” in German. The BIA model suggests that other English and German words that share similar orthographic or phonological features will also be activated, such as “cut” or “can” in English and *Kanne* in German. The BIA model has been supported by numerous studies (e.g., Sunderman & Kroll, 2006) where bilingual has been observed to activate nontarget language.

The dual-route theory, proposed by Frost (1998), suggests that both orthographic and phonological information play roles in lexical access. The dual-route theory posits two distinct pathways for word recognition: a direct lexical route involving visual properties of the words and an indirect sublexical route involving phonological recoding. The theory emphasizes the importance of both routes in managing cross-language activation and interference. Under the view, both sound and form properties will be activated during word processing in bilinguals.

Levelt and colleagues' (1999) theory of lexical access in speech production addressed the process of lexical selection. They believed that lexical items are competing, and the most active one will be chosen for further processing. This model could also be used in a bilingual processing scenario, where competition could involve interference from phonologically or orthographically similar words from the L1 or L2. Access to lexical items can be facilitated or inhibited based on their activation levels and the presence of related or competing items.

The BIA model, dual-route theory, and Levelt's theory of lexical access each contribute unique insights into the understanding of bilingual lexical processing. The BIA model discusses the nonselective access and simultaneous activation of both languages, providing a robust framework for studying bilingual processing. The dual-route theory offers a detailed account of the pathways involved in word recognition, emphasizing the roles of orthographic and phonological information. Levelt's model adds an important perspective on the competitive nature of lexical selection, particularly in speech production. Together, these models highlight the complexity of bilingual lexical access, illustrating how multiple representations and pathways interact and compete during language processing.

Regarding trilinguals, a model that has been widely used in trilingual processing research is the Inhibitory Control Model by Green (1998). Although it was designed to explain how bilinguals manage and control their two language systems, it has been extended into trilingual settings (e.g., Linck et al., 2012). The model is based on the principle that multiple levels of control are required to inhibit potential competitors for production at the lemma level, using language tags to differentiate between languages. Adapted to the L3 processing context, the model suggests that trilinguals, like bilinguals, need to inhibit the languages not in use to focus on the target language (Madrazo & Bernardo, 2018). While bilinguals manage interference between two languages, trilinguals must regulate three linguistic systems, potentially leading to even more enhanced inhibitory control. Madrazo and Bernardo's (2018) experiment with Filipino-English bilinguals and Chabacano-Filipino-English trilinguals confirmed this idea. The results of a cognitive control task they conducted indicated that trilinguals were more accurate and efficient than bilinguals in trials involving interference suppression and response inhibition, suggesting enhanced inhibitory control among trilinguals.

2 Evidence for Cross-Language Activation and Inhibition

As mentioned before, cross-language activation can be a phenomenon of lexical items from multiple languages being active in bilinguals' speech planning process (Hoshino & Thierry, 2011). This implies that not only the target language will be activated during language processing, the non-target language also gets activated. Evidence of nontarget language activation has been found during various types of language processing tasks, such as reading (e.g., Dijkstra et al., 1999, 2000) and speech production (e.g., Colome, 2001). These studies suggest that bilinguals activate both languages, even when only one is being used, leading to cross-language interactions.

As a matter of fact, the nature of bilingual language processing is dynamic. Grosjean and Li (2013) proposed that bilinguals have dynamic activation states because they usually operate along a continuum from a monolingual mode to a bilingual mode. This continuum affects how bilinguals process language, depending on the context and task demands. In a monolingual mode, bilinguals might minimize cross-language activation, while in a bilingual mode, both languages might be more active. Grosjean and Li (2013) also discussed the factors influencing the level of language activation. These factors can be language proficiency (e.g., dominant or non-dominant status), general context (e.g., bilingual environment, laboratory context), interlocutors (e.g., bilingual speakers, bilingual experimenters), task (e.g., decision task, recognition task), topic and stimuli (e.g., whether the stimuli containing cognates or homophones, etc.). For example, Hermans et al. (2011) conducted a phoneme monitoring experiment in which Dutch participants were asked to decide if a phoneme was part of the English name of a picture. For instance, participants were shown a picture of a bottle and asked to determine whether the phonemes /b/ and /t/ were part of the word depicted (in this case, "bottle" contains both /b/ and /t/). Conversely, the phoneme /f/ was also presented but served as a distractor, reflecting its presence in the Dutch word for bottle, *fles*. Reaction time and accuracy were measured. They conducted several experiments with different stimulus lists, which varied in the number of cognates included. The researchers found that the bilinguals' language activation states varied based on contextual factors like stimulus list composition. Specifically, they noted that when the list contained a higher proportion of cognates, language activation was more pronounced, as evidenced by slower reaction times and decreased accuracy. This experiment highlights the importance of stimuli as a factor influencing cross-language activation.

This dynamic nature of bilingual language processing is further supported by numerous studies highlighting the nonselective activation of both target and non-target languages. Several studies have supported a language nonselective view for bilingual processing (e.g., Colomé, 2001; De Groot et al., 2000; Dijkstra et al., 1999), indicating that activation could appear in both target and non-target languages. Homograph studies constitute a significant portion of research in this field. Homographs, which have the same spelling but different meanings in two languages, provide a unique challenge for bilinguals. For instance, De Groot and colleagues' (2000) research on interlexical homographs showed that bilinguals cannot selectively process one language without activating the other. The processing of these words often results in increased reaction times and error rates, indicating that both language systems are active.

Lemhöfer et al. (2004) extended the bilingual nonselective access model to a trilingual context, suggesting trilinguals also coactivate all three languages during processing. The results of their experiment confirmed that Dutch-English-German trilinguals do coactivate all three languages during German lexical decision tasks, suggesting that similar mechanisms of non-selective access and cross-language activation apply to individuals who speak more than two languages.

However, the language nonselective model is not the only voice in this domain. Some researchers proposed a language selective view, suggesting that languages are independent during processing (Gerard & Scarborough, 1989; Scarborough et al., 1984). They proposed that bilinguals could process the L2 independently of the L1. According to this perspective, lexical information is stored in language-specific lexicons, thus allowing for processing the L2 to be free from interference from L1. However, whether this model can be extended beyond two languages remains to be explored. This view has been widely critiqued. For example, studies by Thierry and Wu (2004, 2007) and Wu and Thierry (2010) indicated that L1 interference is inevitable during L2 processing, supporting the view of nonselective access where both languages are activated simultaneously. They suggest that complete independence from the L1 is rarely possible.

A concept has been raised to understand how bilinguals manage interference from L1, which is bilingual L1 inhibition. Bilingual L1 inhibition refers to the cognitive process where bilingual individuals suppress or inhibit their L1 to facilitate the use of their L2. The extent to which bilinguals can inhibit their L1 during L2 processing has been a subject of debate. Using ERP and functional magnetic resonance imaging (fMRI), Rodriguez-Fornells et al. (2002) found that bilinguals could suppress L1 interference when processing L2. Their study showed that words from L1 were rejected before the processing stage in L2. Dijkstra and colleagues' (2000) experiment suggested that bilinguals were only able to suppress their L1 to a certain extent when processing an L2. This phenomenon was observed through various experimental paradigms, such as lexical decision tasks (Rodriguez-Fornells et al., 2002) and word naming tasks (Colomé, 2001), which show that bilinguals cannot completely suppress the non-target language.

3 Phonological Activation

One of the aspects that might cause cross-language influence (whether it is facilitation or interference) from non-target language to target language during processing is phonology. Phonology plays a crucial role in bilingual language comprehension and production. Frost (1998) argued that it is mandatory to activate phonology during language processing. He believed that phonological recoding is automatic and essential. The activation of phonological representations from both L1 and L2 during language tasks has been a significant focus of research, leading to varied findings.

First of all, studies have identified positive effects of phonology activation on language processing. Some experiments showed that L1 phonology could facilitate L2 processing (Brysbaert et al., 1999; Hermans et al., 1998). Brysbaert and colleagues (1999) conducted an interlingual phonological priming experiment with Dutch-French bilinguals, where primes from one language (Dutch) were used to influence target word recognition in another language (French). Priming refers to exposing one stimulus that influences the response to a subsequent stimulus, without giving conscious guidance or intention. Results showed that Dutch homophonic primes facilitated French word recognition in bilinguals, demonstrating the facilitative effects of L1 phonology during L2 processing. Similarly, Hermans et al. (1998) also found that phonologically related stimuli in L1 facilitated the L2 processing.

Conversely, Dijkstra et al. (1999) reported negative effects of phonology activation (phonology interference) on language processing. This interference arises when phonologically similar words in L1 and L2 compete for selection, thereby exhibiting inhibitory effects of L1 phonology on L2 processing. For example, this inhibitory effect was found in Dutch-English bilinguals (Dijkstra et al., 1999). Dijkstra and colleagues used words that had phonological and/or semantic overlaps in their materials. As an illustration, the word *hotel* retains the same meaning and phonological form in both English and Dutch; conversely, the word *step* means "scooter" in Dutch, presenting an overlap in phonological form, but not in semantics. Reaction time and accuracy of word recognition tasks were measured. Data from the experiment showed that words with phonological overlaps resulted in slower reaction times. They argued that the slower reaction was because phonological overlaps caused competition between phonological representations in the target and nontarget languages.

Finally, some studies, such as Wu and Thierry's (2010), have detected the activation of L1 phonology without pinpointing its specific effects. Additionally, this study is notable for its inclusion of a non-alphabetic language. The challenge with alphabetic languages is that phonological and orthographic forms are difficult to distinguish. This issue can be somewhat mitigated by employing non-alphabetic languages, such as Chinese, which benefit from the presence of polyphonic characters[1]. Wu and Thierry (2010) administered an implicit priming paradigm with Chinese-English bilinguals. The participants had to judge whether a series of English word pairs were related in meaning. However, they were unaware that the English word pairs concealed a sound or a spelling (form of Chinese characters) repetition if translated into Chinese. To illustrate, the English word pair *experience-surprise* contains the sound repetition of *Jing* in their Chinese translations (*经验 Jing yan-惊讶 Jing ya*); similarly, the word pair *accountant-conference* features a spelling repetition of 会 when translated into Chinese (*会计 Kuai ji-会议 Hui yi*). This approach allows for the separate investigation of orthographic and phonological forms. If there were any effects with the words that concealed sound/spelling repetition in Chinese, it would mean that the participants implicitly accessed their L1. Wu and Thierry (2010) collected ERP data, as well as the participants' reaction times and error rates. The ERP data suggested that there was a difference with word pairs concealing sound repetitions, but not word pairs concealing spelling repetition. The behavioral data (reaction time and error rate) did not show any effects. The authors

[1] In Chinese, a polyphone (多音字) refers to a character that has multiple pronunciations. Unlike English words that typically have one dominant pronunciation, pronunciations of Chinese characters can vary based on context or usage. For example, the character 发 can be pronounced as *fā* or *fà* depending on whether it means "to send out" or "hair".

concluded that this was due to the unconscious nature of processing. In other words, they believed that the participants were not conscious of activating their L1 (Chinese), therefore, behavioral data were not significant. The findings suggest that L2 processing activates sound, but not spelling in the L1. Similar findings can also be seen in Thierry and Wu's work in 2007.

4 Orthographic Representation Activation

Another aspect that may cause influence from non-target language to target language during processing is non-target language orthographic representations. Although findings are varied and the evidence is mixed in terms of the impact of L1 phonology on L2 processing, it is clear that all studies agree that L1 phonological representations are activated during L2 processing. However, the same doesn't hold for L1 orthographic representations. One example is from Wu & Thierry's (2010) experiment, also referenced in the previous section, demonstrates this phenomenon. As mentioned before, they found evidence of accessing L1 phonology during L2 processing, but not L1 orthography. Specifically, the English word pairs concealing spelling repetition in their Chinese translation did not result in different ERP data compared with other word pairs. This indicates that L1 orthographic forms were not activated during the process.

Contrary to Wu and Thierry's (2010) conclusion that L1 orthographic representations are not activated, another study found that L1 orthographic representations are not only activated but also exert negative effects on L2 processing. Sunderman and Kroll (2006) discovered significant inhibitory effects of translation-related form pairs in low-proficiency learners. To illustrate translation-related form pairs, consider *Cara-Fact/Cara-Fast*. In Spanish, *cara* means *face*. In this example, the pairs *Cara-Fact/Cara-Fast* are considered translation-related from pairs because *fact* and *fast* are close to *face* in form, the English translation of *cara*. In their experiment, English-Spanish bilinguals completed translation recognition tasks, in which they decided whether the two words (one in each language) were translation equivalents. They were tested on their reaction times and error rates. The less proficient bilinguals in their experiment had slower reaction times and higher error rates when processing translation-related form pairs, whereas the more proficient bilinguals did not appear to be affected by these form pairs.

Besides inhibitory effects, facilitative effects of orthographic representations in L1 on L2 processing have also been reported in the literature. For example, studies on cognates and homographs by Dijkstra et al. (1999) showed that orthographic and semantic overlaps facilitate processing. To be more specific, the presence of overlaps in orthographic form yielded faster reaction times and higher accuracy rates, suggesting that Dutch-English bilinguals benefit from shared forms across their languages.

5 Activation Across Different Scripts

As shown by a number of studies, shared orthographies/forms between L1 and L2 could play a facilitative role in bilingual processing (e.g., Dijkstra et al., 1999). What about languages with different scripts?

Studies with Korean-English bilinguals (Choi et al., 2010), Japanese-English bilinguals (Miwa et al., 2014), and Chinese-English bilinguals (Thierry & Wu, 2007) have shown evidence of cross-language phonological and semantic influences during word processing tasks. Research suggests that this activation is stronger in the L1-to-L2 direction (Gollan et al., 1997; Dimitropoulou et al., 2011). For example, Gollan et al. (1997) conducted a masked translation priming task with orthographic primes with Hebrew (L1) and English (L2) learners. They found that facilitation only appeared in the L1-to-L2 direction (which was using Hebrew primes in English processing tasks). They believed this result was due to an overreliance on sound in L2 reading, suggesting that participants may tend to pronounce the words, either aloud or silently, when reading in their second language. Dimitropoulou et al. (2011) also found facilitation only in the L1-to-L2 direction with low proficiency and late Greek-Spanish bilinguals. Duyck and Warlop (2009) were one of the few studies that demonstrated facilitation in L2-to-L1 direction. However, their study did not involve cross-script languages. They recruited unbalanced Dutch-French bilinguals living in an L1-dominant environment to complete a lexical decision task. They attributed the results to the strong mappings between L2 word form and semantic representations. Since the bilinguals had strong enough form-to-meaning mappings in their L2 to activate the words' semantics, L1 processing was facilitated. Stronger mappings can be developed as learner becomes more proficient and their knowledge becomes more automatized. Similarly, Helms-Park and Dronjic (2016) argued for an orthographic threshold; specifically, they suggested that in order for learners to experience facilitation effects or benefit from their L1 during L2 processing, there is a certain proficiency level that they should reach. However, this idea remains to be confirmed empirically.

Besides literature addressing the direction of cross-language activation, the non-selective view remains valid in research involving cross-script languages. Jiang discussed the nonselective access under the context of languages with different scripts in his commentary in 2019. He argued for a phonology-based coactivation by pointing out that there may be an integrated system of phonological representations. Under this view, similar phonetic categories across different languages can lead to coactivation. For example, if a Chinese-English bilingual encounters the English word "cat" (pronounced /kæt/) may activate the Chinese character 咖 (pronounced /kā/), which has a similar initial phonetic sound. This phonological similarity can lead to coactivation, even though the meaning and the orthographic systems of English and Chinese are entirely different.

In a trilingual context, Poarch and Van Hell (2014) conducted a study with three groups of trilinguals: German–English–Dutch, Dutch-English–German, and Russian–English–German trilinguals. They discovered that Russian phonology was activated when participants processed other languages, regardless of the differences in the writing systems of Russian. This provided strong evidence for cross-language and cross-script activation in trilingual contexts.

In conclusion, while shared orthographies and forms between L1 and L2 have been shown to facilitate bilingual processing, languages with different scripts also exhibit cross-language phonological and semantic influences, particularly in the L1-

to-L2 direction. Poarch and Van Hell’s (2014) study extends the activation study into a trilingual area, showing that phonological activation can occur across all three languages. Studies involving languages with different scripts also support the non-selective nature of language processing, suggesting an integrated system of phonological representations.

6 Other Variables Affecting Activation

In Sunderman and Kroll's (2006) study, mentioned above, the performance of two groups of native English speakers with varying proficiency in Spanish was compared on a translation recognition task. It was that proficiency had an impact on the outcomes, with less proficient bilinguals demonstrating slower reaction times and higher error rates when dealing with translation-related form pairs (e.g., cara-fact). Moreover, more proficient learners showed virtually no interference from form-related translation distractors while less proficient learners did. Based on their findings, the authors used the Revised Hierarchical Model (RHM) as an attempt to explain the influence of proficiency. The RHM “captures the interlanguage connections between lexical and conceptual representations as learners become more proficient in the L2” (Sunderman & Kroll, 2006, p.392). The RHM model was proposed by Kroll and Stewart (1994), focusing on word-to-concept mappings rather than the dynamics of lexical recognition during language processing. According to the RHM, L1-meaning connections are strong in the early stages of learning, while L2-meaning connections are rather weak. As their proficiency in L2 increases, bilinguals develop stronger direct connections between L2 words and their meanings, reducing their dependence on L1 translations. In other words, the RHM model posits that bilinguals initially rely on L1 meanings for L2 words, but gradually build direct L2-to-meaning connections as their proficiency grows. The study by Duyck and Warlop (2009), mentioned above, also underscores the role of proficiency. It suggests that as L2 proficiency increases, form-to-meaning mappings strengthen, thereby facilitating L1 processing. Festman (2008) investigated the role of proficiency in a trilingual context. They found that lower proficiency learners experience more interference, directed from the stronger language to the weaker languages. In Festman's (2008) case, German (L1) experienced the least interference, while French (L3) experienced the most, from both L1 and L2 (English). These findings all indicate that proficiency plays a crucial role in managing cross-language interference. Another aspect that could affect activation is the age of acquisition. Poarch and Van Hell's (2012) study with various groups of bilingual and trilingual children found that activation was not only modulated by proficiency, age of acquisition also impacted activation levels of lexical items in both the dominant and nondominant languages. Children who acquired their L2 at an earlier age showed higher levels of cross-language activation. Specifically, more balanced bilinguals and trilinguals exhibited significant cognate facilitation effects in both their dominant and nondominant languages, unlike L2 learners who displayed this effect only in their nondominant language. This suggests that earlier exposure could enhance the coactivation of languages during lexical retrieval. There is also evidence, albeit limited, indicating that the age of acquisition may play a more significant role than proficiency. Neuroimaging data from trilinguals doing semantic categorization tasks suggest that the mechanism of trilinguals' language control during processing depended more on age of acquisition or language exposure, rather than proficiency (Hut et al., 2017).

7 Paradigms and Outcome Measures

To thoroughly understand cross-language activation and its implications, various experimental paradigms and outcome measures have been employed. This section summarizes the methodologies used to investigate lexical activation in bilinguals.

A widely used task in activation studies is the masked priming paradigm. This paradigm involves presenting a prime word very briefly, followed by a mask and then the target word. This technique allows researchers to examine automatic and unconscious lexical activation without participants being aware of the prime. It provides insights into the early stages of lexical processing and the extent of cross-language activation. This method avoids creating an artificial bilingual context, especially compared with overt translation tasks, where bilingual participants translate from L1 to L2 or from L2 to L1 (e.g., De Groot & Hoeks,1995), and cross-language priming, where participants are aware of the stimuli word list being bilingual (e.g., Dijkstra et al., 2000). Thierry and Wu (2007) also concluded that the mixing stimuli from both languages of these tasks will create an artificial bilingual environment for the participants. This raises questions about whether cross-language activation is spontaneous or induced by the stimuli, potentially leading to biased outcomes. Hence, the importance of designing monolingual tasks is emphasized to minimize such biases. The masked priming paradigm can be considered functionally monolingual since the participants are not quite aware of the prime.

Most studies examine ERPs, reaction times, and error rates as the outcome variables of cross-language activation experiments. ERPs can "provide a continuous account of brain activity time-locked to an external stimulus" (Thierry & Wu, 2007, p. 1230,). ERP studies have shown that cross-language activation can modulate brain potentials and have provided a neurophysiological basis for understanding bilingual lexical activation.

Reaction times and error rates are also widely used as behavioral data to assess cross-language interference and facilitation (e.g., Sunderman & Kroll, 2006; Wu & Thierry, 2010). These metrics are crucial for quantifying the effects of cross-language activation during processing. Studies that measure activation usually compare these metrics to see if there is any interference. The logic is that if the processing is language selective, bilinguals should not be sensitive to the words involving cross-language activation (Helms-Park & Dronjic, 2016; Sunderman & Kroll, 2006).

8 Significance of the Research

The significance of this research is multifaceted and builds upon existing literature to provide new insights into several areas. First of all, the linguistic diversity among Chinese, English, and Hungarian enhances the research's value. Chinese, English, and Hungarian are very distant languages from each other. Chinese is orthographically different, and all three languages are in different language families. Previous studies mostly focused on relatively close languages (i.e., the same writing system or in the same language family). Many studies focused on European languages with the same script and similar grapheme-phoneme correspondences. As a result, “the relative contribution of spelling and sound in cross-language interactions is difficult to tease apart” (Wu & Thierry, 2010, p. 7646). Wu and Thierry (2010) also discussed that doing research in English and Chinese could dissociate sound and form, which previous studies failed to do because of the intrinsic link between spelling and sound in alphabetic writing systems. They also called for more research among cross-script languages. Answering this call, this study will be investigating languages with different writing systems, language families, and typologically distant.

Secondly, Hungarian is an understudied language despite its interesting linguistic characteristics, such as its agglutinative structure and extensive vowel harmony. This study aims to provide insights into cross-language activation involving this less-studied language, thereby contributing to a broader understanding of linguistic processing in atypical language pairs.

Thirdly, research involving trilinguals in this field is relatively scarce. Most existing studies on cross-language activation focus on bilinguals. Exploring trilingualism is crucial for determining whether the mechanisms of language activation and interference in trilinguals mirror those observed in bilinguals, or if they exhibit unique patterns due to the additional language system. More research is needed to clarify these dynamics, making this study's contribution potentially significant in expanding our understanding of multilingual cognitive processes.

In terms of task design, this study will use the implicit priming paradigm, which will create a monolingual environment, so that the activation is spontaneous. Like Wu and Thierry (2010), who also used the implicit priming paradigm, the upside of this design is that it doesn’t create an artificial bilingual context. A lot of previous studies use stimuli from two languages (e.g., Sunderman & Kroll, 2006), creating a bilingual context. Bilinguals are more likely to activate both of their languages in this context, potentially resulting in biased outcomes.

9 Aims, Research Questions and Predictions

Considering the points discussed in the previous section, the research questions of this study are designed to address the identified gaps in the current literature. This study not only examines the cognitive processes underlying multilingual language activation in a typologically diverse context but also explores whether the activation of L1 and L2 manifests differently in terms of reaction times and error rates, providing insights into the relative influence of each language on L3 processing. Additionally, it aims to clarify the role of language proficiency in managing cross-language interactions. Specifically, this research investigates the cognitive processes involved in the activation of the first language (L1), second language (L2), and third language (L3) during L3 word processing, focusing on how beginner multilinguals manage the interaction between Chinese (L1), English (L2), and Hungarian (L3). To address these questions, this study measures reaction time and error rates to capture the activation of languages, thus offering a comprehensive understanding of multilingual cognitive processing.

The research questions are stated as follows:

1. Are L1 (Chinese), and L2 (English) activated when processing L3 (Hungarian)?
2. Does L1 and L2 activation display different effects in terms of reaction times and error rates?
3. Does proficiency affect activation?

For research question 1, both L1 (Chinese) and L2 (English) are expected to be activated when processing L3 (Hungarian). Regarding research question 2, it is anticipated that the activation of L1 and L2 will result in different effects on reaction times and error rates, with potentially more pronounced interference from the more proficient language, which is Chinese. To be more specific, in scenarios where L1 is activated, higher error rates and longer reaction times are anticipated compared to scenarios where L2 is activated. In terms of research question 3, it is evident from the literature that proficiency plays a role in cross-language activation. In particular, participants' L2 and L3 proficiency levels are expected to influence their behavioral data.

Methodology

The study employs a quantitative approach through a designed experiment to investigate cross-language activation in Hungarian major Chinese students. This chapter includes detailed descriptions of the participants, the materials used, the experimental design, and the preliminary norming process to ensure the accuracy and clarity of the tasks.

1 Participants

The study included a total of 32 participants, comprising 7 males and 25 females. All of them were Hungarian major Chinese students studying in Chinese universities. All participants had previously studied English, as it is a mandatory subject in the Chinese education system. The participants' level of education in Hungarian was controlled to ensure they were beginners. Among them, 14 were first-year university students and 18 were second-year university students. All participants were above 18 years old, ranging from 18 to 22 years (M = 19.5, SD = 1.02). They had never been exposed to or learned Hungarian before entering university.

The recruitment criteria included three aspects: participants had to be adults, they had to be in their first or second year of learning Hungarian at the university and their first language had to be Chinese, with English as their second language and Hungarian as their third language. One of the objectives was to try to recruit people with lower proficiency levels in Hungarian. According to the Revised Hierarchical Model (RHM) mentioned above, beginners may have a stronger tendency to use their L1 to build word-meaning connections than advanced learners. The reason we recruited both first-year and second-year students was that most universities in China do not enroll Hungarian major students every year, but every few years. Therefore, there is a chance that a certain school only has second-year students and no first-year students in a Hungarian major.

Participants were recruited via personal connections. To incentivize participation, participants were offered the opportunity to enter a prize draw by providing their email addresses at the end of the experiment. The participants all gave written consent to take part in the experiment that was approved by the Central University Research Ethics Committee (CUREC) of the University of Oxford. The ethics reference number is [C1B-24TT-Educ-038]. A prize draw was offered to better incent the participants.

To determine the participants' proficiency level in both English and Hungarian, we first included some demographical questions and some questions about their language learning experience. (see Appendix C). Table 1 shows the data of the participants' language learning experience.

Table 1: Questions about language learning

Descriptive Statistics						
	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Hungarian learning time /months	2	24	14.56	1.153	6.52	42.512
Everyday learning time for Hungarian /hour	0.5	9	3.797	0.3205	1.8133	3.288
Everyday learning time for Hungarian outside of class /hour	0	3	1.281	0.1165	0.6591	0.434
English learning time /months	10	270	135.75	11.144	63.043	3974.387
Everyday learning time for English /hour	0	3	1.0516	0.12176	0.68879	0.474
Everyday learning time for English outside of class /hour	0	3	0.71353	0.109567	0.619803	0.384

2 Materials

Apart from the self-reported measures mentioned before, additional tasks were also included in both Hungarian and English to investigate their proficiency level on a more accurate level. The tasks are introduced below:

The *LexTALE*[2] (Lemhöfer & Broersma, 2012) is a quick vocabulary knowledge test for speakers of English as a second language. It only takes about 4 minutes to complete. The test is a good predictor of English vocabulary knowledge and it has also been shown to give a fair indication of general English proficiency (Lemhöfer & Broersma, 2012). The LexTALE consists of 60 trials of visual lexical decision tasks, in which test-takers have to decide whether the word on the screen is a word or a nonword.

The Hungarian Placement Test was adopted from an online Hungarian test[3]. The reason for selecting this test was its ability to assess learners across various proficiency levels. Moreover, it is both quick and easy to administer online. The Hungarian Placement Test consists of 50 single-choice questions, evaluating knowledge across different domains, including grammar, vocabulary, and usage.

The materials used for the Hungarian processing task consist of 45 items in Hungarian (see Appendix A): 15 items were Hungarian word pairs related in meaning (e.g., *orvos-beteg*, meaning "doctor-sick") and 30 items were Hungarian word pairs unrelated in meaning (e.g., *vonat-sonka*, meaning "train-ham"). The 15 related items acted as fillers in the experiment, which could prevent the participants from guessing that all word pairs were unrelated, thus inducing bias.

The 30 unrelated items were divided into 3 groups, with 10 items in each group. The word pairs in the first group were unrelated in meaning, but the Chinese translations of these Hungarian word pairs each contained one repeated Chinese character. For example, the Chinese translation of the Hungarian word pair *vonat-sonka* is *火车-火腿*, both containing the character *火*. Since Chinese has many

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2 www.lextale.com
3 https://hungarianlesson.eu/quiz/placement-test/

polyphonic characters, we specifically selected word pairs where the Chinese translations include orthographically and phonologically identical repeated characters for this group. For example, in the aforementioned word pair translation, the character 火 in both 火车 (*huǒchē*[4], meaning "train") and 火腿 (*huǒtuǐ*, meaning "ham") is pronounced the same, *huǒ*, and also written the same.

The second group also contained meaning-unrelated word pairs. What differentiated the second group from the first group was that the Hungarian words in the second group contained repetition in their English translation. For example, the English translation for the Hungarian word pair *tapasztalat – várakozás* is "experience - expectation". The repetition in the English translation refers to the part "expe-" in this case. These repetitions in the English translations contained at least one syllable of overlap, which was intended to be noticeable for participants should they translate the words into English.

The third group of items was the control group, which consisted of 10 random meaning-unrelated Hungarian word pairs. These word pairs did not contain any repetition in their Chinese or English translations (e.g., *alma- cipő*, meaning "apple-shoes"). The 45 items were presented in a random order in the experiment.

Since all participants were beginner-level learners of Hungarian, the words included in this experiment were all from A1-A2 levels. However, there can be significant differences in proficiency levels among first-year and second-year students. Therefore, we tried to select vocabulary that was as simple as possible to ensure that all participants, regardless of their year, could recognize the words. The corresponding English translations were also at a beginner level to accommodate participants with varying levels of English proficiency, ensuring that all could recognize the words. Another consideration for the Chinese/English translation of the Hungarian words was the uniqueness and accuracy. Ideally, each Hungarian word should correspond to a single Chinese or English translation to minimize ambiguity. This would enhance the clarity and consistency needed for the experiment.

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[4]*Huǒchē* is the Pin Yin form of 火车. Pin Yin is the alphabetic transposition of the Chinese character's phonological form.

Below is a demonstration of the three groups of unrelated word pairs (Table 2) and one group of related word pairs (fillers) (Table 3).

Table 2: Demonstration of unrelated word pair groups

unrelated (-)		
	repetition in Chinese translation (+)	no repetition in Chinese translation (-)
repetition in English translation (+)		**Group 2:** *tapasztalat --- várakozás* (HU) *经验 jing yan ---- 期待 qi dai* (CH) ***exper****ience* --- ***expec****tation* (EN)
no repetition in English translation (-)	**Group 1:** *Vonat --- sonka* (HU) *火车* ***Huo*** *che --- 火腿* ***Huo*** *tui* (CH) *Train --- ham* (EN)	**Group 3 (control group):** *lámpa – vonat* (HU) *灯 deng - 火车 huoche* (CH) *lamp – train* (EN)

Table 3: Demonstration of fillers (related word pairs)

related (+)
Fillers: *orvos – beteg* (HU) *医生 yi sheng - 生病的 sheng bing de* (CH) *doctor – sick* (EN)

3 Design

The experiment was set up on the online experiment platform Gorilla. The participants had to follow the instructions that appeared on the screen. The L3-processing main task in Hungarian was conducted first, followed by the strategy questionnaire in Chinese, the proficiency tests in English and Hungarian, and finally the demographic questionnaire in Chinese. This order was intended to prevent giving the participants clues about cross-language processing.

The main experiment consisted of the processing task and some follow-up questions. The task used an implicit priming paradigm, which was also used in Wu and Thierry's (2010) experiment. This paradigm involved using word pairs that concealed certain information in their translation and it can examine whether the bilingual participants activated L1 unconsciously while preventing an artificial bilingual environment. The task in the present study required participants to decide whether the words of the Hungarian word pair appearing on the screen were related. It is worth noting that participants could only see the word pairs in Hungarian without any Chinese or English translations on the screen. The "implicit" aspect of the design is that the character repetition in Chinese and repetition in English was concealed. The goal was to find out if the participants would notice this hidden factor and whether they would be affected by it. If they were affected, it would suggest that they activated language(s) besides Hungarian, i.e., translated the Hungarian word pairs into Chinese or English. Ideally, this would be reflected in their reaction times and their accuracy in the decision task. To minimize the time that the experiment took and to obtain more accurate reaction time data, participants could simply respond by pressing specific keys on their keyboard. Corresponding instructions and an example were given to help participants comprehend what they needed to do. Each word pair appeared for 5 seconds before moving on to the next one to prevent the participants from looking up the word. Setting a time limit could also prevent them from overthinking, since the experiment aimed to test an unconscious process. In order to prevent creating an artificial multilingual environment and giving clues on cross-language processing, the decision task appeared entirely in Hungarian, including the instructions and the examples. After the decision task, the participants were asked about whether they noticed the hidden relations between the word pairs (i.e., the hidden relations in their translation equivalents), and about the strategies they used and language activation state (see Appendix B). These questions were presented in Chinese and the participants could also give answers in Chinese.

The second part of the study investigated the participants' proficiency level as well as some demographic information. The second part began with the LexTALE, which assessed the English proficiency of the participants. Following this, the Hungarian Placement Test was administered to evaluate their proficiency in Hungarian. Following the administration of the two tests, participants were asked to complete a questionnaire regarding their background information and their language learning experiences in Hungarian and English, encompassing details such as duration of language study and daily time devoted to language learning (see Appendix C). The questionnaire was also presented in Chinese, and could be completed in Chinese as well.

4 Norming

Prior to the main experiment, a small-scale norming/piloting experiment was conducted to ensure the items were accurate and error-free. This experiment also aimed to assess the relatedness of the items (i.e., whether the items are determined as related or unrelated by Hungarian native speakers) and to evaluate the overall design of the experiment. A similar design that involved native speakers for norming can also be seen in Sunderman and Kroll's (2006) study, where the authors recruited 41 native English speakers to rate the similarity of their target words. 6 Hungarian native speakers were recruited for this purpose. Although their data were not analyzed statistically, they provided valuable feedback on the items and the experiment, which was documented and taken into consideration.

One of the main goals of this norming experiment was to assess whether it was easy to decide the relatedness of the 45 word pairs. According to the feedback of the 6 Hungarian native speakers, the relatedness was quite salient, the task was clear and the decision was also not hard to make. Their results also indicated a 100% accuracy rate, further demonstrating that the decision task was clear and that it was easy to determine the relatedness of the pairs. The potential issue with the word pairs concealing Chinese character repetition in translation is that such repetitions might inadvertently lead to semantic overlaps. Since Chinese characters are logograms—where each character directly conveys meaning—character overlaps are likely to result in meaning overlaps. However, in our study, we aimed to prevent semantic overlaps in Group 1, which is designated as the meaning-unrelated group. Therefore, word pairs in Group 1 were meticulously selected to ensure that their Chinese translations involved only character repetition, with no overlap in meaning. Therefore, the norming experiment also needed to examine whether this was achieved. The results of the norming experiment provided reassurance that the implicit manipulation in the Chinese translation of the word pairs did not affect the perceived relatedness of the Hungarian word pairs.

However, there were some word pairs that looked unrelated but might appear together in Hungarian collocations and therefore could cause confusion according to the participants' feedback. For example, *tanács-épít* (suggestion-build) falls under this category. In Hungarian, people could say *tanácsot építeni*, which means "to build a suggestion". However, these collocations are typically taught at more advanced stages. Since the participants of the experiment were all beginner Hungarian learners in their first or second year of college, it was deemed unlikely that they would be familiar with these collocations and get confused by them. Therefore, the items were not modified.

Another change that was made after the norming experiment was the language choice in the decision task. Originally, the whole task was presented in Hungarian, attempting to create a monolingual environment, without any clues of cross-language processing. However according to the feedback from the norming experiment, especially from an experienced teacher who had been teaching Hungarian in China, the Hungarian instructions would be confusing and difficult to comprehend for first- and second-year university students. According to this Hungarian teacher, Chinese instructions could help participants grasp the purpose of the task, while the bilingual example pages could act as a transition page, further helping participants adapt to the main task afterward. Since the aim of the instructions and example pages would be for students to understand the task and how it works, it was considered vital for them to fully understand what to do in the experiment. Hence, Chinese was added to the example pages for the main task along with Hungarian, and the instruction pages were fully translated into Chinese. The main task pages remained in Hungarian as an effort to maintain a relatively monolingual environment. See Figure 1 for an illustration of the example page.

A few suggestions for a clearer layout and design for the main task pages made by the pilot participants were also adopted. See Figure 2 for a demonstration of the final design. Furthermore, the time limit for each page in the main task was extended from 5 seconds to 8 seconds. Feedback from the norming experiment indicated that even native Hungarian speakers found the original time limit slightly rushed. Therefore, to provide Chinese participants with sufficient time for the decision task, the time limit was extended by 3 seconds.

Figure 1: Example page of the experiment

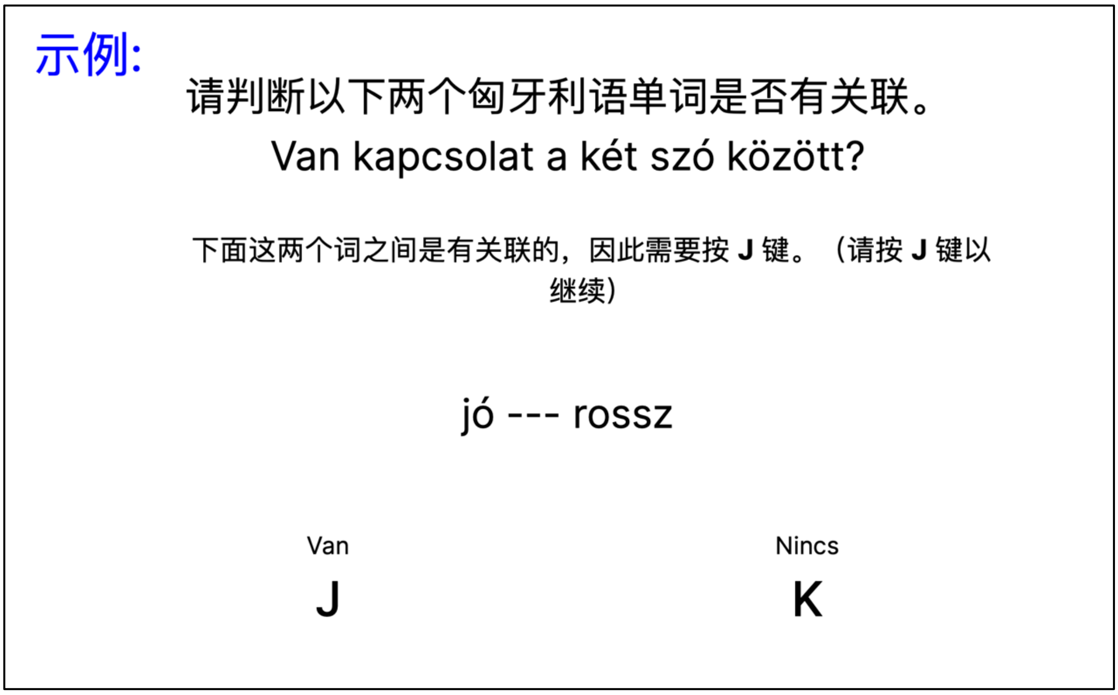

Figure 2: Task page illustration of the experiment

Results

This chapter presents the findings of the study, focusing on the analysis of data collected from the various tasks and questionnaires administered to the participants. Detailed statistical analyses, including paired t-tests, correlation analyses, and regression models, are used to interpret the data and draw conclusions about cross-language activation.

1 Data analysis

English proficiency was measured by LexTALE score. The LexTALE score is the percentage of correct responses, corrected for the unequal proportion of words and nonwords in the test by averaging the percentages correct for these two item types[5]. The calculation is shown as follows:

((number of words correct/40*100) + (number of nonwords correct/20*100)) / 2

Hungarian proficiency was assessed using the Hungarian Placement Test, which comprises 50 single-choice questions. To align the scoring with the LexTALE's full score of 100, each question in the Hungarian test was assigned a value of 2 points, ensuring that the full score is also 100. The correct answer was coded in the Gorilla design.

In the 45-word-pair Hungarian processing task, the correct responses for each task were also pre-coded in Gorilla. Error rates were calculated based on the number of wrong answers in Excel and recorded as a percentage. They were then manually categorized into Group 1, Group 2, and Group 3. Reaction times were automatically recorded in milliseconds by Gorilla and also manually categorized into these three groups. Recall that each group comprised 10 word pair tasks, with the remaining 15 tasks serving as fillers. Group 1 consisted of Hungarian word pairs that shared a repetitive element in their Chinese translations, Group 2 of Hungarian word pairs that shared a repetitive element in their English translations, and Group 3 served as the

[5] https://www.lextale.com/scoring.html

control, containing random meaning-unrelated Hungarian word pairs. It is also important to note that the three groups were word pairs unrelated in meaning while the fillers were related word pairs. The fillers are not scored and examined in this experiment.

Initial analysis indicated that most of the dependent variables, including the error rates, proficiency test scores, and reaction times, were normally distributed. Exceptions were found in Group 2 error rate (kurtosis = 3.948), Group 3 error rate (skewness = 2.405, kurtosis = 7.501), and total error rate (kurtosis = 2.521). An outlier affecting all three variables was identified and winsorized to the highest number within the normal distribution range, resulting in adjusted data that met normal distribution criteria (Field, 2018). The adjusted descriptive data are shown in Table 4.

Table 4: Adjusted descriptive data

	N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Group 1 error rate (%)	32	0	80	27.5	21.1
Group 2 error rate (%)	32	0	60	22.5	17.6
Group 3 error rate (%)	32	0	50	14.06	15.83
Total error rate (%)	32	6.67	48.89	25.21	10.46
Group 1 reaction time (ms)	32	160.3	8000.1	3448.2	1876.3
Group 2 reaction time (ms)	32	57.2	7999.8	3197.2	1837.2
Group 3 reaction time (ms)	32	13.9	7994.9	2862.8	1674.9
LexTALE (score out of 100)	32	37.5	67.5	50.43	7.42
Hungarian placement test (score out of 100)	32	38	85	64.38	13.42

1.1 Research question 1: Are the L1 (Chinese) and the L2 (English) activated when processing L3 (Hungarian)?

Paired t-tests were conducted comparing error rates and reaction times between Group 1 words and Group 3 words, and Group 2 words and Group 3 words. To correct for multiple comparisons, Bonferroni correction was manually applied. The new significant p-value threshold is .025.

To examine whether the L1 (Chinese) was activated, the reaction times and error rates of Group 1 and Group 3 were compared. In terms of error rate, Group 1 words yielded a significantly higher error rate (M = 27.5, SD= 21.1) compared to Group 3 ones (M = 14.06, SD= 15.8), $t(31)$= 5.24, $p < .001$, with a large effect size (d = .926). In terms of reaction time, Group 1 required a significantly longer reaction time (M = 3448.2, SD= 1876.3) compared to Group 3 (M = 2862.8, SD= 1674.9), $t(319)$= 4.76, $p < .001$, but this effect represented a small effect size (d = .266).

To examine whether the L2 (English) was activated, the reaction times and error rates of Group 2 and Group 3 were compared. In terms of error rate, Group 2 words also yielded a significantly higher error rate (M = 22.5, SD= 17.6) compared to Group 3 ones (M = 14.06, SD= 15.8), $t(31)$=3.26, p = .003, with a medium effect size (d = .577). In terms of reaction time, Group 2 also had a significantly longer reaction time (M = 3197.2, SD= 1837.2) compared to Group 3 (M = 2862.8, SD= 1674.9), $t(319)$= 2.86, p = .005, with a small effect size (d = .160).

These results indicate that participants made more errors and took more time to respond to word pairs in Groups 1 (Chinese translation) and Group 2 (English translation) compared to Group 3 (no translation). This suggests that word pairs with hidden repetitions in the L1 and the L2 translations (Groups 1 and 2) increase both error rates and reaction times. If the L1 and L2 were not activated during L3 word processing, the reaction times between Groups 1 and 3, and Groups 2 and 3, would be similar. Therefore, a longer reaction time in Group 1 compared to Group 3 implies that the L1 is activated, and a longer reaction time in Group 2 compared to Group 3 implies that the L2 is activated.

Given that the results in our data for Groups 1 and 2 differ significantly from Group 3 (the control group), it can be concluded that both L1 and L2 are activated during L3 processing. Moreover, this activation of L1 and L2 not only occurs but also inhibits decision task accuracy and increases decision-making time during L3 processing.

1.2 Research question 2: Does L1 (Chinese) and L2 (English) activation display any differences?

To determine differences in L1 and L2 activation, comparisons were made between Group 1 and Group 2 for both error rates and reaction times using paired t-tests.

Group 1 had a significantly higher error rate (M = 27.5, SD= 21.1) compared to Group 2 (M = 22.5, SD= 17.6), t(31)= 2.18, p = .037, with a small to medium effect size (d = .386). Group 1 did not have a significantly longer reaction time (M = 3448.2, SD= 1876.3) compared to Group 2 (M = 3197.2, SD= 1837.2), t(319)= 1.96, p = .051, with a small effect size (d = .110).

These findings indicate that L1 (Chinese) hidden repetitions result in higher error rate compared to L2 (English) hidden repetitions, though they do not significantly affect reaction times. This suggests that L1 (Chinese) activation has a greater inhibitory effect to some extent than L2 (English) activation during L3 processing, primarily reflected in the error rates.

1.3 Research question 3: Does proficiency affect activation?

A proficiency test was administered in both of the participants' languages: English Lextale (hereafter ENtest) and Hungarian placement test (hereafter HUtest). A correlation analysis was conducted to determine which variables (error rates and reaction times of the groups) correlated with the proficiency test scores. Results showed that the ENtest score had a positive significant correlation with Group 1 error rate, r(318)=.16, p=.01, and a negative significant correlation with total error rate, *r*(318)= -.18, *p*<.001. The HUtest score had a negative significant correlation with Group 1 reaction time, *r*(318)=-.13, *p*=.02, Group 3 reaction time, *r*(318)=-.16, *p*=.00, Group 1 error rate, *r*(318)=-.35, *p*<.001, Group 2 error rate, *r*(318)=-.16, *p*=.00, Group 3 error rate, *r*(318)=-.40, *p*<.001, and total error rate, *r*(318)=-.52, *p*<.001.

Group 1 error rate and total error rate were the only two variables that had a significant correlation with proficiency level in both languages. Whereas the total error rate had a negative significant correlation with the HUtest and the ENtest, Group 1 error rate only had a negative significant correlation with the HUtest but a positive one with EN test.

It can be concluded that higher English proficiency correlates with more errors in Group 1 words (Chinese translation) and fewer errors in the whole task. A higher Hungarian proficiency level correlates with fewer errors in all the groups of words and the whole task, as well as shorter decision time in Group 1 words and Group 3 words (control).

Subsequently, linear regressions were conducted to further explore the relationship between language proficiency error rates and reaction times. It should be noted that regression analyses were conducted only on variables that demonstrated significant correlations with proficiency scores, as identified in the previous section. Conducting regression on other variables is unlikely to yield significant results. Based on the correlation analysis previously discussed, regressions were conducted using the ENtest scores as predictors for Group 1 and total error rates, and HUtest scores as predictors for Group 1 and 3 reaction times, as well as Group 1, 2, 3, and total error rates as dependent variables. A separate regression analysis was conducted for each dependent variable. Results showed that ENtest was a significant predictor of Group 1 error rate (F (1,318) = 7.974, p = .005, R^2 =.024) and total error rate (F (1,318) =11.042, p < .001, R^2 =.034). HUtest was a strong predictor of Group 1 error rate (F (1,318) = 43.699, p < .001, R^2 =.121), Group 2 error rate (F (1,318) = 8.636, p = .004, R^2 =.026), Group 3 error rate (F (1,318) = 60.283, p < .001, R^2 =.159), and total error rate (F (1,318) = 118.454, p < .001. R^2 =.271). Hungarian Proficiency was also a significant predictor of Group 1 reaction time (F (1,318) = 5.472, p = .02, R^2 = .017) and Group 3 reaction time (F (1,318) = 8.260, p = .004, R^2 = .025).

In terms of error rates, the Hungarian proficiency score emerged as a stronger predictor compared to the English proficiency score, as it explained 26.9% of the variance (compared to 3.1%). In terms of reaction time, Hungarian proficiency also proved to be the only predictor among the two proficiency scores. English proficiency did not significantly correlate with reaction times for any of the outcome measures.

These findings indicate that higher proficiency in Hungarian can reduce errors and reaction times. A higher Hungarian proficiency level can improve accuracy and speed in these decision tasks. English proficiency, on the other hand, doesn't affect accuracy and speed as much as Hungarian proficiency.

2 Strategy and activation state questionnaire data

The full questionnaire of strategy use can be seen in Appendix B. Participants tended to focus more on describing how related word pairs were connected rather than paying attention to unrelated word pairs, suggesting that the related word pairs captured more of their attention. Additionally, some participants described how they made associations and expanded their imagination with unrelated word pairs.

When asked if they translated the word pairs into Chinese, 23 participants self-reported that they always did, while the remaining 9 reported that they sometimes did. No participant reported never translating into Chinese. In response to whether they translated the word pairs into English, 13 participants reported that they never did, 3 reported that they always did, and 16 participants reported that they sometimes did.

Among those who always translated into Chinese, 3 participants noticed the repetition in the Chinese translations. They were the only ones to identify this repetition. One of them, participant A, provided an example, noting that the word pair "rizs-méter" in Group 1 was translated into the same character in Chinese, 米. Another one of them mentioned only noticing sound repetition when translating into

Chinese. In contrast, participants who sometimes or always translated into English did not discover any hidden repetitions in the English translations.

In terms of activation state, three participants explicitly described their active L1 (Chinese) state when asked about the strategies they used during the task. One of them was participant A, who reported being in a Chinese language state, not activating English, and always translating Hungarian word pairs into Chinese. Another participant said that he/she always chose to translate Hungarian word pairs into Chinese. The third participant described that the brain would almost automatically translate the Hungarian word pairs into Chinese, also indicating a highly active L1 state. There were few comments regarding an L2 (English) state. One participant explained that their limited English vocabulary led to less involvement of English, making it less likely for them to translate Hungarian into English. Another participant mentioned that they only thought of English when encountering Hungarian loanwords[6]. Such as the Hungarian word *dinoszaurusz* in the stimuli set, which means "dinosaur". There was also one participant who claimed to be in a Hungarian monolingual state, without activating any other languages. However, the data from this participant casts doubt on the accuracy of this claim.

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[6] Loanwords are words adopted by one language from another language with little or no modification. This phenomenon occurs when different cultures come into contact through various forms of interaction. Over time, these borrowed words become an integral part of the borrowing language, often filling gaps for concepts, items, or ideas that did not previously exist in the language.

Discussion

This chapter provides a comprehensive interpretation of the study's findings, positioning them within the broader context of multilingual language processing research. The chapter begins with an analysis of the primary research questions, followed by an exploration of the strategy and activation state questionnaire data. Additionally, it aligns the study's findings with previous research, discusses the differing impacts of error rates and reaction times as outcome measures, explores the reasons for choosing the specific languages of this study, and ultimately extends the discussion to a trilingual context.

1 Research Questions

1.1 Research Question 1: Are L1 (Chinese) and L2 (English) activated when processing L3 (Hungarian)?

The data provide compelling evidence that both L1 (Chinese) and L2 (English) are activated during L3 (Hungarian) processing. The findings also align with the predictions. Specifically, participants demonstrated higher error rates and longer reaction times when processing Hungarian word pairs that had hidden repetitions in their Chinese and English translations (Groups 1 and 2) compared to control pairs that had no hidden repetitions in their translations in either language (Group 3). This suggests that, when participants encounter Hungarian words, they unconsciously translate these words into their other known languages, activating both L1 and L2 in the process. Given that similar results were found in terms of both error rates and reaction times, it is clear that this activation is not just a peripheral effect but significantly impacts cognitive processing during the task.

This aligns with the bilingual interactive activation (BIA) model, which posits that both languages in a bilingual's mind are activated simultaneously during word recognition tasks. It also extends the BIA model into a trilingual setting (perhaps a

Trilingual Interactive Activation model), suggesting that all three languages could be activated simultaneously during L3 processing tasks.

The activation of L1 and L2 during L3 processing highlights the interconnected nature of multilingual lexical systems. When participants process L3 stimuli, the activation of their other known languages indicates a non-selective access to their lexicons. This non-selective access can be seen as both a resource and a challenge. On one hand, it allows for a richer pool of linguistic resources to draw from, potentially aiding in comprehension and learning. On the other hand, it can lead to interference, as evidenced by the increased error rates and slower reaction times.

These findings are consistent with the concept of language co-activation, where multiple languages are simultaneously active to varying degrees depending on the context and the task. In the case of this study, although an attempt was made to maintain a monolingual environment to ensure that activation is spontaneous, the hidden repetitions in the stimuli were sufficient to trigger this co-activation, leading to observable effects in participants' performance. This suggests that, even in tasks designed to appear monolingual, multilinguals cannot entirely switch off their other languages, reflecting the dynamic and fluid nature of multilingual language processing.

The activation pattern also supports Levelt and colleagues' (1999) theory of lexical access. Levelt et al. (1999) proposed that lexical items compete for selection process and the most active item will be chosen for further processing. The results of this study align with this theory, showing that participants' performance was influenced by the hidden repetitions in their L1 and L2, leading to increased cognitive load and processing difficulty. This was shown by the increased reaction times and error rates.

1.2 Research Question 2: Does L1 (Chinese) and L2 (English) activation display any differences?

The comparative analysis between L1 (Chinese) and L2 (English) activation shows a clear distinction in their influence on L3 (Hungarian) error rates. Specifically, participants showed higher error rates when the Hungarian word pairs had hidden repetitions in their Chinese translations (Group 1) compared to English translations (Group 2). There was also a descriptive difference (although not statistically significant, but approached significance, $p = .051$) in reaction time, as in Group 1 words yielded slower reaction times than Group 2 words. These results partially align with the predictions.

The lack of significant effect could be due to the small sample size in the present study. While the small sample size is justified given the exploratory nature of the study, a larger-scale replication could ensure a more robust investigation of the effect and its significance.

The results suggest that the interference from L1 significantly affected error rates, likely due to stronger, more established connections between L1 and the conceptual system, as suggested by the Revised Hierarchical Model (RHM). The RHM posits that lower proficiency in a second language (or third, in this case) leads to greater reliance on L1 for conceptual understanding, which can result in more significant interference. Given that we recruited beginner-level learners of Hungarian, the participants have not yet established a robust L3-to-meaning connection. Consequently, they may rely on their other languages for comprehension. As Chinese is their native language and English their second language, proficiency in Chinese invariably exceeds that in English, resulting in a stronger L1-to-meaning connection. This dominance of L1, being the most entrenched language in a multilingual's cognitive system, means that lexical and conceptual connections are more robust, making it difficult to suppress L1 activation when processing L3 stimuli. Therefore, when L1 influences the processing of L3, it leads to higher error rates. However, reaction time did not significantly differ in Group 1 and Group 2. Therefore, further research is necessary to conclusively determine whether L1 causes more interference than L2.

The typological distance between Chinese (L1) and Hungarian (L3) may contribute to the inhibitory effects of L1 activation. The significant differences in script, phonology, and syntax between Chinese and Hungarian likely increase the cognitive load when participants unconsciously translate Hungarian stimuli into Chinese. This increased load manifests as greater interference, reflected in higher error rates observed in performance measures. In contrast, the lesser impact of L2 (English) activation suggests that participants were better able to manage interference from L2. This could be due to the closer typological and structural similarities between English and Hungarian compared to Chinese and Hungarian.

These findings highlight the complexity of cross-language interactions in multilinguals and underscore the importance of considering the unique characteristics of each language pair when examining language processing. The differential impact of L1 and L2 activation shows the complexity of cross-language interactions in multilinguals and also supports the idea that multilingual language processing is influenced by both language dominance and typological distance, contributing to our understanding of how multilinguals navigate their linguistic repertoire.

1.3 Research Question 3: Does proficiency level affect activation?

The study also explored the impact of proficiency levels on language activation during L3 processing. The results corroborate the predictions that proficiency is influential, showing that higher proficiency in Hungarian was associated with lower error rates in general and shorter RTs in Group 1 and Group 3. The regression results also seemed to suggest that higher proficiency in Hungarian appeared to mitigate the inhibiting effects of L1 and L2 activation during L3 processing. This could be because higher proficiency in Hungarian allowed participants to form stronger direct connections between Hungarian words and their meanings, reducing the need to rely on their other known languages and resulting in less active L1 and L2 states. Overall, the results align with the RHM model, which suggests that as proficiency in L3 increases, the reliance on L1 and L2 translation equivalents decreases, facilitating more direct word-to-concept mappings between L3 and the conceptual system. The finding that higher English proficiency correlated with fewer errors in the whole task also serves as evidence for the RHM.

However, data also showed that higher English proficiency was associated with increased errors in Group 1 (Chinese hidden repetition), although with weak effects. This complex interaction observed between English proficiency and error rates in the Chinese hidden repetition condition might indicate that proficiency does not necessarily mitigate L1 interference. This specific phenomenon does not align with what the RHM suggests. The possible explanation is that while proficiency in L2 can enhance overall language processing skills, it might also lead to increased activation and potential interference from L1 in specific contexts. In this case, higher English proficiency might have led to greater cognitive flexibility and increased activation of Chinese, resulting in more errors when Chinese repetitions were present. Given the weak effects observed, further research with better statistical power is necessary to elucidate the complex relationship between proficiency and activation.

Compared to English proficiency scores, Hungarian proficiency scores seemed to correlate with more variables. To be more specific, English proficiency test scores showed significant correlations only with Group 1 and total error rates. Meanwhile, Hungarian proficiency test scores were significantly correlated with Group 1 and 3 reaction times, as well as all error rate variables. This finding is logical, given that the main task solely involves Hungarian and essentially assesses Hungarian proficiency. Therefore, it follows that Hungarian proficiency would be a significant predictor of performance outcomes in the task.

These findings emphasize the importance of considering proficiency levels in multilingual studies and suggest that proficiency influences the nature and extent of cross-language activation. The finding of proficiency not necessarily mitigate L1 interference also highlights the need for a nuanced understanding of how proficiency interacts with cross-language activation in trilinguals. The dynamic interplay between proficiency and cross-language interference calls the need for further research to unravel the mechanisms underlying these interactions and their implications for multilingual language processing.

2 Strategy and Activation State Questionnaire Data

The strategy and activation state questionnaire provided insightful data regarding participants' language processing strategies and their subjective experiences of language activation during the task. The responses revealed distinct patterns in how participants approached the decision tasks and how they managed the cross-language interactions between L1 (Chinese), L2 (English), and L3 (Hungarian). These patterns are crucial for understanding the cognitive processes underlying multilingual language activation and the factors that influence these processes.

Participants reported varying degrees of reliance on their L1 and L2 during the Hungarian word pair decision tasks. A significant majority of participants (23 out of 32) indicated that they always translated the Hungarian word pairs into Chinese (L1), while the remaining participants reported that they sometimes did so. This high level of L1 activation suggests that participants relied heavily on their dominant language to facilitate comprehension and decision-making. This reliance is also consistent with RHM, which posits that lower proficiency in a new language (L3 in this case) leads to greater reliance on L1 for conceptual understanding.

Conversely, the responses regarding English (L2) translation were more varied. Thirteen participants stated that they never translated the Hungarian word pairs into English, three participants always did, and sixteen reported that they sometimes did. This distribution indicates a more selective activation of L2, likely influenced by the participants' proficiency levels and the specific demands of the task. The selective activation of L2 aligns with the findings from the reaction time and error rate analyses (in research question 2), where L2 showed a less salient impact on task performance compared to L1.

Interestingly, among the participants who always translated into Chinese, only three noticed the hidden repetitions in the Chinese translations. This suggests that they were more attuned to the form and sound patterns in Chinese. In contrast, participants who sometimes or always translated into English did not identify any hidden repetitions, indicating that their L2 activation was not strong enough to engage deeper phonological or orthographic processing. This could be attributed to the differing levels of proficiency between the L1 (Chinese) and the L2 (English). As participants had not formed strong L2-to-meaning connections in the L2, they could not activate it sufficiently to notice the repetition.

The explicit descriptions of L1 activation provided by the three participants clearly show the strong influence of L1 on cognitive processing and the challenges involved in managing multiple language activations simultaneously. These three participants also mentioned different extents of activation states. The extent of activation ranged from "chose to translate Hungarian word pairs into Chinese" to "the brain would almost automatically translate the Hungarian word pairs into Chinese" according to the participants.

As for L2 activation, even fewer comments were reported, reflecting the more variable and selective nature of English activation. One participant attributed the less active state of L2 to a limited vocabulary in English, providing further evidence for RHM that low proficiency in a language is less likely to activate it. Another participant noted the role of Hungarian loanwords in English activation, suggesting that specific lexical items can trigger L2 activation.

The comments concerning the activation state show the complex and context-dependent nature of L1 and L2 activation in multilinguals. Most participants did not explicitly report their activation of other languages. This phenomenon shows that participants were mostly unaware of the concept of cross-language activation during the experiment process, which confirms that there were few clues of cross-language activation in the experiment design. Thus, the activation we discovered in the data could be counted as spontaneous.

Overall, the strategy and activation state questionnaire data provide valuable insights into the strategies employed by trilinguals during language processing tasks, particularly with regard to their cognitive processes and how they processed and retained cross-language information. The heavy reliance on L1 and the selective activation of L2 reflect the complex interplay of proficiency, task demands, and individual differences in managing cross-language interactions.

3 Alignment with Previous Literature

The observation of error rates being a more sensitive measure than reaction times, especially salient in the findings of research question 2, contrasts with some previous studies. For example, Wu and Thierry (2010) suggested that reaction time was slightly more sensitive, if not equally so, to subtle cognitive processes compared to error rates. However, neither measurement was sensitive enough to detect significant outcomes for cross-language activation. Instead, it was ERP (Event-Related Potential) data that successfully captured these effects. This discrepancy could be attributed to differences in experimental design, such as the nature of the word pairs used, the tasks given to participants, and the characteristics of the participant sample, including their proficiency levels and language backgrounds.

In Wu and Thierry’s (2010) study, spelling and sound repetition were separated. The separation could result in the repetition being more subtle and harder for participants to detect. This subtlety could lead to insignificant outcomes in their behavioral data. The repetitions in the present study did not distinguish sound and form. Specifically, the repetitions overlapped in both sound and form in both Chinese and English. By keeping both form and sound repetitions together, the study maximized the cognitive load and likelihood for participants to be influenced by these repetitions. This design also aimed to maintain consistency between the two languages, as distinguishing between sound and form in English could be challenging. The decision not to separate form and sound also reflects the complexity of cross-language interactions in multilinguals more accurately. In real-world language processing, form and sound are often intertwined, and separating them might create an artificial task that does not accurately reflect the cognitive processes involved in everyday multilingual language use. By combining these elements, the study aimed to create a more valid task that better captures the dynamic and fluid nature of multilingual language processing. This approach proved to be successful, leading to more pronounced results in behavioral data.

Another reason the present study observed significant results in behavioral data, unlike Wu and Thierry's (2010) study, is the difference in participant proficiency levels. Wu and Thierry recruited bilinguals with high proficiency in English (L2), while the current study involved participants with relatively low proficiency in Hungarian (L3). The participants in Wu and Thierry's (2010) study had already formed strong L2-to-meaning connections and relied less on their L1. They were also more likely to stay in an English monolingual state and less likely to experience cross-language activation.

Previous studies have consistently shown that cross-language activation occurs in bilinguals and trilinguals, with proficiency playing a crucial role in modulating this activation (bilinguals: e.g., Sunderman and Kroll, 2006; trilinguals: e.g.,Festman, 2008; Poarch & Van Hell, 2012). Whether it is bilinguals or trilinguals, the results all point out that low proficiency leads to more interference. The findings of the present study align with previous literature as well, showing that proficiency in Hungarian reduces cross-language interference, supporting the idea that proficiency modulates the extent of cross-language activation.

4 Error Rate vs. Reaction Time

The finding that error rates have larger magnitudes of the effects than reaction times in detecting cross-language activation is noteworthy. The experimental data in the present study showed that error rates yielded larger effect sizes than reaction times. Individual differences could explain the observed discrepancy between error rates and reaction times as outcome measures. Variations in processing strategies and proficiency levels among participants may have contributed to greater variability in error rates, making them a more reliable indicator of cross-language activation. Another possible factor contributing to this difference between error rates and reaction times could be proficiency. If this study were to recruit participants with high proficiency, as Wu and Thierry (2010) did, the error rates might not have been as indicative, since the participants would have been better able to manage cross-language interference. In contrast, those with lower proficiency in the present study experienced greater interference, leading to higher error rates.

The design of the task, which involved a decision-making process under time constraints, might have inherently favored the detection of accuracy differences over speed differences. The time constraints might have urged the participants to answer the question. In doing so, participants didn't have enough time to manage cross-language interference. Additionally, the decision task required participants to determine the relatedness of Hungarian word pairs, with hidden repetitions in their Chinese and English translations. This task is likely to increase the cognitive load, making participants more susceptible to errors when hidden repetitions are present. Especially under time constraints, the concept of meaning-unrelated word pairs with hidden repetition and meaning-related word pairs might be confusing to a certain extent in this case. For instance, when participants encounter a word pair that is semantically unrelated but has a hidden repetition in the translation, they may establish a connection between the two words due to their shared element. Under conditions of high cognitive load and limited time, this connection could be mistakenly perceived as a semantic relationship.

5 Roles of Chinese and Hungarian

Since the majority of research in this area is English dominated, the unique roles of Chinese and Hungarian in this study provide valuable insights into the dynamics of cross-language activation in multilinguals. The logographic nature of Chinese means that each character represents both meaning and sound, creating a more complex system for lexical access and processing. This nature is likely to increase cognitive load and interference during L3 processing due to the need for orthographic and phonological recoding. This differs from the processing of alphabetic languages like English and Hungarian, where phonological and orthographic representations are more directly linked.

Hungarian, as a typologically distant language with an agglutinative structure and extensive vowel harmony, presents a unique context for examining cross-language activation. The typological distance between Hungarian and both Chinese and English means that participants must adapt to a different set of linguistic rules and structures when processing Hungarian stimuli. This adaptation likely increases cognitive load and interference, as participants must reconcile the differences between their known languages and Hungarian.

The study's findings contribute to a broader understanding of how diverse linguistic features, such as script type and language family, influence multilingual processing. The increased error rates and longer RTs in the experimental conditions suggest that the cognitive load associated with navigating these differences leads to greater cross-language activation and interference. However, future research needs to identify the specific mechanisms of how linguistic distance and script difference influence cross-language activation. Furthermore, this trilingual study contributes to the linguistic diversity in psycholinguistic research and underscores the need for further studies involving less commonly studied languages.

6 Differences Between Trilinguals and Bilinguals

The differences between trilinguals and bilinguals in the context of cross-language activation are significant and worth exploring further. Trilinguals face more complex interactions between their languages compared to bilinguals. The results of this study indicate that trilinguals experience significant cross-language activation from both L1 and L2 during L3 processing, leading to increased error rates and longer RTs. This aligns with findings from Poarch and Van Hell (2012, 2014), which suggest that trilinguals activate all three languages, albeit with varying degrees of interference based on proficiency and language distance.

Bilingual literature often shows more straightforward patterns of L1 interference during L2 processing, as bilinguals only need to manage the interaction between two languages. In contrast, trilingual studies must account for the added complexity of managing an additional language system (i.e., the tridirectional nature of interference among all three languages). This complexity is reflected in the increased error rates and RTs observed in this study. Further research is needed to understand the unique challenges faced by trilinguals.

Limitations and Future Directions

This chapter addresses the limitations of the current study and offers directions for future research. It begins by discussing the limitations related to the materials used, specifically the proficiency tests. Subsequently, the design of the study is critically evaluated, covering aspects such as the absence of neuroimaging and native speaker data, sample size, participant recruitment, and the language environment during the experiment.

1 Limitations in the Materials used

Both proficiency tests in the present study were quick and easy to navigate. This consideration ensures that the online tasks are not overly extensive, preventing participants from losing patience and dropping out, causing us to lose data. However, both tests have their limitations. The proficiency test used to assess participants' Hungarian proficiency in this study lacked validation. It was sourced from an online platform, found via Google. It mainly tests the grammatical and vocabulary aspect of Hungarian language proficiency. The use of an unverified test introduces potential biases and inaccuracies, which could affect the study's conclusions. Given the unique characteristics of the Hungarian language and the scarcity of research on it, finding a valid and quick proficiency test suitable for the online experiment in this study was particularly challenging. However, the reliance on a non-validated tool is a significant limitation. LexTALE, on the other hand, also cannot fully capture the English general proficiency, as it only tests out receptive vocabulary knowledge (Lemhöfer & Broersma, 2012). While receptive vocabulary is an essential component of language proficiency, it is not sufficient to provide a comprehensive assessment. Future research should aim to develop or identify more reliable and validated proficiency tests for Hungarian and more comprehensive tests for English, while also taking into account the length of time. This would ensure more accurate assessments of language skills of participants with different L1 backgrounds and allow for more robust conclusions. Collaborating with language experts and institutions to create standardized proficiency tests could address this limitation and improve the quality of future studies in this area.

2 Limitations in Design

2.1 Lack of Neuroimaging Data

Although reaction times and error rates are standard online measures in psycholinguistic research, they may not capture the full extent of cognitive processes and mental representations involved in cross-language activation (Ferreira and Yang, 2019). Neuroimaging data such as event-related potentials (ERPs) or functional magnetic resonance imaging (fMRI) can provide more detailed insights into brain activity and subtle activation patterns. Behavioral measures like reaction times and error rates can sometimes miss unconscious activation of languages, which neuroimaging techniques can detect. For example, Wu and Thierry (2010) found that while there were no significant differences in reaction times, ERP data revealed subtle activation differences, suggesting that access to L1 was unconscious for bilinguals tested in L2. This indicates that some cognitive processes may be too subtle for behavioral data to capture, and incorporating neuroimaging methods could provide a more comprehensive understanding of cross-language activation.

Although the present study successfully detected cross-language activation through reaction time and error rate measurements, it would be more rigorous to compare these behavioral data with neuroimaging data. The absence of neuroimaging data limits the ability to understand the underlying neural mechanisms of cross-language activation. Specifically, ERPs can provide quantitative, qualitative and time-locked information about neural processing stages, while fMRI can offer spatial localization of brain activity (Mueller, 2005). These methods can help identify specific brain regions involved in managing interference from L1 and L2 during L3 processing. Future research should include these techniques to capture the neural dynamics of multilingual language processing, allowing for a more in-depth understanding of how different languages are activated and interact in the brain.

2.2 Absence of Native Speaker Data

While the study included a control group of words (Group 3) for baseline comparisons, its robustness could be significantly enhanced by including data from both native Chinese and Hungarian speakers performing decision tasks. The Chinese native speakers should perform the task with Hungarian word pairs translated into Chinese, while the Hungarian native speakers do the original task. Although the present study included Hungarian native speakers for piloting, the data they provided was not analyzed. Comparing their data with that of the trilingual participants would provide deeper insights. A similar design could be seen in Wu and Thierry's (2010) study, where they asked Chinese and English native speakers to judge the relatedness of the words' Chinese translation. They believed that native English speakers would show the same effect when processing related word pairs and display no effects with word pairs that conceal Chinese repetition, given their ignorance of Chinese. In our design, including Hungarian native speakers could have a similar function, while collecting data from native Chinese speakers could offer insights into the baseline L1 performance and could help isolate the effects of the L2 and L3 proficiency on cognitive performance. Including native speaker data would also help determine whether the observed effects are due to proficiency differences or inherent linguistic properties of the languages involved. This would enhance the study's rigor and provide a more detailed understanding cross-language interaction.

2.3 Small Sample Size

It could be quite challenging to find Chinese-English-Hungarian trilinguals, therefore, the study's sample size of 32 participants is relatively small, which can affect the generalizability of the findings. Small sample sizes can lead to increased variability and reduced statistical power (Field, 2018), making it more difficult to detect significant effects and draw broad conclusions. The limited number of participants may also increase the likelihood of Type I and Type II errors, where true effects might be missed, or non-existent effects might appear significant (Field, 2018).

2.4 Participant Demographics

The participant demographics in this study differ from those in previous studies. The present study only recruited beginner level Hungarian learners. This might cause biased outcomes, since lower proficiency learners experience cross-language interference more easily. Future studies should also investigate on whether learners with higher proficiency levels in Hungarian experience the same interference as beginners.

Furthermore, the current study's participants were all adults. Language processing and cross-language activation can vary significantly across different age groups. Adults, particularly those in a university setting, may have more established cognitive and language processing strategies compared to younger individuals or older adults. This difference in cognitive strategies and language use can influence how languages are activated and interact in the brain. By focusing solely on adults, the study may not capture the full spectrum of language processing behaviors that exist across different age groups.

2.5 Challenges of a Hungarian Monolingual Environment

As discussed in the Literature Review section, creating a monolingual environment is a crucial aspect in experimental design, as it guarantees the spontaneous activation of non-target languages. However, maintaining a fully Hungarian monolingual environment for the study was challenging, despite adjustments, such as scheduling the English proficiency tests and Chinese questionnaires after the decision task. This was particularly due to the need for ethical approval and instructions to be provided in Chinese, in order to ensure that beginner participants could fully understand the information and comprehend the task. This requirement introduced potential confounding variables that can affect the study's findings. For beginners, receiving instructions in their L1 (Chinese) might inevitably activate their L1, giving clues to L1 cross-language interference during the task. This interference could skew the results, making it difficult to decide whether the effects are spontaneous L1 activation.

To address this limitation, future studies should consider implementing strategies that minimize L1 activation. For example, designing tasks and instructions that are more intuitive and less reliant on verbal explanations could help reduce the need for L1 activation.

Conclusion

This dissertation investigated the cognitive processes involved in cross-language activation among Chinese-English-Hungarian trilinguals. The study primarily aimed to understand whether L1 (Chinese) and L2 (English) are activated during L3 (Hungarian) processing, how proficiency levels affect this activation, and whether the activation of the L1 and the L2 differ in their impact on L3 processing. The findings provide insights into the nonselective access of multilingual lexical systems and the complexities involved in managing multiple languages simultaneously.

The study indicated that both L1 and L2 are activated during L3 processing. Participants exhibited higher error rates and longer reaction times when processing Hungarian word pairs that contained hidden repetitions in their Chinese and English translations. This suggests that cross-language activation is a pervasive phenomenon in trilinguals, with both L1 and L2 being unconsciously accessed during L3 word processing. The significant differences observed in both error rates and reaction times indicate that this activation is not merely a peripheral effect but rather a central component of cognitive processing during multilingual tasks.

The comparative analysis between L1 and L2 activation revealed distinct differences in terms of error rates. Participants showed significantly higher error rates when Hungarian word pairs had hidden repetitions in their Chinese translations. This is likely due to the stronger, more established connections between L1 and the conceptual system, as well as the greater typological distance between Chinese and Hungarian compared to English and Hungarian. However, this conclusion is constrained because only a descriptive and non-significant difference was observed in reaction times. Studies with greater statistical power are needed to robustly confirm whether L1 exerts more interference on L3 processing than L2.

It was also found that the learners' proficiency levels in the L2 and L3 significantly influenced cross-language activation. Higher proficiency in Hungarian was associated with lower error rates and shorter reaction times, indicating that as participants become more proficient in L3, they rely less on their other languages.

This aligns with the Revised Hierarchical Model (RHM), which suggests that as proficiency in L3 increases, reliance on L1 for conceptual understanding decreases. Conversely, higher English proficiency was correlated with increased errors in the Chinese hidden repetition condition, suggesting a complex interaction where higher proficiency in one non-target language might lead to increased activation of another non-target language.

The findings of this study have theoretical implications for our understanding of multilingual language processing. The evidence supporting the nonselective access hypothesis in trilinguals extends the Bilingual Interactive Activation (BIA) model to a trilingual context, suggesting that *all* known languages are activated during language processing tasks. This supports the idea that multilinguals cannot selectively process one language without activating their other languages, leading to simultaneous activation and competition among lexical items from all languages. Furthermore, the study also contributes to the Revised Hierarchical Model (RHM) by demonstrating that proficiency modulates cross-language activation and interference. As proficiency in the L3 increases, reliance on the L1 and L2 decreases, allowing for more efficient processing of L3 stimuli. This highlights the dynamic nature of multilingual lexical systems and the importance of considering proficiency levels when examining cross-language activation.

From a practical perspective, the findings of this study can inform language teaching and learning strategies. Educators and language learners can benefit from understanding the dynamics of cross-language activation and the potential for interference. This knowledge can help develop more effective teaching methods that account for the challenges of managing multiple languages and provide strategies for minimizing cross-language interference. Techniques such as targeted practice in weaker languages and the use of cognitive strategies to compartmentalize language processing could be particularly beneficial. Targeted practice in weaker languages involves creating tailored exercises that focus on strengthening the learner's proficiency in their less dominant languages. This could include immersive activities, vocabulary drills, and contextual usage that help solidify language foundations and reduce the cognitive load from stronger languages. Cognitive strategies to compartmentalize language processing can help learners manage multiple languages by creating mental boundaries between them. One effective approach is context-based learning, where each language is associated with distinct contexts or activities, such as using one language at home and another at work. Another pedagogical implication is that boosting L3 proficiency could help reducing interference from L1/L2 and promoting more effective L3 activation. This, in turn, can lead to more efficient and effective language learning, enabling learners to achieve greater fluency and confidence in their third language.

While the study successfully detected cross-language activation through behavioral measures, the absence of neuroimaging data is a significant limitation. There are also several design flaws, such as the lack of native speakers' data, recruitment of participants and keeping a monolingual environment.

Apart from these limitations, the proficiency tests used in this study, particularly for Hungarian, lack validation and/or do not provide a comprehensive assessment of overall proficiency. Future studies should use more reliable and validated proficiency tests to ensure accurate assessments of language skills.

To sum up, this study provides insights into cross-language activation in trilingual individuals, highlighting the complexities of managing multiple languages simultaneously. The findings support the nonselective access hypothesis and extend it to trilinguals, demonstrating that L1 and L2 are activated during L3 processing. Proficiency levels significantly influence cross-language activation, with higher proficiency in L3 reducing interference from L1 and L2. These results have important theoretical and practical implications, contributing to our understanding of multilingual language processing and informing language teaching. Future research should address the limitations identified in this study and continue to explore the intricate dynamics of multilingual language activation.

References

Brysbaert, M., Dyck, G. V., & de Poel, M. V. (1999). *Visual Word Recognition in Bilinguals: Evidence From Masked Phonological Priming*.

Choi, W., Nam, K., & Lee, C. H. (2010). Nonselective Access of Phonological Lexicon for Two Different Orthographies: Korean and English. *Perceptual and Motor Skills*, *110*(3), 693–698. https://doi.org/10.2466/pms.110.3.693-698

Colomé, À. (2001). Lexical Activation in Bilinguals' Speech Production: Language-Specific or Language-Independent? *Journal of Memory and Language*, *45*(4), 721–736. https://doi.org/10.1006/jmla.2001.2793

De Angelis, G. (2007). Third or additional language acquisition (Vol. 24). Multilingual Matters.

De Groot, A. M., & Hoeks, J. C. (1995). The development of bilingual memory: Evidence from word translation by trilinguals. *Language learning*, 45(4), 683-724.

De Groot, A. M., Delmaar, P., & Lupker, S. J. (2000). The processing of interlexical homographs in translation recognition and lexical decision: Support for non-selective access to bilingual memory. *The Quarterly Journal of Experimental Psychology: Section A*, *53*(2), 397-428.

Dijkstra, T., Grainger, J., & Van Heuven, W. J. B. (1999). Recognition of Cognates and Interlingual Homographs: The Neglected Role of Phonology. *Journal of Memory and Language*, *41*(4), 496–518. https://doi.org/10.1006/jmla.1999.2654

Dijkstra, T., Timmermans, M., & Schriefers, H. (2000). On Being Blinded by Your Other Language: Effects of Task Demands on Interlingual Homograph Recognition. *Journal of Memory and Language*, *42*(4), 445–464. https://doi.org/10.1006/jmla.1999.2697

Dimitropoulou, M., Duñabeitia, J. A., & Carreiras, M. (2011). Masked translation priming effects with low proficient bilinguals. *Memory & Cognition*, *39*(2), 260–275. https://doi.org/10.3758/s13421-010-0004-9

Duyck, W., & Warlop, N. (2009). Translation Priming Between the Native Language and a Second Language: New Evidence From Dutch-French Bilinguals. *Experimental Psychology*, *56*(3), 173–179. https://doi.org/10.1027/1618-3169.56.3.173

Ferreira, F., & Yang, Z. (2019). The problem of comprehension in psycholinguistics. Discourse

Processes, 56(7), 485-495.

Festman, J. (2008). *Cross-language interference during trilingual picture-naming in single and mixed language conditions*.

Field, A. (2018). Discovering statistics using IBM SPSS statistics. Sage publications limited.

Frost, R. (1998). *Toward a Strong Phonological Theory of Visual Word Recognition: True Issues and False Trails*.

Gerard, L. D., & Scarborough, D. L. (1989). *Language-Specific Lexical Access of Homographs by Bilinguals*.

Gollan, T. H., Forster, K. I., & Frost, R. (1997). Translation priming with different scripts: Masked priming with cognates and noncognates in Hebrew–English bilinguals. *Journal of Experimental Psychology: Learning, memory, and cognition, 23*(5), 1122.

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

Grosjean, F., & Li, P. (2013). Chapter 3: Speech production. In *The psycholinguistics of bilingualism*.

Helms-Park, R., & Dronjic, V. (2016). 5. Crosslinguistic Lexical Influence: Cognate Facilitation. In R. Alonso Alonso (Ed.), *Crosslinguistic Influence in Second Language Acquisition* (pp. 71–92). Multilingual Matters. https://doi.org/10.21832/9781783094837-007

Hermans, D., Bongaerts, T., De Bot, K., & Schreuder, R. (1998). Producing words in a foreign language: Can speakers prevent interference from their first language? *Bilingualism: Language and Cognition*, *1*(3), 213–229. https://doi.org/10.1017/S1366728998000364

Hermans, D., Ormel, E., van Besselaar, R., & Van Hell, J. (2011). Lexical activation in bilinguals' speech production is dynamic: How language ambiguous words can affect cross-language activation. *Language and Cognitive Processes, 26(10)*, 1687-1709.

Hoshino, N., & Thierry, G. (2011). Language selection in bilingual word production: Electrophysiological evidence for cross-language competition. *Brain research, 1371,* 100-109.

Hut, S. C. A., Helenius, P., Leminen, A., Mäkelä, J. P., & Lehtonen, M. (2017). Language control mechanisms differ for native languages: Neuromagnetic evidence from trilingual language switching. *Neuropsychologia*, *107*, 108–120. https://doi.org/10.1016/j.neuropsychologia.2017.11.016

Jared, D., & Kroll, J. F. (2001). Do bilinguals activate phonological representations in one or both of their languages when naming words?. *Journal of memory and language*, *44*(1), 2-31.

Jiang, N. (2019). Phonology-based bilingual activation among different-script bilinguals? *Bilingualism: Language and Cognition*, *22*(04), 693–694. https://doi.org/10.1017/S1366728918000664

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of memory and language*, *33*(2), 149-174.

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

Lemhöfer, K., Dijkstra, T., & Michel, M. (2004). Three languages, one ECHO: Cognate effects in trilingual word recognition. *Language and Cognitive Processes*, *19*(5), 585–611. https://doi.org/10.1080/01690960444000007

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22*(01). https://doi.org/10.1017/S0140525X99001776

Linck, J. A., Schwieter, J. W., & Sunderman, G. (2012). Inhibitory control predicts language switching performance in trilingual speech production. *Bilingualism: Language and Cognition*, *15*(3), 651-662.

Madrazo, A. R., & Bernardo, A. B. (2018). Measuring two types of inhibitory control in bilinguals and trilinguals: Is there a trilingual advantage?. *Psychological Studies*, *63*, 52-60.

Marian, V., & Spivey, M. (2003). Competing activation in bilingual language processing: Within-and between-language competition. Bilingualism: *Language and cognition, 6(2)*, 97-115.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychological review, 88(5)*, 375.

Miwa, K., Dijkstra, T., Bolger, P., & Baayen, R. H. (2014). Reading English with Japanese in mind: Effects of frequency, phonology, and meaning in different-script bilinguals. *Bilingualism: Language and Cognition*, *17*(3), 445–463. https://doi.org/10.1017/S1366728913000576

Mueller, J. L. (2005). Electrophysiological correlates of second language processing. *Second Language Research*, *21*(2), 152–174. https://doi.org/10.1191/0267658305sr256oa

Poarch, G. J., & Van Hell, J. G. (2012). Cross-language activation in children's speech production: Evidence from second language learners, bilinguals, and trilinguals. *Journal of Experimental Child Psychology*, *111*(3), 419–438. https://doi.org/10.1016/j.jecp.2011.09.008

Poarch, G. J., & Van Hell, J. G. (2014). Cross-language activation in same-script and different-script trilinguals. *International Journal of Bilingualism*, *18*(6), 693–716. https://doi.org/10.1177/1367006912472262

Rodriguez-Fornells, A., Rotte, M., Heinze, H.-J., Nösselt, T., & Münte, T. F. (2002). Brain potential and functional MRI evidence for how to handle two languages with one brain. *Nature*, *415*(6875), 1026–1029. https://doi.org/10.1038/4151026a

Scarborough, D. L., Gerard, L., & Cortese, C. (1984). Independence of lexical access in bilingual word recognition. *Journal of Verbal Learning and Verbal Behavior*, *23*(1), 84–99. https://doi.org/10.1016/S0022-5371(84)90519-X

Schwieter, J. W. (Ed.). (2015). The Cambridge handbook of bilingual processing. Cambridge University Press.

Sunderman, G., & Kroll, J. F. (2006). FIRST LANGUAGE ACTIVATION DURING SECOND LANGUAGE LEXICAL PROCESSING: An Investigation of Lexical Form, Meaning, and Grammatical Class. *Studies in Second Language Acquisition*, *28*(03). https://doi.org/10.1017/S0272263106060177

Thierry, G., & Wu, Y. J. (2004). Electrophysiological evidence for language interference in late bilinguals. *Neuro Report*, *15*(10), 1555–1558. https://doi.org/10.1097/01.wnr.0000134214.57469.c2

Thierry, G., & Wu, Y. J. (2007). Brain potentials reveal unconscious translation during foreign-language comprehension. *Proceedings of the National Academy of Sciences*, *104*(30), 12530–12535. https://doi.org/10.1073/pnas.0609927104

Van Heuven, W. J., Dijkstra, T., & Grainger, J. (1998). Orthographic neighborhood effects in bilingual word recognition. *Journal of memory and language*, *39*(3), 458-483.

Wu, Y. J., & Thierry, G. (2010). Chinese–English Bilinguals Reading English Hear Chinese. *The Journal of Neuroscience*, *30*(22), 7646–7651. https://doi.org/10.1523/JNEUROSCI.1602-10.2010

Appendices

Appendix A

The 45 Hungarian Word Pairs Used for The Decision Task

Group 1: Hungarian word pairs with hidden repetition in Chinese translation

	Hungarian	Chinese translation	English translation
	unrelated (-)	repetition (+)	no repetition (-)
example	*Vonat --- sonka*	*火车* ***Huo*** *che --- 火腿* ***Huo*** *tui*	*Train --- ham*
1	vonat - sonka	火车 huoche 火腿 huotui	train - ham
2	méter - rizs	米 mi 米 mi	meter - rice
3	számítógép - mozi	电脑 diannao 电影院 dianyingyuan	computer - cinema
4	templom - tanterem	教堂 jiaotang 教室 jiaoshi	church - classroom
5	tanács - épít	建议 jianyi 建造 jianzao	advice - build
6	dinoszaurusz - horrorfilm	恐龙 konglong 恐怖电影 kongbudianying	dinosaur - horror film
7	magazin - bonyolult	杂志 zazhi 复杂的 fuzade	magazine - complex
8	bérel - taxi	出租 chuzu 出租车 chuzuche	rent out - taxi
9	mikró - mosolyog	微波炉 weibolu 微笑 weixiao	microwave - smile
10	kolléga - egyetért	同事 tongshi 同意 tongyi	colleague - agree

Group 2: Hungarian word pairs with hidden repetition in English translation

	Hungarian	Chinese translation	English translation
	unrelated (-)	no repetition (-)	repetition (+)
example	*tapasztalat --- várakozás*	*经验 jing yan ---- 期待 qi dai*	***exp****erience ---* ***exp****ectation*
1	tapasztalat - várakozás	经验 期待	experience - expectation
2	vonat - edzés	火车 训练	train - training
3	múzeum - zene	博物馆 音乐	museum - music
4	száj - egér	嘴巴 老鼠	mouth - mouse

5	növény - terv	植物 计划	plant - plan
6	vizsga - példa	考试 例子	exam - example
7	igen - tegnap	对 昨天	yes - yesterday
8	strand - bab	海滩 豆子	beach - bean
9	méh - sör	蜜蜂 啤酒	bee - beer
10	december - eldönt	十二月 决定	December - decide

Group 3 (control group): Hungarian word pairs with no hidden repetition in either translation

	Hungarian	**Chinese translation**	**English translation**
	unrelated (-)	no repetition (-)	no repetition (-)
example	*lámpa - vonat*	*灯 deng - 火车 huoche*	*lamp - train*
1	repül - fiatal	飞 年轻的	fly - young
2	idő - toll	时间 笔	time - pen
3	szín - király	颜色 国王	color - king
4	alma- cipő	苹果 鞋子	apple - shoes
5	szoba - kenyér	房间 面包	room bread
6	édes - könyv	甜的 书	sweet - book
7	ajtó - víz	门 水	door - water
8	kert - táska	花园 包	garden - bag
9	kutya - nap	狗 太阳	dog - sun
10	zene - szél	音乐 风	music - wind

Fillers: Hungarian word pairs related in meaning

	Hungarian	**Chinese translation**	**English translation**
	related (+)	no repetition (-)	no repetition (-)
example	*orvos - beteg*	*医生 yi sheng - 生病的 sheng bing de*	*doctor sick*

1	orvos - beteg	医生 生病的	doctor sick
2	papucs - csizma	拖鞋 靴子	slippers boots
3	asztal - szék	桌椅	table chair
4	kávé - tea	咖啡 茶	coffee tea
5	nyaklánc - gyűrű	项链 戒指	necklace ring
6	bepakol - utazás	打包 旅行	pack up, travel
7	pilóta - repülőgép	机长 飞机	pilot plane
8	fazék - leves	大锅 汤	pot soup
9	nagy - kis	大小	big small
10	recept - megkóstol	菜谱 品尝	recepe taste
11	főnök - iroda	老板 办公室	boss office
12	dal - énekel	歌 唱歌	song sing
13	agy - ügyes	脑子 聪明的	brain smart
14	fa - zöld	树 绿色的	tree green
15	hegy - folyó	山 河	mountain river

Appendix B

Questionnaire for Strategy Use

1. 你是否注意到有些词组有一些规律？（头脑风暴一下！）如果有请尝试描述一下是什么样的规律。
2.

在刚才的实验中，你用了以下哪（些）种策略来辅助你的决策？

	从不	有时候	总是	不愿透露
我用到了我的母语（将匈语词组翻译成中文然后做出判断）				
我用到了英语（将匈语词组翻译成英语然后做出判断）				

其他（请说明） 例如：我做判断时一直处在一个匈牙利语的语境中，没有激活到其他语言。

Appendix C

Demographic and Language Learning Background Questionnaire

您现在是几年级?

- ◯ 大一
- ◯ 大二
- ◯ 其他

性别

- ◯ 男
- ◯ 女
- ◯ 其他

年龄

学习匈牙利语多久了？（请输入数字，以月为单位）

是否从大学开始接触匈牙利语以及学习匈牙利语?

- ◯ 是
- ◯ 不是（请说明从什么时候开始学过）

平均每天花在匈牙利语上的时间是多长？（请输入数字，以小时为单位。可以输入小数。例如：1.5，代表一个半小时。）

平均每天 **课外** 花在匈牙利语上的时间是多长？（请输入数字，以小时为单位。可以输入小数。例如：1.5，代表一个半小时。）

学习英语多久了？（请输入数字，以月为单位）

平均每天花在英语上的时间是多长？（请输入数字，以小时为单位。可以输入小数。例如：1.5，代表一个半小时。）

平均每天 **课外** 花在英语上的时间是多长？（请输入数字，以小时为单位。可以输入小数。例如：1.5，代表一个半小时。）

Appendix D

Consent form and Information sheet

DEPARTMENT OF EDUCATION

UNIVERSITY OF OXFORD

[L1 and L2 phonological activation during L3 word processing]

CUREC Approval Reference: C1B-24TT-Educ-038

General Information

The aim of this research is to explore cross-language activation in L3 processing. We appreciate your interest in participating in this online task. You have been invited to participate as you are a Hungarian majoring student in a Chinese university. Please read through this information before agreeing to participate (if you wish to) by ticking the 'yes' box below. You may ask any questions before deciding to take part by contacting the researcher (details below).

The Principal Researcher is Chenxiang Peng, who is attached to the Department of Education at the University of Oxford. This research is being completed under the supervision of Dr. Faidra Faitaki. The results will be written up for a Master's degree.

In the online task, you will complete a judgement tasks. You will be shown of several groups of words (each group containing 2 words). And you will have to click "Yes" or "No" to indicate whether the word pairs are related. Afterwards there will be a few small questions about the task process. The entire process should take about 20-30 minutes. No background knowledge is required. Your results will be anonymized and will only be used by the researcher for the analytical purpose of his dissertation research project. No third party will be given access to your data. You can enter your email address in the last page if you wish to enter the prize draw, in which you have a chance to win a 50-pound-voucher.

Do I have to take part?

No. Please note that participation is voluntary. If you do decide to take part, you may withdraw at any point for any reason before submitting your answers by pressing the 'Exit' button/ closing the browser. We have included a 'Prefer not to say' option for the question part should you prefer not to answer a particular question.

How will my data be used?

We will only collect your email address if you want to enter the prize draw. This will be done through the University of Oxford's Nexus 365 Forms, which is a secure platform. The email addresses will be stored on the University's Nexus 365 OneDrive, and will be deleted after the prize draw. The prize will be given out in the form of voucher. Other than that, we will not collect any data that could directly identify you. Your IP address will not be stored. The responses you provide to the tasks will be stored in a password-protected electronic file on University of Oxford's Nexus 365 OneDrive, and may be used in academic publications. Research data will be stored for 3 years after publication or public release of the work of the research.

Who will have access to my data?

The University of Oxford is the data controller with respect to your personal data and, as such, will determine how your personal data is used in the research. The University will process your personal data for the purpose of the research outlined above. Research is a task that we perform in the public interest. Further information about your rights with respect to your personal data is available from https://compliance.admin.ox.ac.uk/individual-rights.

Who has reviewed this research?

The application was reviewed and approved by my supervisor on behalf of the Departmental of Education's Research Ethics Committee.

Who do I contact if I have a concern or I wish to complain?

If you have a concern about any aspect of this research, please speak to Chenxiang Peng <chenxiang.peng@education.ox.ac.uk> or his supervisor Dr. Faidra Faitaki <faidra.faitaki@education.ox.ac.uk>, and we will do our best to answer your query. We will acknowledge your concern within 10 working days and give you an indication of how it will be dealt with. If you remain unhappy or wish to make a formal complaint, please contact the Chair of the Research Ethics Committee at the University of Oxford who will seek to resolve the matter as soon as possible: Education Departmental Research Ethics Committee (DREC), email: student.curec@education.ox.ac.uk

Please note that you may only participate in this survey if you are 18 years of age or over.

☐ I certify that I am 18 years of age or over

If you have read the information above and agree to participate with the understanding that the data (including any personal data) you submit will be processed accordingly, please tick the box below to start.

☐ Yes, I agree to take part

实验知情同意书

首先，感谢您参与此线上实验！本次实验数据将用于本人撰写应用语言学及二语习得理学硕士毕业论文。请阅读以下信息。若您同意参与实验请勾选文末“我同意”的方框以正式开始实验。

【被试要求】

请确认您满足以下所有要求:

- 年满 18 岁
- 大一或者大二的匈牙利语专业在读大学生
- 母语为中文，会英语

【研究内容】

本次实验是一个探究语言处理方式的简单心理语言学实验。实验将持续 20-30 分钟。实验过程非常简单，主要是对屏幕上出现的词做出一些判断，并在之后回答一些问题。您的答案是完全匿名的并且仅会用于论文研究。任何第三方都无法访问您的数据。

【关于研究者】

主要研究者为彭辰翔，就读于牛津大学教育系应用语言学及二语习得。这项研究是在 Dr. Faidra Faitaki 的指导下完成的。

【自愿参与】

参与实验是完全自愿的。您也可以随时选择退出。若您选择中途退出请务必告诉研究者。请注意，只有完成所有实验才有资格参加抽奖。

【隐私与数据安全】

如果您愿意参与抽奖，您可以将邮箱地址填写到结束页中的 Nexus 365 Microsoft 表单链接。您的信息在这里将会收到保护，并且抽奖结束后邮件地址也会被删除。除此之外，我们不会收集任何可以直接识别您的数据（例如 IP

地址等）。我们将采取一切合理措施确保数据的安全。您在实验中的答案将存储在牛津大学安全服务器上的受密码保护的电子文件中，并可能用于学术出版。研究数据将在发表或公开发布研究成果后存储 3 年。

【审查与审批】

这项研究已由牛津大学研究伦理委员会审查，并获得了伦理审批 [C1B-24TT-Educ-038]。

【联系方式】

若您对实验有任何问题可以联系研究者本人，彭辰翔 <chenxiang.peng@education.ox.ac.uk> 或他的导师 Dr. Faidra Faitaki <faidra.faitaki@education.ox.ac.uk>。我们会尽力解决您的问题。若您希望提交投诉，请联系牛津大学研究伦理委员会主席（Education Departmental Research Ethics Committee (DREC)，邮箱: student.curec@education.ox.ac.uk

☐ 我同意

Appendix E

CUREC Approval Letter

I am writing to acknowledge receipt of your CUREC 1B application entitled '*L1 and L2 lexical form activation during L3 word processing*'. The application was reviewed and approved by ____, your supervisor. No further approval from the Education DREC is required for applications reviewed under the CUREC 1B process. As such, the project will not receive a formal letter of ethical approval from the SSH IDREC.

The ethics reference for your application is [C1B-24TT-Educ-038]. Please add this reference to your CUREC 1B form and include it on documents for the research participants such as the participant information sheet.

Appendix F

Message for Participants

VOLUNTEERS NEEDED FOR A LINGUISTIC RESEARCH

We are looking for university students to participate in a simple psycholinguistic experiment. You may win £50 voucher through a prize draw!

To participate in the study, you must meet all of the following conditions:

- A Hungarian major student in China,
- A 1^{st} of 2^{nd} year university student
- Age above 18

The experiment will be conducted online and will last about 20-30 min. You will be asked to perform simple decision tasks and answer a few questions.

If you have a concern about any aspect of this research, please speak to _____, and we will do our best to answer your query. There is no obligation to take part.

Thank you!

语言学实验被试招募

您好，我是来自牛津大学应用语言学及二语习得专业的一名在读硕士生，正在为我的硕士论文招募被试，收集数据。实验过程轻松简单，还有机会抽中 200 元奖金。如果您满足要求，欢迎您积极参加！

【被试要求】

您需要同时满足以下所有要求：

- 年满 18 岁
- 大一或者大二的匈牙利语专业在读大学生
- 母语为中文，会英语

【实验内容】

实验将在线上进行，**需要用到电脑**，持续约 20-25 分钟。实验过程中需要被试者做出一些简单的判断以及回答问题。

【参与实验】

参与实验是完全自愿的。

Appendix G

The Hungarian Placement Test (adopted from https://hungarianlesson.eu/quiz/placement-test/)

1. Mit kérsz?

Kérek egy kávé.

Kérek egy kávétot.

Kérek kávét.

Kérek egy kávét.

Nem tudom.

2. Hol élsz?

Magyarország

Magyarországban

Magyarországon

Magyarországen

Nem tudom.

3. Hány éves vagy?

22 év

22 éves

22 évet

22 évek

Nem tudom.

4. 48

negyvenhat

negyvenhét

negyvennyolc

nyolcvannégy

Nem tudom.

5. Milyen nyelven beszélsz?

Magyarul és németul.

Magyarul és németül.

Magyarül és németul.

Magyarül és németül.

Nem tudom.

6. Hányadik emeleten laksz?

kettő

kettes

kettedik

második

Nem tudom.

7. Ki Ő? Az apám apja...

az én anyám.

az én nagybátyám.

az én nagypapám.

az én testvérem.

Nem tudom.

8. Milyen színű a bor?

piros

vörös

kék

fekete

Nem tudom.

9. Melyik a korrekt válasz?

A magyar lányok szép.

A magyarok lányok szép.

A magyar lányok szépek.

Nem tudom.

10. Hány óra van? 7:45

reggel negyed 7

reggel háromnegyed 7

reggel negyed 8

reggel háromnegyed 8

Nem tudom.

11. Milyen pizzát kérsz?

sonka

sonkás

sonkát

sonkásat

Nem tudom.

12. Kié ez a toll?

az enyém

az én

a nekem

az engem

Nem tudom.

13. Hogy tetszik __________?

Budapest

Budapestet

Budapestek

Budapestről

Nem tudom.

14. Nagyon szeretem ____________.

magyar étel

a magyar étel

a magyar ételek

a magyar ételeket

Nem tudom.

15. Nagyon szeretlek ___________.

te

tet

téged

őt

Nem tudom.

16. Nagyon szeretek a szabadidőmben ___________.

sportol

sportot

sportolni

sportokat csinalni

Nem tudom.

17. Hol vannak a __________?

toll

tollat

tollak

tollakat

Nem tudom.

18. Hova mész?

A repülőtérre.

A repülőtérbe.

A repülőtéren.

A repülőterek.

Nem tudom.

19. Honnan jösz?

A boltba.

A boltból.

A boltban.

A bolton.

Nem tudom.

20. én sietek, te sietsz, ő siet, mi ...?

siettek

sietjük

sietünk

Nem tudom.

21. Hova mész ma?

fodrászba

fodrásznál

fodrászhoz

fodrásztól

Nem tudom.

22. Tegnap (én) moziban ___________ Csillával.

vagyok

leszek

voltam

vannak

Nem tudom.

23. (Te) mit ___________ tegnap este?

ettem

ettél

etted

ettetek

Nem tudom.

24. Mióta élsz Magyarországon?

három éve

három év

három évek

három éves

Nem tudom.

25. __________ tanultál magyarul?

Hány évig

Hány évek

Hány éves

Mióta

Nem tudom.

26. István nagyon beteg. Nem __________ dolgoznia és sokat __________ pihennie.

szabad/szabad

szabad/kell

kell/kell

kell/tilos

Nem tudom.

27. Kissék soha __________ voltak még Berlinben.

-

még

nem

többé

Nem tudom.

28. Ádám és Éva három évvel ezelőtt __________. Most már nem házasok.

elválni

elválik

elvált

elváltak

Nem tudom.

29. Kriszta 167 cm magas, Éva is 167 cm magas. Mind a ketten __________ magasok.

ugyanaz

ugyanannál

ugyanazt

ugyanolyan

Nem tudom.

30. Hova tegyem a könyveket? _____ _____ az asztalra.

Tegyél ide

Tedd ide

Tenni ide

Tesz oda

Nem tudom.

31. - Nagyon szomjas vagyok. - ________ egy pohár vizet.

Iszik

Igyad

Igyál

Inni

Nem tudom.

32. - Elnézést! __________ hol van a Keleti pályaudvar?

Megtudni mondani

Megmond

Meg tud mondani

Meg tudja mondani?

Nem tudom.

33. Mit csinálnál, ha sok pénzed __________?

lesz

lenni

lett

lenne

Nem tudom.

34. Ha tegnap nem __________ az eső, moziba __________.

esne/megyünk

esett/mentünk

esett volna/mentünk volna

esne/menni

Nem tudom.

35. Ezt a gyógyszert __________ kétszer kell bevennie.

nap

napot

napig

naponta

Nem tudom.

36. Ha jólesett valami, akkor azt az ember:

utálta

nagyon akarta

nagyon félt

nagyon élvezte

Nem tudom.

37. Imre nagyon fél a __________.

póknak

pókoknak

pókot

pókoktól

Nem tudom.

38. - Szerintem Anna egy kicsit kövér. - __________. Szerintem Anna nagyon csinos.

Nem egyetértek veled.

Nem értek egyet veled.

Nem egyetértek neked.

Nem értek egyet neked.

Nem tudom.

39. Péter erősebb __________.

Tomit

Tominak

Tominál

Tomihoz

Nem tudom.

40. A magyaróra hamarosan __________.

elkezd

elkezdem

elkezdenek

elkezdődik

Nem tudom.

41. Péternek nagyon __________ a barátai.

hiányzik

hiányol

hiányoznak

hiányolják

Nem tudom.

42. Ez a leves nem finom, egyszerűen rossz és _________.

ehető

ehetnél

megehető

ehetetlen

Nem tudom.

43. Ha __________ a házi feladatot elmehetsz moziba.

írod

elírod

megírod

felírod

Nem tudom.

44. Megígérem, hogy __________ a házi feladatot.

megírlak

meg fogod írni

megírni fogom

megírom

Nem tudom.

45. - Este otthon leszel?

__________ később?

Visszahívni

Tudok hívni vissza

Tudhatlak hívni vissza

Vissza tudlak hívni

Nem tudom.

46. Mi a szinonimája? Elveszíti az eszméletét.

elmegy

elalszik

elájul

meghal

Nem tudom.

47. Nagyon hosszú már a hajam, ezért holnap ____________ a fodrásszal.

levágom

levágja

levágat

levágatom

Nem tudom.

48. Az immunrendszert a sok mozgás is __________.

erősödik

erősíti

erősebbek

erősebben

Nem tudom.

49. A hetes busz __________ indul, __________ tegnap találkoztunk.

onnan/ahol

onnan/ahova

oda/ahonnan

ott/itt

Nem tudom.

50. David nagyon jól beszél magyarul, __________ magyar a barátnője.

tehát

azaz

tudniilik

ugyanis

Nem tudom.

Appendix H

Participants Strategy Questionnaire Data

Participant Private ID	你是否注意到有些词组有一些规律？（头脑风暴一下！）如果有请尝试描述一下是什么样的规律。	你是否注意到有些词组有一些规律？（头脑风暴一下！）如果有请尝试描述一下是什么样的规律。
11213767	__other	2
11215408	没有	1
11215437	__other	2
11219192	__other	2
11219884	__other	2
11220419	__other	2
11220533	__other	2
11221080	__other	2
11226237	没有	1
11227065	__other	2
11234499	没有	1
11239248	__other	2
11257001	没有	1
11257006	__other	2
11257037	没有	1
11257057	__other	2
11257073	没有	1
11257656	__other	2
11257703	__other	2
11258177	没有	1
11258215	__other	2
11261001	没有	1
11261386	__other	2

11264031	__other	2
11265746	__other	2
11266843	__other	2
11267452	__other	2
11277070	__other	2
11279013	__other	2
11279255	__other	2
11279464	没有	1
11279645	__other	2

Participant Private ID	你是否注意到有些词组有一些规律？（头脑风暴一下！）如果有请尝试描述一下是什么样的规律。
11213767	有同类的，比如鞋子、咖啡和茶；有属性上相关的，比如医生治病和飞行员开飞机；有根据一定特性联想到的，如树通常是绿色的；也有更发散的联想，比如歌曲和风有联系是因为想到 tavaszi szély 这首曲子
11215408	
11215437	一些词之间存在种类关联，例如电脑和电影；还有一些词在翻译成中文后十分相似，例如 rizs 和 méter 翻译成中文都是“米”。
11219192	形容词加名词或者反义词
11219884	有一些是形状相似，院子和球。有些是用途相似，例如家具里的座子和椅子。还有的是生活中性质可以常常联系到一起的，例如花和其是否好看。还有反义词的规律，例如大和小。我觉得其中有很多相似的地方，从不同的角度其实都是可以找到规律的。
11220419	有含义相反的，也有含义相关的（）如“fa”和“zöld”
11220533	有些是反义词，有些是同类词
11221080	感觉有些词属于一类事物，或常成对出现（桌椅，咖啡茶）
11226237	
11227065	某些词是同一个类别的，比如桌子和椅子都属于家具；还有属于关联性极强的单词，比如歌曲和唱歌，通常作为动宾结构。

11234499	
11239248	一些词组属于反义词，一些词组属于同一类事物，还有一些词组中的词具有相关性
11257001	
11257006	有些词组意思相近或者反意，还有些在形态和颜色上有联系，比如树和绿色
11257037	
11257057	relative word like tree and grenn
11257073	
11257656	有一些是互相关联的，有一些是意思相反的
11257703	有些匈牙利语单词跟英文单词相似，即使不认识匈牙利语单词也可以通过英文推敲出来
11258177	
11258215	互为反义词，或者配套出现
11261001	
11261386	近义词，或者包含
11264031	反义词
11265746	反义词
11266843	含有相同字母 中文发音一样
11267452	英译词 有 的词组翻译成中文是同一个字 有的词语是对 另一个词的描述 同一个类型等
11277070	同义词或反义词或有联系的词
11279013	反义词，描述性的词（树是绿色），职业和工作地点
11279255	反义词，近义词，可以修饰的，形容词+名词
11279464	
11279645	反义词，职业和工作地点，

Participant Private ID	**我用到了我的母语（将匈语词组翻译成中文然后做出判断）**	**我用到了我的母语（将匈语词组翻译成中文然后做出判断）Quantised**	**我用到了英语（将匈语词组翻译成英语然后做出判断）**	**我用到了英语（将匈语词组翻译成英语然后做出判断）Quantised**

11213767	总是	3	有时候	2
11215408	总是	3	有时候	2
11215437	总是	3	有时候	2
11219192	有时候	2	有时候	2
11219884	总是	3	从不	1
11220419	总是	3	有时候	2
11220533	总是	3	从不	1
11221080	总是	3	有时候	2
11226237	总是	3	从不	1
11227065	总是	3	有时候	2
11234499	总是	3	从不	1
11239248	有时候	2	从不	1
11257001	有时候	2	从不	1
11257006	总是	3	有时候	2
11257037	总是	3	从不	1
11257057	总是	3	总是	3
11257073	有时候	2	从不	1
11257656	有时候	2	有时候	2
11257703	总是	3	有时候	2
11258177	有时候	2	有时候	2
11258215	总是	3	从不	1
11261001	有时候	2	从不	1
11261386	总是	3	从不	1
11264031	总是	3	总是	3
11265746	有时候	2	有时候	2
11266843	总是	3	有时候	2
11267452	总是	3	有时候	2
11277070	总是	3	总是	3
11279013	总是	3	有时候	2

11279255	总是	3	从不	1
11279464	总是	3	有时候	2
11279645	有时候	2	从不	1

Participant Private ID	**其他（请说明）例如：我做判断时一直处在一个匈牙利语的语境中，没有激活到其他语言。**
11213767	
11215408	
11215437	我做判断时处在中文语境中，因此经常忘记匈牙利语与英语之间的联系。
11219192	
11219884	做这些题的时候我一直处在匈牙利语的语境中，在没有出现其他语言的时候，我并没有激活其他语言。
11220419	pilota 和 repülőgép
11220533	
11221080	
11226237	有些词不认识就瞎写的，，不好意思
11227065	只有极少的外来词汇可能会想到英语，平时记忆的时候一部分会借用到英语辅助学习记忆匈牙利语单词。
11234499	
11239248	
11257001	大部分单词已经学过，少部分单词无法快速判断所以选了否
11257006	
11257037	
11257057	they say “szia” i will translate it to English or Chinese then reply it.
11257073	
11257656	
11257703	
11258177	

11258215	
11261001	
11261386	
11264031	
11265746	
11266843	
11267452	
11277070	
11279013	我在做题时，一直有激发到我的母语（中文），先翻译为中文，后进行判断。另外，我的英语词汇积累并不多，所以很少使用匈翻英来判断；但有一些词，我并不认识，所以没办法无法判断是否相关。
11279255	大脑会立刻将匈语单词翻译成汉语，再判断
11279464	
11279645	

Appendix I

Descriptive Statistics

Initial Data of Error Rates and Proficiency Scores

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
%G1 error rate out of 10	32	0.00%	80.00%	27.5000%	21.09885%	445.161	.725	.414	-.117	.809
%G2 error rate out of 10	32	0.00%	100.00%	23.7500%	21.36473%	456.452	1.613	.414	3.948	.809
%G3 error rate out of 10	32	0.00%	100.00%	15.6250%	21.08929%	444.758	2.405	.414	7.501	.809
%error rate out of 45	32	6.67%	64.44%	25.6944%	11.86594%	140.800	1.239	.414	2.521	.809
LexTale final score out of 100	32	37.50	67.50	50.4297	7.42306	55.102	.473	.414	-.336	.809
HU test score out of 100	32	38	84	64.38	13.416	179.984	-.460	.414	-.793	.809

Valid N (listwise)	32									

Adjusted Data of Error Rates and Proficiency Scores

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Participant Private ID	32	65878	11213767	11279645	11249081.25	3955.427	22375.275	500652924.710	-.325	.414	-1.352	.809
%G1 error rate out of 10	32	80.00%	0.00%	80.00%	27.5000%	3.72978%	21.09885%	445.161	.725	.414	-.117	.809
%G2 error rate out of 10	32	60.00%	0.00%	60.00%	22.5000%	3.11086%	17.59765%	309.677	.616	.414	-.471	.809
%G3 error rate out of 10	32	50.00%	0.00%	50.00%	14.0625%	2.79903%	15.83369%	250.706	1.145	.414	.464	.809

%error rate out of 45	32	42.22%	6.67%	48.89%	25.2084%	1.84962%	10.46303%	109.475	.583	.414	.024	.809
LexTale final score out of 100	32	30.00	37.50	67.50	50.4297	1.31222	7.42306	55.102	.473	.414	-.336	.809
HU placement test score out of 50	32	23	19	42	32.19	1.186	6.708	44.996	-.460	.414	-.793	.809
HU test score out of 100	32	46	38	84	64.38	2.372	13.416	179.984	-.460	.414	-.793	.809
Valid N (listwise)	32											

Descriptive Statistics of Reaction Time Data

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	Kurtosis

	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Participant Private ID	320	65878.0	11213767.0	11279645.0	11249081.3	1233.0	22057.4	486527920.6	-.3	.1	-1.3	.3
G1_RT	320	7839.8	160.3	8000.1	3448.2	104.9	1876.3	3520484.1	1.0	.1	.2	.3
G2_RT	320	7942.6	57.2	7999.8	3197.2	102.7	1837.2	3375249.8	1.1	.1	.5	.3
G3_RT	320	7981.0	13.9	7994.9	2862.8	93.6	1674.9	2805383.4	1.2	.1	1.2	.3
Valid N (listwise)	320											

Appendix J

Paired Sample t-test Results for Research Question 1

Error Rates Analysis

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	%G1 error rate out of 10	27.5000%	32	21.09885%	3.72978%
	%G3 error rate out of 10	14.0625%	32	15.83369%	2.79903%
Pair 2	%G2 error rate out of 10	22.5000%	32	17.59765%	3.11086%
	%G3 error rate out of 10	14.0625%	32	15.83369%	2.79903%

Paired Samples Test

		Paired Differences					t	df	Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	%G1 error rate out of 10 - %G3 error rate out of 10	13.43750%	14.50459%	2.56407%	8.20804%	18.66696%	5.241	31	<.001	<.001
Pair 2	%G2 error rate out of 10 - %G3 error rate out of 10	8.43750%	14.61536%	2.58366%	3.16810%	13.70690%	3.266	31	.001	.003

Paired Samples Effect Sizes

			Standardizer[a]	Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
Pair 1	%G1 error rate out of 10 - %G3 error rate out of 10	Cohen's d	14.50459%	.926	.506	1.337
		Hedges' correction	14.86771%	.904	.493	1.304
Pair 2	%G2 error rate out of 10 - %G3 error rate out of 10	Cohen's d	14.61536%	.577	.198	.948
		Hedges' correction	14.98126%	.563	.194	.925

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation of the mean difference.

Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Reaction Time Analysis

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	G1_RT	3448.231	320.000	1876.295	104.888
	G3_RT	2862.815	320.000	1674.928	93.631
Pair 2	G2_RT	3197.170	320.000	1837.185	102.702
	G3_RT	2862.815	320.000	1674.928	93.631

Paired Samples Test

	Paired Differences Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Significance One-Sided p	Two-Sided p
Pair 1 G1_RT - G3_RT	585.417	2201.008	123.040	343.344	827.489	4.758	319.000	<.001	<.001

Pair 2	G2_RT - G3_RT	334.356	2092.278	116.962	104.241	564.470	2.859	319.000	.002	.005

Paired Samples Effect Sizes

			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
Pair 1	G1_RT - G3_RT	Cohen's d	2201.008	.266	.154	.377
		Hedges' correction	2206.199	.265	.154	.376
Pair 2	G2_RT - G3_RT	Cohen's d	2092.278	.160	.049	.270
		Hedges' correction	2097.214	.159	.049	.269

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation of the mean difference.

Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Appendix K

Paired Sample t-test Results for Research Question 2

Error Rates Analysis

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	%G1 error rate out of 10	27.500%	32.000	21.099	3.730
	%G2 error rate out of 10	22.500%	32.000	17.598	3.111

Paired Samples Test

		Paired Differences					t	df	Significance	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				One-Sided p	Two-Sided p
					Lower	Upper				
Pair 1	%G1 error rate out of 10 - %G2 error rate out of 10	5.000	12.952	2.290	.330	9.670	2.184	31.000	.018	.037

Paired Samples Effect Sizes

			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
Pair 1	%G1 error rate out of 10 - %G2 error rate out of 10	Cohen's d	12.952	.386	.024	.743
		Hedges' correction	13.276	.377	.023	.724

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation of the mean difference.

Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Reaction Time Analysis

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	G1_RT	3448.231	320.000	1876.295	104.888
	G2_RT	3197.170	320.000	1837.185	102.702

Paired Samples Test

		Paired Differences					t	df	Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			One-Sided p	Two-Sided p
Pair 1	G1_RT - G2_RT	251.061	2290.903	128.065	-.898	503.020	1.960	319.000	.025	.051

Paired Samples Effect Sizes

			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
Pair 1	G1_RT - G2_RT	Cohen's d	2290.903	.110	.000	.219
		Hedges' correction	2296.307	.109	.000	.219

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation of the mean difference.

Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Appendix L

Correlation Analysis and Regression Analysis Results for Research Question 3

Correlation Analysis

Correlations

		Group1_Reaction time	Group2_Reaction time	Group3_Reaction time	Filler_Reaction time	%G1 error rate out of 10	%G2 error rate out of 10	%G3 error rate out of 10	%error rate out of 45	LexTale final score out of 100	HUtest_score
Group1_Reaction time	Pearson Correlation	1.00	.24**	.24**	.06	.11*	.05	.17**	.11	.02	-.13*
	Sig. (2-tailed)		<.001	<.001	.25	.05	.35	.00	.05	.78	.02
	Sum of Squares and Cross-products	1123034417.91	262775913.66	236288469.41	67661997.43	1367924.49	539856.44	1575656.89	668473.83	69304.63	-1029537.44
	Covariance	3520484.07	823748.95	740716.21	212106.58	4288.16	1692.34	4939.36	2095.53	217.26	-3227.39

	N	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00
Group2_Reaction time	Pearson Correlation	.24**	1.00	.29**	.05	.11	.09	.06	.06	.02	-.06
	Sig. (2-tailed)	<.001		<.001	.41	.05	.10	.25	.26	.72	.33
	Sum of Squares and Cross-products	262775913.66	1076704686.33	287579128.75	47731268.62	1335122.09	948301.59	585062.84	380670.32	85822.34	-427506.70
	Covariance	823748.95	3375249.80	901501.97	149627.80	4185.34	2972.73	1834.05	1193.32	269.04	-1340.15
	N	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00
Group3_Reaction time	Pearson Correlation	.24**	.29**	1.00	.02	.02	.04	.17**	.13*	-.04	-.16**
	Sig. (2-tailed)	<.001	<.001		.74	.79	.45	.00	.02	.49	.00

	Sum of Squares and Cross-products	236288469.41	287579128.75	894917295.29	17206770.11	170119.47	393152.26	1415495.00	720085.38	-153110.48	-1124354.16
	Covariance	740716.21	901501.97	2805383.37	53939.72	533.29	1232.45	4437.29	2257.32	-479.97	-3524.62
	N	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00
Filler_Reaction time	Pearson Correlation	.06	.05	.02	1.00	-.02	-.01	-.03	-.01	-.05	.09
	Sig. (2-tailed)	.25	.41	.74		.76	.90	.63	.82	.38	.11
	Sum of Squares and Cross-products	67661997.43	47731268.62	17206770.11	983957822.81	-203754.56	-69123.65	-237708.08	-75754.31	-201912.42	661091.68
	Covariance	212106.58	149627.80	53939.72	3084507.28	-638.73	-216.69	-745.17	-237.47	-632.95	2072.39

	N	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00
%G1 error rate out of 10	Pearson Correlation	.11*	.11	.02	-.02	1.00	.79**	.73**	.80**	.16**	-.35**
	Sig. (2-tailed)	.05	.05	.79	.76		<.001	<.001	<.001	.01	<.001
	Sum of Squares and Cross-products	1367924.49	1335122.09	170119.47	-203754.56	138000.00	91000.00	75250.00	55056.14	7593.75	-30500.00
	Covariance	4288.16	4185.34	533.29	-638.73	432.60	285.27	235.89	172.59	23.80	-95.61
	N	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00
%G2 error rate out of 10	Pearson Correlation	.05	.09	.04	-.01	.79**	1.00	.62**	.76**	-.11	-.16**
	Sig. (2-tailed)	.35	.10	.45	.90	<.001		<.001	<.001	.06	.00

	Sum of Squares and Cross-products	539856.44	948301.59	393152.26	-69123.65	91000.00	96000.00	53750.00	43389.31	-4343.75	-11900.00
	Covariance	1692.34	2972.73	1232.45	-216.69	285.27	300.94	168.50	136.02	-13.62	-37.30
	N	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00
%G3 error rate out of 10	Pearson Correlation	.17**	.06	.17**	-.03	.73**	.62**	1.00	.84**	-.01	-.40**
	Sig. (2-tailed)	.00	.25	.00	.63	<.001	<.001		<.001	.83	<.001
	Sum of Squares and Cross-products	1575656.89	585062.84	1415495.00	-237708.08	75250.00	53750.00	77718.75	43229.57	-433.59	-26287.50
	Covariance	4939.36	1834.05	4437.29	-745.17	235.89	168.50	243.63	135.52	-1.36	-82.41
	N	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00

%error rate out of 45	Pearson Correlation	.11	.06	.13*	-.01	.80**	.76**	.84**	1.00	-.18**	-.52**
	Sig. (2-tailed)	.05	.26	.02	.82	<.001	<.001	<.001		<.001	<.001
	Sum of Squares and Cross-products	668473.83	380670.32	720085.38	-75754.31	55056.14	43389.31	43229.57	33937.25	-4410.68	-22669.45
	Covariance	2095.53	1193.32	2257.32	-237.47	172.59	136.02	135.52	106.39	-13.83	-71.06
	N	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00
LexTale final score out of 100	Pearson Correlation	.02	.02	-.04	-.05	.16**	-.11	-.01	-.18**	1.00	-.17**
	Sig. (2-tailed)	.78	.72	.49	.38	.01	.06	.83	<.001		.00

	Sum of Squares and Cross-products	69304.63	85822.34	-153110.48	-201912.42	7593.75	-4343.75	-433.59	-4410.68	17081.54	-5351.56
	Covariance	217.26	269.04	-479.97	-632.95	23.80	-13.62	-1.36	-13.83	53.55	-16.78
	N	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00
HUtest_score	Pearson Correlation	-.13*	-.06	-.16**	.09	-.35**	-.16**	-.40**	-.52**	-.17**	1.00
	Sig. (2-tailed)	.02	.33	.00	.11	<.001	.00	<.001	<.001	.00	
	Sum of Squares and Cross-products	-1029537.44	-427506.70	-1124354.16	661091.68	-30500.00	-11900.00	-26287.50	-22669.45	-5351.56	55795.00
	Covariance	-3227.39	-1340.15	-3524.62	2072.39	-95.61	-37.30	-82.41	-71.06	-16.78	174.91
	N	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Regression Analysis

ENtest & HU test with Group 1 Error Rate:

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	LexTale final score out of 100[b]	.	Enter
2	HUtest_score[b]	.	Enter

a. Dependent Variable: %G1 error rate out of 10

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.156[a]	.024	.021	20.575
2	.361[b]	.130	.125	19.457

a. Predictors: (Constant), LexTale final score out of 100

b. Predictors: (Constant), LexTale final score out of 100, HUtest_score

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3375.868	1	3375.868	7.974	.005[b]
	Residual	134624.132	318	423.346		
	Total	138000.000	319			
2	Regression	17988.018	2	8994.009	23.757	<.001[c]
	Residual	120011.982	317	378.587		
	Total	138000.000	319			

a. Dependent Variable: %G1 error rate out of 10

b. Predictors: (Constant), LexTale final score out of 100

c. Predictors: (Constant), LexTale final score out of 100, HUtest_score

HU test with Group 1 Error Rate:

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	HUtest_score[b]	.	Enter

a. Dependent Variable: %G1 error rate out of 10

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.348[a]	.121	.118	19.53286%

a. Predictors: (Constant), HUtest_score

ANOVA[a]

Model	Sum of Squares	df	Mean Square	F	Sig.

1	Regression	16672.641	1	16672.641	43.699	<.001[b]
	Residual	121327.359	318	381.533		
	Total	138000.000	319			

a. Dependent Variable: %G1 error rate out of 10

b. Predictors: (Constant), HUtest_score

ENtest and HU test with Total Error Rate:

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	LexTale final score out of 100[b]	.	Enter
2	HUtest_score[b]	.	Enter

a. Dependent Variable: %error rate out of 45

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.183[a]	.034	.031	10.15576%
2	.590[b]	.349	.344	8.35141%

a. Predictors: (Constant), LexTale final score out of 100

b. Predictors: (Constant), LexTale final score out of 100, HUtest_score

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1138.895	1	1138.895	11.042	<.001[b]
	Residual	32798.360	318	103.139		

	Total	33937.255	319			
2	Regression	11827.771	2	5913.885	84.792	<.001[c]
	Residual	22109.484	317	69.746		
	Total	33937.255	319			

a. Dependent Variable: %error rate out of 45

b. Predictors: (Constant), LexTale final score out of 100

c. Predictors: (Constant), LexTale final score out of 100, HUtest_score

HU test and Total Error Rate:

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	HUtest_score[b]	.	Enter

a. Dependent Variable: %error rate out of 45

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.521[a]	.271	.269	8.81799%

a. Predictors: (Constant), HUtest_score

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9210.573	1	9210.573	118.454	<.001[b]
	Residual	24726.682	318	77.757		
	Total	33937.255	319			

a. Dependent Variable: %error rate out of 45

b. Predictors: (Constant), HUtest_score

HU test and Group 1 Reaction Time:

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	HUtest_score[b]	.	Enter

a. Dependent Variable: Group1_Reaction time

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.130[a]	.017	.014	1863.2807709618

a. Predictors: (Constant), HUtest_score

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18997174.314	1	18997174.314	5.472	.020[b]
	Residual	1104037243.597	318	3471815.231		
	Total	1123034417.911	319			

a. Dependent Variable: Group1_Reaction time

b. Predictors: (Constant), HUtest_score

HU test and Group 3 Reaction Time:

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	HUtest_score[b]	.	Enter

a. Dependent Variable: Group3_Reaction time

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.159[a]	.025	.022	1656.187035494419200

a. Predictors: (Constant), HUtest_score

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22657447.390	1	22657447.390	8.260	.004[b]
	Residual	872259847.900	318	2742955.497		
	Total	894917295.289	319			

a. Dependent Variable: Group3_Reaction time

b. Predictors: (Constant), HUtest_score

HU test and Group 2 Error Rate:

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	HUtest_score[b]	.	Enter

a. Dependent Variable: %G2 error rate out of 10

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.163[a]	.026	.023	17.14367%

a. Predictors: (Constant), HUtest_score

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2538.041	1	2538.041	8.636	.004[b]
	Residual	93461.959	318	293.906		
	Total	96000.000	319			

a. Dependent Variable: %G2 error rate out of 10

b. Predictors: (Constant), HUtest_score

HU test and Group 3 Error Rate:

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	HUtest_score[b]	.	Enter

a. Dependent Variable: %G3 error rate out of 10

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.399[a]	.159	.157	14.33358%

a. Predictors: (Constant), HUtest_score

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12385.208	1	12385.208	60.283	<.001[b]

	Residual	65333.542	318	205.451		
	Total	77718.750	319			

a. Dependent Variable: %G3 error rate out of 10

b. Predictors: (Constant), HUtest_score