Chapter 4

Processing of L2 Phonological Word Forms

In the previous chapter, the phonological word forms of L2 words in low and high proficient late bilinguals were investigated. It was discovered that in late bilinguals the coding of L2 word representations seems to be influenced by the representation of L1 words, especially in the earlier stages of acquisition. Subsequently, the aim of this next study was to look into how these L2 words are then accessed in word production in late bilinguals.

4.1 Introduction

4.1.1 Keeping the Two Languages Apart

A central issue regarding bilingual word production is how bilinguals keep their two languages apart when speaking. This issue arises from the assumption that when a word is to be named, a concept does not only activate the target's lexical representation, but also lexical representations of semantically related words (Dell, 1986; Levelt et al., 1999). Evidence for this assumption comes from a series of picture-word interference (PWI) paradigms. In PWI paradigms, a target picture has to be named in the presence of a distractor word that is printed above or below the target picture. A common finding is that when the distractor word is semantically related to the target picture (e.g., sheep – COW; picture is upper-case) the picture is named more slowly compared to when the distractor word is unrelated (e.g., pencil – COW) to the target picture (e.g., Schriefers et al., 1990). This finding has led not only to the assumption that concepts activate semantically related words to some extent, but also to the assumption that lexical selection, the act of selecting the target word from a number of activated possible lexical representations, is competitive. According to this view, the semantic interference effect in the PWI paradigm arises because target selection is dependent on the activation of the target relative to the activation of other active alternatives (Levelt et al., 1999).

In the case of bilinguals, the finding and assumptions above lead to another assumption of how lexical selection takes place. It is assumed that a concept does not only activate semantically related items in one language, but also translation equivalents and other semantically related items in the other language. Evidence for this assumption comes from bilingual versions of the PWI paradigm. Corresponding to the monolingual semantic interference effect, semantically related distractors in a non-target language (e.g., mesa [table in Spanish] – CHAIR) interfere with target naming compared to unrelated (e.g., perro [dog] – CHAIR) distractors (Costa & Caramazza, 1999). The assumption that a shared concept activates lexical items in both languages then leads to the question of how the target item in the target language is selected. Three solutions have been proposed for this question.

The first solution is based on the finding that in bilingual PWI paradigms, identity (translation) distractors (e.g., mesa – TABLE) facilitate target naming compared to unrelated (e.g., perro – TABLE) distractors. This finding has led to the proposal that lexical selection is language specific and that only lexical items from the target language are considered, while non-target language alternatives are not considered (Costa & Caramazza, 1999; Costa et al., 1999). According to this view, the target language is specified within the concept to be expressed and language specificity is then achieved by a binding-and-checking mechanism (see Levelt et al., 1999; Roelofs, 1998). This binding-and-checking mechanism analyses whether activated nodes are linked to selected nodes at the previous concept level; for instance, whether a lexical node matches the intention of using the target language as specified in the concept. If a node does not match the previously selected nodes (e.g., the concept which also specifies the target language) it is discarded. In this case, the only influence non-target language alternatives have during selection is to send activation to their target language translation equivalent before they are discarded, hence the facilitation effect of translation equivalents (Costa & Caramazza, 1999; Costa et al., 1999).

This proposal leads back to the supported prediction that translation equivalent non-target language distractors (e.g., mesa – TABLE) facilitate target naming due to the distractor sending activation to the target. The proposal also leads to the supported prediction that semantically related non-target language distractors (e.g., mesa – CHAIR) interfere with target naming by sending activation to the semantically related word in the target language (TABLE) which then causes the semantic interference effect (table – CHAIR) also observed in monolinguals (Costa & Caramazza, 1999; Costa et al., 1999).

The second solution is similar to the first solution in that it states that the target language is specified at the concept level which subsequently causes the target lexical item in the target language to receive greater activation than its translation equivalent and other semantically related items (La Heij, 2005). La Heij (2005, p. 289) calls this "complex access, easy selection". The core idea behind this solution originates from the fact that in monolinguals there are also different words for the same concept, depending on the situation of use (e.g., people "go to the loo" when they are at the pub with their mates, but they "use the toilet" when they are at work). In each case it is argued that the right formulation (target language or level of formality) is specified in the conceptual representation sending greater activation to the target node (La Heij, 2005). Contrary to the first solution, in La Heij's proposal specifying the target language in the concept is enough to achieve an activity advantage at the lexical level for simple lexical selection. In the first solution, a backwards working binding and checking-mechanism is added to ensure that only the activity of items in the target language compete for selection (Costa & Caramazza, 1999; Costa et al., 1999).

The third solution utilises language-external mechanisms to control and make sure that the target language is activated. Green (1998) Inhibition Control (IC) model is based on Norman and Shallice (1986) supervisory attentional system (SAS) and consists of a system including a conceptualiser, the SAS, a set of language task schemas and language tags at the lemma level within the bilingual lexico-semantic system. The conceptualiser is responsible for constructing conceptual representations, which in the case of word production includes the concept to be expressed (e.g., dog/Hund) and the language in which it should be expressed in (e.g., German). The process of constructing a conceptual representation is driven by a goal to achieve something through the use of language. This conceptual representation is then transmitted to evoke language task-schemas via the SAS and is also transmitted to the bilingual lexico-semantic system. The SAS, as defined by Norman and Shallice (1986), is an entity that monitors the current situation and intervenes when a novel or unforeseen situation requires actions or, in this case, communicative intentions to be inhibited, altered or constructed anew. This entity transmits the current conceptual representations including the communicative intention to evoke language task schemas. Language task schemas are, according to Green (1998), "mental devices or networks that individuals may construct or adapt on the spot in order to achieve a specific task" (p. 69). A current conceptual representation can activate a number of schemas. The intention to produce a word in German, for instance, could activate the schema for producing a word, for producing a word in German, for producing a word in English, and for translating a word from English to German. The appropriate schema is then selected by receiving more activation from the SAS and by also inhibiting competing schemas itself. At the same time, the conceptual representation is also transmitted to the bilingual lexico-semantic system in which it activates corresponding lemmas. As with schema activation, not only the target lemma (e.g., Hund), but also similar lemmas (e.g., dog, Pudel, cat, Tier) are activated. Selecting the target lemma is then achieved by the language task schema (e.g., producing the word for the concept 'poodle' in German). Each lemma has a language tag which specifies what language the lemma is in. The language task schema can inhibit lemmas on the basis of the language tag so that the right lemma is selected for further processing. As the language tag is shared by all lemmas of a given language, inhibiting a language tag will result in the inhibition of other lemmas not selected in the first place. A prediction made by the IC model is that if the intention to produce one language (e.g., L2) changes to produce the other language (e.g., L1) this will take a while because of the inhibitory processes taking place at the language schema and the lemma level. If the intention changes, a new schema (e.g., produce L1 word) has to be involved that has to dominate the previously employed one (e.g., produce L2 word). Also, if the previous intention caused the lemmas of the previous non-target language (e.g., L1) to be inhibited through their language tags, it takes a while for these items to recover from inhibition to be used as the new target language. The amount of inhibition involved is theorised to depend on the dominance of schemas and lemmas, and therefore the more dominant schemas and lemmas are, the longer it will also take to switch back to use them (Green, 1998).

This prediction has been supported using language switching paradigms in which bilingual participants have to name digits or pictures, in either their L1 or L2, as indicated by a colour frame around the picture to be named. The critical feature of this task is the switch from a series of L1 trials to a series of L2 trials and vice versa. Using a switching paradigm, a study showed that it does not only take participants longer to name digits switching from one language to the other, but that it takes participants longer to name a digit when switching from their L2 to their L1 (Meuter & Allport, 1999). Following the predictions made by the IC model, Meuter and Allport (1999) explained these asymmetrical switching costs as being the result of a dominant L1 that requires greater inhibition than the L2 and, consequently, more time to recover from that inhibition.

4.1.2 Issues Within the Proposals

However, all three solutions come with their own issues (see Finkbeiner, Gollan, & Caramazza, 2006). In the study that found facilitation of reaction times when distractors were translation equivalents of the target in a bilingual PWI paradigm, it was also found that the presence of unrelated non-target language distractors (e.g., cerveza [beer] – SHEEP) produced faster target naming times compared to unrelated target language distractors (e.g., beer – SHEEP; Costa & Caramazza, 1999). If lexical selection is language specific and distractors in a non-target language also send activation to their translation equivalent (as shown in semantic interference and facilitation of reaction time when the distractor is a translation equivalent), then unrelated target and non-target language distractors should produce an equivalent amount of interference.

The finding that unrelated target language distractors produce more interference than unrelated non-target language distractors can, however, be explained by the "complex access, simple selection" proposal (La Heij, 2005). According to this proposal, lexical selection is easy, because the lexical entry in the target language gets the most activation thanks to language specification in the concept. Here, unlike unrelated non-target language distractors, unrelated target language distractors would receive some activation from the language specification and therefore cause interference. However, the "complex access, simple selection" proposal has difficulty accounting for the facilitation found in the identity condition of the bilingual PWI paradigm (Costa & Caramazza, 1999). In this condition, both target and distractor activate one concept, but in different languages. According to "complex access, simple selection," translation equivalents should actually be the strongest distractor as they receive almost as much activation as the target itself. However, contrary to that expectation, they have been found to facilitate target selection (Costa & Caramazza, 1999).

Furthermore, it has also been found that switching costs may be a post-access task effect. In a modified switching paradigm, participants had to switch between naming digits and pictures. The digits had to be named either in the participants' L1 or L2 indicated by a colour cue, while the pictures had to be named exclusively in the participants' L1 (Finkbeiner, Almedeida, et al., 2006). According to the IC model (Green, 1998), when saying a word in the L2, not only the translation equivalent in the L1 is inhibited, but the L1 in general, which then needs some time to recover when it is to be used again. Therefore it should not matter whether one switches from naming a digit in the L2 to naming a digit in the L1 or to naming a picture in the L1. The IC model predicts a switching cost in either case. Contrary to the predictions of the IC model, however, when switching from naming L2 digits to naming L1 pictures, no switching costs were found (Finkbeiner, Almedeida, et al., 2006).

Additionally, switching costs were found in monolinguals having to name either the colour a word was presented in or the word itself. Words had either a high frequency name (e.g., stone) or a low frequency name (e.g., pebble). When switching from colour naming to naming a high frequency word, reaction times were slower than when switching to a low frequency word. These findings were explained in terms of expectations after the response criterion changes from naming colours to naming words; in contrast with previous responses, the high frequency word becomes available too fast so one becomes suspicious of the response and blocks it at first. This would then also explain why it takes bilinguals longer to switch back to their, arguably, more readily available L1 after the response criterion (name the word in your L1 vs. name the word in your L2) changed (Finkbeiner, Almedeida, et al., 2006).

4.1.3 An Alternative View: Non-Competitive Selection

Given these issues with the previously introduced solutions, it has been argued that the assumption of competitive lexical selection needs to be re-examined; lexical selection is not necessarily a competitive process (Finkbeiner, Almedeida, et al., 2006; Finkbeiner, Gollan, & Caramazza, 2006; Miozzo & Caramazza, 2003). Evidence for this comes from the observation that once a semantically related distractor in the PWI paradigm is masked, it actually facilitates target naming (Finkbeiner & Caramazza, 2006). If lexical selection was competitive, a masked semantically related distractor should interfere with target naming nonetheless. Furthermore,Miozzo and Caramazza (2003) also challenged the assumption that lexical selection is competitive by looking at the interference of unrelated distractors that varied in frequency. According to the assumption that selection is competitive, a high frequency distractor should cause greater interference than a low frequency distractor. High frequency distractors should be more interfering because they have faster and higher activation relative to low frequency distractors which, in competitive selection, is weighted against target activation. Contrary to this expectation, low frequency distractors interfered more with targets than did high frequency distractors (Miozzo & Caramazza, 2003). This finding was explained by assuming that the target cannot be named before the distractor is also processed for articulation. So while the distractor does not interfere with the target during lexical selection (activation levels are not relative; the selection of the target does not depend on the activation levels of other active items), it will interfere post-lexical access just before articulation. Low frequency words take more time to be processed (Forster & Chambers, 1973), so it will take them time to be ready for articulation. As a result, for the target to be named it has to wait for the distractor to be retrieved and to be rejected first (Miozzo & Caramazza, 2003).

So if lexical selection is not competitive, how do bilinguals select the right word in the right language? One solution is similar to the "complex access, easy selection" (La Heij, 2005) proposal, where the target language might be specified at the conceptual level, providing greater activation to the target lexical item in the target language. But unlike the "complex access, easy selection" (La Heij, 2005) proposal, this solution assumes that lexical selection is not competitive (Finkbeiner, Gollan, & Caramazza, 2006). In this account, previous findings are then explained easily. The finding that in the PWI paradigm targets are named faster in the presence of a non-target language unrelated distractor compared to a target language unrelated distractor (Costa & Caramazza, 1999) is then attributed to the fact that non-target language distractors meet fewer response selection criteria and are rejected more easily. At the same time, identity distractors facilitate naming because at the lexical level there is only facilitation between nodes.

4.1.4 The Current Study

The aim of this current study was to investigate the issue of competitive versus non-competitive selection further while also looking into language suppression mechanisms and neighbourhood density. To do so, a picture-picture interference (PPI) paradigm was used within a flanker task using unrelated stimuli from different neighbourhoods.

While most previous studies have used PWI paradigms, this study used a PPI paradigm in order to integrate it into the flanker task. Previously, the PPI task has been found to be as effective as the PWI, also showing the semantic interference effect (Geng, Kirchgessner, & Schnur, 2013). Using the PPI paradigm allows for investigation into two possible loci of competition associated with different predictions. At the stage of lexical access, if lexical selection is competitive, the activity of the distractor should influence the retrieval of the target lexical entry, resulting in longer access times, and so longer naming times. Later, at the output stage, a non-competitive account suggests that target and distractor should again compete for being articulated and the amount of interference by the distractor most likely depends on how fast it can be rejected: If the distractor can be rejected quickly, then there will be no interference. Miozzo and Caramazza (2003) found that high frequency distractors did not interfere with picture naming, as predicted by a competitive selection account, assuming that the greater activation level of high frequency items would interfere with target selection. Instead, low frequency distractors interfered with target naming the most. This finding has then been linked to a non-competitive lexical selection. In non-competitive selection, competition takes place at the output stage where a target has to wait for the slower low frequency distractor to be rejected.

Unlike Miozzo and Caramazza (2003), this current study used neighbourhood density as a lexical factor to replicate these previous findings and also to link it to the previous chapter that looked at how the L2 neighbourhood is represented and organised in the presence of an L1 neighbourhood. As in the case of frequency, high-density (HD) items are named faster than low-density (LD) items (Vitevitch, 2002). This has been argued to be either the result of a more efficient coding and therefore greater ease at retrieval in the case of HD items (see previous chapter) or the result of a greater activation level of words from HD neighbourhoods (Vitevitch, 2002). One distinction between frequency and neighbourhood density is that frequency is argued to have an effect at the lemma level, while neighbourhood effects have been attributed to the lexeme level as they are defined by form (Goldrick & Rapp, 2007). If lexical selection is competitive, it can only be influenced by neighbourhood density provided that there is no strict separation between the lemma and the lexeme (e.g. Caramazza, 1997; Dell, 1986).

This way, like frequency, neighbourhood density should play a role during selection and during the output phase; if lexical selection is competitive, HD items should show greater interference during lexical selection and if targets have to wait for distractors to be rejected before they can be articulated, LD items should show greater interference at the output stage. Additionally, using neighbourhood density as a factor further extends the findings in Chapter 4 looking at whether the predicted effects at the end of this introduction are found when density is defined by L1 or L2 neighbourhood in bilinguals.

4.1.5 The Role of Cognitive Control

In the past, many studies have reported a bilingual advantage on tasks that require different cognitive control functions such as the inhibition of irrelevant information. These advantages have been found in children (Bialystok, 2010; Bialystok, Martin, & Viswanathan, 2005; Martin-Rhee & Bialystok, 2008) as well as in younger and older adults (Bialystok, 2006; Bialystok, Craik, et al., 2005; Bialystok, Craik, & Luk, 2008; Bialystok et al., 2004; Bialystok & DePape, 2009; Costa, Hernandez, Costa-Faidella, & Sebastián-Gallés, 2009; Costa, Hernandez, & Sebastián-Gallés, 2008; Emmorey, Luk, Pyers, & Bialystok, 2008; Luk & Bialystok, 2008). The most prominent explanation for such advantages lies within the assumption that bilinguals have to continuously control their two languages during usage to avoid non-target language interference. For instance, Green (1998) IC model describes one possible method of dealing with cross-language competition through the use of cognitive inhibition and has often been likened to the bilingual advantages reported. Additionally, others have acknowledged that while there might not be a specific suppression mechanism that resolves lexical competition as suggested by the IC model (Green, 1998), the reported advantages point at least to the involvement of a control process inherent to bilingual language use, for instance, when determining the language to communicate within a given situation (Costa et al., 2009).

So far, most studies investigating bilingual advantages with regards to cognitive control functions only included participants that were early bilinguals. That is, bilinguals who had acquired their L1 not later than the age of six. This begs the question of whether the found advantage (e.g., Bialystok, 2007; Bialystok et al., 2004) is exclusive to early bilinguals and their early experience with juggling two languages or whether late bilinguals also can develop an advantage over time. Festman, Rodriguez-Fornells, and Münte (2010) investigated individual differences with regards to language control and general cognitive control functions in late bilinguals who had acquired their L2 around the age of 12. They found that late bilinguals who rarely displayed non-target language intrusions in a picture naming task performed significantly better on a number of cognitive control tasks than late bilinguals who displayed more non-target language intrusions. Thus, it does appear as if there is also a link between language control and advanced cognitive control functions in late bilinguals, even though the direction of this relationship remains unclear.

Therefore, the PPI paradigm was embedded in a negative priming paradigm measuring cognitive inhibition. In this negative priming paradigm, trials consisted of either two successive unrelated PPI trials (control condition) or two successive related PPI trials (distractor becomes target (DT) condition). In the DT condition, the distractor on the first trial (known as the prime trial) becomes the target on the second trial (known as the probe trial). Compared to reaction times on control probe trials, reaction time on DT probe trials are found to be slower because the distractor is supposed to be inhibited on the prime trial and so it takes longer for it to become available again when it is the target on the probe trial. The negative difference in reaction time between control and DT probe trials is known as the negative priming effect, a measure of cognitive inhibition (Tipper, 2001).

Previously, it has been shown that the bilingual cognitive control advantage actually turns into a disadvantage in negative priming paradigms. Early bilinguals actually showed greater negative priming effects than monolinguals (Treccani, Argyri, Sorace, & Della Sala, 2009). It took the bilinguals significantly longer to respond to a target that was previously inhibited as a distractor. In this case, the bilinguals ability to inhibit distractors more strongly is a disadvantage because, consequently, the previously inhibited distractor-turned-target takes more time to become available again (Treccani et al., 2009).

The aim of the negative priming paradigm was thus to further investigate whether the cognitive control advantage, or better, disadvantage, on this task, extends to late bilinguals by comparing the performance of monolinguals with the performance of late bilinguals. Additionally, participants also completed a less language-dependent digit naming negative priming paradigm. The aim of this digit naming negative priming paradigm was to explore whether any found advantage would also extend to tasks that required more general cognitive control (see Dehaene, Piazza, Pinel, & Cohen, 2003, on the difference between word and number processing) as suggested by Festman et al. (2010).

As in Chapters 2 and 3, two groups of late bilinguals were looked at: a low and a high proficient group as determined in Chapter 2. This was done to once again investigate possible differences as late bilinguals become more proficient.

With regards to the PPI, if lexical selection is competitive, hd distractors should interfere the most as they have arguably greater activation levels than ld distractors, influencing the relative activation of the target. In contrast, if lexical selection is non-competitive, ld distractors should interfere the most, as they are the slowest to be retrieved for rejection before articulation (Miozzo & Caramazza, 2003).

With regards to the negative priming paradigm, if late bilinguals also have an advantage with cognitive control functions, late bilinguals should show greater negative priming effects compared to monolinguals. Additionally, if this advantage is related to proficiency, high proficient bilinguals should show greater negative priming effects than low proficient bilinguals.

The used stimuli varied in neighbourhood density, in contrast to frequency (see Miozzo & Caramazza, 2003), to link to the previous chapter. If, as illustrated in the previous chapter's study, the coding of L2 lexical representations in late bilinguals is first influenced by the L1 and then by the L2, the hypothesised effects above are expected to occur in low proficient late bilinguals when neighbourhood density is defined by the L1, and in high proficient bilinguals when neighbourhood density is defined by the L2.

4.2 Experiment 4

4.2.1 Method

Participants

A total of 106 participants participated in this study. Fifty-eight participants were monolingual, 48 participants were bilingual (33 German-English bilinguals, 15 Icelandic-English bilinguals). All but one of the participants were the same as those in Experiments 2 and 3.

Materials

Monolingual participants The same high and low neighbourhood density pictures as in Experiment 2 were used in this paradigm.

Bilingual participants The same high and low neighbourhood density pictures as in Experiment 3 were used in this paradigm.

Procedure

On each trial, two overlapping pictures were presented, as illustrated in the examples given in Figure 4.1. One picture was coloured in red, while the other picture was coloured in black. The red picture was always the target; the black picture was the distractor. The trials were presented in pairs of two: a prime and a probe trial. The pictures in the probe display differed according to two different conditions as illustrated in Figure 4.1.

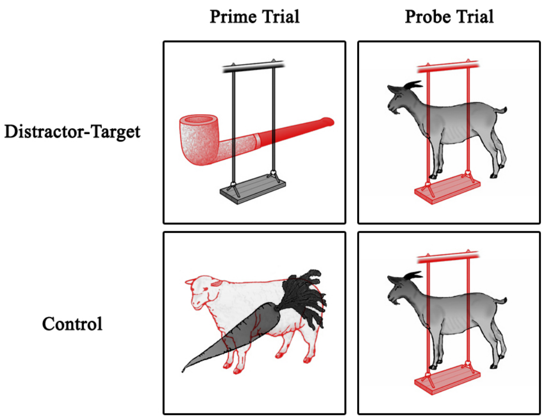

Figure 4.1: Illustration of control and distractor-target conditions across prime and probe trials in the picture naming negative priming paradigm.

In the control condition, both pictures in the prime display (e.g., carrot – SHEEP) were different to the ones in the probe display (e.g., goat – SWING). However, in the distractor-target (DT) condition the distractor picture in the prime display (e.g., SWING) was identical to the target picture in the probe display (e.g., SWING), while the distractor in the probe display (e.g., GOAT) was a picture not used in the prime display.

At the beginning of this experiment, the participants were told that they would always see a red and a black picture at the same time and that their job was to name the red target picture in English while ignoring the black one. Each set of paired trials started with a 640ms blank screen followed by a fixation cross displayed for 1500ms followed by a prime display. The prime display was presented for a maximum of 2000ms or until the voice switch was triggered by a naming response, whichever occurred first. When no response was made within 2000ms (timeout), a message immediately appeared on the screen reminding the participant to respond faster and asking them to press the request button to proceed. Once the voice switch was triggered, or on pressing the request button after a timeout, a blank screen was presented for 540ms. The probe display then immediately followed this response-stimulus interval (RSI). The probe display also showed a red target and a black distractor picture. Once again, a naming response had to be made within 2000ms before the next pair of trials started (RSI = 2140ms). After six practice prime and probe trial pairs, each participant completed 80 experimental prime and probe trial pairs. The German and Icelandic participants completed this task after completing the tasks outlined in Chapter 2 and 3 and before completing the task in the following experiment in one session with the opportunity to have a quick break in between tasks if needed. The English participants completed this task after completing the monolingual task outlined in Chapter 3, also in one session.

Design

Single pictures were combined as target and distractors in prime and probe trial pairs according to a Latin square design. This way, each participant saw each item in every position (prime target, prime distractor, probe target, probe distractor) in one of four conditions: (a) Control - target and distractor coming from the same neighbourhood grouping [HDhd or LDld]; (b) Control – target and distractor coming from a different neighbourhood grouping [LDhd or HDld]; (c) DT target and distractor coming from the same neighbourhood grouping; and (d) DT – target and distractor coming from a different neighbourhood grouping. For the bilinguals, each item appeared in every condition in every position across participants. A detailed illustration of this Latin square design can be found in Appendix C. Unfortunately for the monolinguals, not all items appeared in every condition across participants because of issues with the design when it was first used. An illustration of the distribution of items for the monolinguals can also be found in Appendix C. Note that as a result of the faulty design, no item analysis could be conducted for the monolinguals. No item analysis could be conducted for the bilinguals either as the neighbourhood grouping of the items according to either their German or Icelandic neighbourhood did not always correspond.

Apparatus

See Experiments in Chapter 3.

4.2.2 Results: Picture-Picture Interference

Reaction time (RT) and error rates for both the control and DT primes combined were examined in the three language groups (monolinguals, low proficient bilinguals, high proficient bilinguals); looking at the prime trials in isolation is equivalent to the traditional picture-picture interference paradigm. There are a number of different outcomes than can be expected regarding the interference found in the PPI paradigm.

If lexical selection is competitive, hd distractors should interfere the most, as they have arguably greater activation levels than ld distractors interfering with the relative activation of the target. Therefore, if selection is competitive, HDhd items should be named more slowly than HDld items and LDhd items should be named more slowly than LDld items.

In contrast, if lexical selection is non-competitive, ld distractors should interfere the most, as they are the slowest to be retrieved for rejection before articulation (Miozzo & Caramazza, 2003). Therefore, if selection is not competitive, HDld items should be named more slowly than HDhd items and LDld items should be named more slowly than LDhd items.

Additionally, if, as illustrated in the previous chapter's study, the coding of L2 lexical representations in late bilinguals is first influenced by the L1 and then by the L2, the hypothesised effects above are expected to occur in low proficient late bilinguals when neighbourhood density is defined by the L1, and in high proficient bilinguals when neighbourhood density is defined by the L2.

Monolinguals

To investigate interference patterns on the prime trials, three-way mixed ANOVAs were conducted for the factors Target Density (HD vs. LD), Distractor Density (hd vs. ld) and Participant Group. In this chapter, a non-repeated factor Group was always added to the analyses to extract variance due to counterbalancing (Latin square design), while effects involving this factor are not reported. Mean RTs and Error rates can be found in Table 4.1

Table 4.1: Mean RTs (ms) and Error Rates (%) and their Associated Standard Deviations (in parentheses) across the Four Neighbourhood Density Combinations for the Prime Trials

Target Density	HD		LD	
Distractor Density	hd	ld	hd	ld
RT	836 (90.7)	819 (82.9)	857 (90.6)	836 (89.5)
Error rate	15.2 (8.40)	12.7 (9.81)	16.8 (11.5)	18.9 (9.27)

Reaction times Looking at the impact of Distractor Density on target naming, a significant main effect of Distractor Density was revealed, $F(1, 53) = 9.08$, $MSE = 1810$, $p < .01$, showing a small effect $\eta^2 = .033$, in the absence of a significant interaction between Target Density and Distractor Density, $F < 1$. In line with the prediction made from a competitive approach to lexical selection, targets accompanied by an hd distractor were named 16ms more slowly than targets accompanied by an ld distractor. There was also a significant main effect for Target Density, $F(1, 53) = 8.26$, $MSE = 2419$, $p < .01$, also showing a small effect $\eta^2 < .041$. Overall, LD targets were named 18ms more slowly than HD targets. This is in line with simple picture naming studies (e.g., Vitevitch, 2002), in which LD targets were also named more slowly than HD targets.

Error rates Looking at the error rate patterns across the four neighbourhood combinations, no significant main effect of Distractor Density, $F < 1$ was found. However, there was a significant main effect for Target Density, $F(1, 53) = 11.2$, $MSE = 80.9$, $p < .001$, showing a medium effect $\eta^2 = .072$. There was also a significant interaction between Target Density and Distractor Density, $F(1, 53) = 2.34$, $MSE = 37.3$, $p < .01$, showing a small effect, $\eta^2 = .026$. As illustrated in Figure 4.2, it appears as if for HD targets, hd distractors caused more errors, while the opposite seemed to be the case for ld targets.

Looking at each Target Density separately using two two-way mixed ANOVAs, when the Target's Density was HD, indeed a significant effect for Distractor Density was found, $F(1, 53) = 4.61$, $MSE = 36.6$, $p < .05$, showing a medium effect $\eta^2 = .071$. On average, 2.42% more errors were made for HD targets with an hd distractor compared to HD targets with an ld distractor. When the Target's Density was LD, a significant effect for Distractor Density was also found, $F(1, 53) = 4.75$, $MSE = 33.3$, $p < .05$, showing a small to medium effect $\eta^2 = .058$. In contrast to HD targets, on average, 2.35% more errors were made for LD targets with an ld distractor compared to LD targets with an hd distractor.

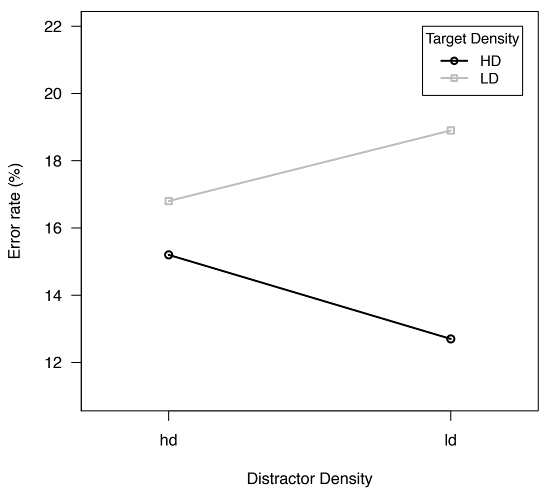

Figure 4.2: Interaction between target and distractor density.

Low Proficient Bilinguals

Three-way mixed ANOVAs were also conducted to investigate interference patterns on prime trials in the low proficient bilingual group for the factors Target Density (HD vs. LD), Distractor Density (hd vs. ld) and Participant Group. Separate ANOVAs were conducted to investigate interference patterns when neighbourhood was defined by the L1 and by the L2. Mean RTs and Error rates can be found in Table 4.2.

Reaction times When density was defined by the L1, no significant main effect for Distractor Density, $F < 1$, nor a significant interaction between Target Density and Distractor Density, $F(1, 18) = 1.71$, $MSE = 2346$, $p = .208$, $\eta^2 = .001$, nor a significant main effect for Target Density was found, $F(1, 18) = 2.29$, $MSE = 4424$, $p = .148$, $\eta^2 = .004$. Contrary to the expected pattern, when density was defined by the L1, neither hd distractors as in the monolingual group, nor ld distractors seem to have influenced target naming.

Table 4.2: Mean RTs (ms) and Error Rates (%) and their Associated Standard Deviations (in parentheses) across the Four Neighbourhood Density Combinations for the Prime Trials when Density was Defined by the Low Proficient Bilingual's L1 and L2

	Target Density	HD		LD	
Language	Distractor Density	hd	ld	hd	ld
L1 (Ger/Ice)	RT	907 (99.7)	893 (101)	904 (137)	933 (119)
	Error rate	7.33 (7.44)	10.9 (13.2)	10.1 (10.8)	11.3 (12.6)
L2 (English)	RT	889 (112)	910 (103)	916 (125)	933 (119)
	Error rate	9.82 (10.4)	9.43 (8.86)	7.52 (7.78)	10.3 (11.7)

When density was defined by the L2, there was also no significant main effect for Distractor Density, nor a significant interaction between Target Density and Distractor Density, both $F < 1$. Contrary to the expectations and unlike what has been found in the monolingual group, Distractor Density did not influence naming time. However, there was a significant main effect for Target Density, $F(1, 18) = 6.38$, $MSE = 761$, $p < .05$, showing a small effect , $\eta^2 = .027$. In line with simple naming experiments (e.g., Vitevitch, 2002), regardless of the distractor's density, HD targets were, on average, named 17ms faster than LD targets.

Error rates Examining the error rate patterns across the four neighbourhood combinations when density was defined by the L1, again, no significant main effect for Distractor Density was found, $F(1, 18) = 1.64$, $MSE = 59.2$, $p = .138$, $\eta^2 = .032$. The interaction between Target and Distractor Density and the main effect for Target Density were also not significant, all Fs < 1.

When density was defined by the L2, there was also no significant main effect for Distractor Density, no significant interaction between Target and Distractor Density and no significant main effect for Target Density, all $F < 1$. Contrary to what was expected, in the low proficient monolingual group, neighbourhood density had no influence on RTs and error rates.

High Proficient Bilinguals

Three-way mixed ANOVAs were also conducted to investigate interference patterns on control probe trials in the high proficient bilingual group for the factors Target Density (HD vs. LD), Distractor Density (hd vs. ld) and Proficiency Group. Separate ANOVAs were conducted to investigate interference patterns when neighbourhood was defined by the L2 and by the L1. Mean RTs and Error rates can be found in Table 4.3.

Table 4.3: Mean RTs (ms) and Error Rates (%) and their Associated Standard Deviations (in parentheses) across the Four Neighbourhood Density Combinations for the Prime Trials when Density was Defined by the High Proficient Bilingual's L2 and L1

	Target Density	HD		LD	
Language	Distractor Density	hd	ld	hd	ld
L2 (English)	RT	880 (101)	877 (84.3)	899 (91.5)	909 (96.7)
	Error rate	6.66 (5.64)	9.76 (7.40)	8.77 (6.47)	8.80 (8.22)
L1 (Ger/Ice)	RT	885 (90.1)	902 (86.4)	919 (134)	892 (86.9)
	Error rate	8.18 (6.01)	8.08 (8.93)	9.41 (8.10)	9.20 (7.40)

Reaction times It was expected that L2 would be the dominant determinant of density, but when density was defined by the L2, there was no significant main effect for Distractor Density, nor was there a significant interaction between Target and Distractor Density, all $F < 1$. There was, however, a significant main effect of Target Density, $F(1, 20) = 5.97$, $MSE = 1636$, $p < .05$, $\eta^2 = .049$. On average, targets were named 30ms faster when they were HD compared to when they were LD which is in line with previously reported RTs for items differing in neighbourhood density (e.g., Vitevitch, 2002). In contrast to the monolinguals, and contrary to the expectations, for high proficient bilinguals just like for low proficient bilinguals, only the L2 Target Density influenced RTs.

When density was defined by the L1, no significant main effect for Distractor Density, no significant interaction between Distractor Density and Target Density, nor a significant main effect for Target Density were found, all Fs < 1. As expected, when density was defined by the L1 in contrast to when defined by the L2, no effects were found.

Error rates Examining error rates when density was defined by the L2, there was a significant main effect for Distractor Density, $F(1,\ 20) = 10.7$, $MSE = 182$, $p < .01$, showing a medium effect $\eta^2 = .076$, in the absence of a significant interaction between Target and Distractor Density, $F < 1$. Regardless of Target Density, on average 3.85 more errors were made when the Distractor's Density was ld compared to when the Distractor's Density was hd. Additionally, there was no significant main effect for Target Density, $F < 1$.

When density was defined by the L1, no significant effects were found, all Fs < 1. This is in line with the expectation that effects would only be found when density was defined by the L2. The finding that more errors were made for ld distractors is in line with the non-competitive position.

4.2.3 Interim Summary: Picture-Picture Interference

In the PPI task, the findings in the monolingual group were consistent with what was predicted by a competitive account of lexical selection: hd distractors delayed both HD and LD targets significantly more than ld distractors. For HD targets, hd distractors also caused more errors, however, curiously, for LD targets, more errors were caused by ld distractors.

In the low proficient bilingual group, contrary to the expectation that effects would be found when the L1 defined density, an effect was found when density was defined by the L2. Unlike the prediction that distractor density would influence target naming and unlike what was found in the monolingual group, only an effect for target density was found with HD targets being named faster than LD targets. Somehow, low proficient bilinguals named the items just like on a simple picture naming task with no distractors present (e.g., Vitevitch, 2002). No error effects were found when the L1 or the L2 defined density.

In the high proficient group, as predicted, there were only effects present when the L2 defined density. In line with the low proficient bilinguals' results, there was also only an effect of target density on naming, with HD targets being named faster than LD targets. Unlike in the low proficient bilingual group, a main error effect for distractor density was found, with more errors made for picture with an ld distractor. This is in line with the non-competitive position that predicts greater interference from ld distractors.

To summarise, the findings in the monolingual group suggest that lexical selection is a competitive process in which HD distractors act as a stronger competitor during selection. The findings for the low bilingual group do not allow such a conclusion, as naming in this group was only influenced by target density. In the high proficient group, naming was also only influenced by target density. However, error rates were influenced by distractor density, with more errors made for ld distractors, compatible with the non-competitive position. It is unclear why only error rates in high proficient bilinguals were influenced by distractor density, while naming time in both group depended on target density only.

4.2.4 Order of Analysis

To analyse the data from the negative priming paradigm, probe RTs were analysed with regards to Target and Distractor Density combinations and their Prime Type difference (DT vs. Control Prime). As a reminder, there were four different density combinations across prime and probes as illustrated in Table 4.4.

Table 4.4: The Four Density Combinations in the Negative Priming Paradigm

Combination	1	2	3	4
Prime	HDhd	HDld	LDhd	LDld
Probe	HDhd	LDhd	HDld	LDld

The main interest lay in the magnitude of inhibition of the prime distractor, as evident in the negative priming effects exhibited by the same word as the target in the subsequent probe. Therefore, when talking about the negative priming effects as an indicator of suppression of the prime distractor, the four conditions should be referred to in terms of their prime combination. After all, the main aim was to see whether hd or ld distractors (relative to HD and LD targets) in the prime receive more inhibition. In contrast, when talking about effects that do not involve the Prime Type factor found across the four conditions analysing the probe trials, the conditions should be referred to in terms of their probe combination.

To avoid confusion when referring to either the prime or the probe's density combination, the results from this experiment will be examined in two sections. The first section (section 4.2.5) will examine the inhibition of prime distractors in terms or their effect in the probe in the form of negative priming and the four combinations will be referred to in terms of their prime combination (unless indicated otherwise, e.g., in the descriptive RT tables). The second section (section 4.2.7) will examine any additional effects that do not involve the Prime Type factor and the four combinations will then be referred to in terms of their probe combination.

4.2.5 Results: Negative Priming Effects

After looking at the primes only, RT and error rates for control and DT probes were then examined in the three language groups. There are a number of different outcomes that can be expected regarding negative priming patterns.

With regards to the negative priming paradigm, if late bilinguals also have more developed cognitive control functions, late bilinguals should show greater negative priming effects compared to monolinguals. Additionally, if this advantage is related to proficiency, high proficient bilinguals should show greater negative priming effects than low proficient bilinguals.

If selection is competitive, as suggested by the monolingual findings in the PPI task, hd distractors should interfere the most and should therefore need to be inhibited more strongly than ld distractors. In that case, the negative priming effect should be bigger following HDhd relative to HDld primes (as a reminder, this would involve data from HDhd and LDhd target/distractor probe combinations, respectively) and also bigger for LDhd items than for LDld items (corresponding to HDld vs. LDld in the probe trial).

If selection is non-competitive, ld distractors should interfere the most and should, therefore, need to be inhibited more strongly than hd distractors. In that case, the negative priming effect should be bigger for HDld items than for HDhd (corresponding to LDhd vs. HDhd in the probe trial) items and should also be bigger for LDld items than for LDhd items (corresponding to LDld vs. HDld in the probe trial).

Again, if, as illustrated in the previous chapter's study, the coding of L2 lexical representations in late bilinguals is first influenced by the L1 and then by the L2, the hypothesised effects above are expected to occur in low proficient late bilinguals when neighbourhood density is defined by the L1, and in high proficient bilinguals when neighbourhood density is defined by the L2.

Monolinguals

Reaction times To investigate the negative priming pattern across picture names in HD and HD neighbourhoods in the monolingual group, a four-way, mixed design ANOVA was used to analyse these factors as defined by the Prime: Distractor Density (hd vs. ld), Target Density (HD vs. LD), Prime Type (Control vs. DT) and Participant Group. Mean RTs (ms) and standard deviations across conditions plus the RT magnitude of priming differences can be found in Table 4.5. The results of the analysis are summarised in Table 4.6.

Table 4.5: Mean RTs (ms) and Standard Deviations (in parentheses) in the Control and DT Probe Trials across all Target Density$_{prime}$ (HD vs. LD) x Distractor Density$_{prime}$ (hd vs. ld) Combinations in the Monolingual Group

Target Density$_{prime}$	HD		LD	
Distractor Density$_{prime}$	hd	ld	hd	ld
Control	790 (105)	786 (119)	801 (119)	821 (123)
DT	816 (110)	829 (136)	822(124)	816 (124)
Priming Effect	-26 (80.1)	-43 (110)	-21 (81.7)	5 (115)
Probe Combination	HDhd	LDhd	HDld	LDld

Table 4.6: Results of the Four-Way, Mixed Design ANOVA for the Monolingual Group

	F(1,53)	p	η^2
1. Distractor$_{prime}$ or Target$_{probe}$ Density	2.15	.148	.002
2. Target$_{prime}$ or Distractor$_{probe}$ Density	3.72	.059	.007
3. Prime Type	10.8**	.002	.028
1 x 2	0.05	.831	.000
1 x 3	0.06	.810	.000
2 x 3	5.75*	.020	.119
1 x 2 x 3	3.73	.059	.006

Note. *$p < .05$ **$p < .01$

The Distractor Density by Target Density by Prime Type interaction showed a trend towards significance, with $F(1, 53) = 3.57$, $MSE = 3606$, $p = .059$, showing a very small effect, $\eta^2 = .006$. Given the low observed power of .475 for this interaction, two three-way mixed design ANOVAs were conducted to analyse the factors Distractor Density, Prime Type and Participant Group for each Prime Target Density.

When the Target's Density was HD, neither a significant interaction between Distractor Density and Prime Type, nor a significant main effect for Distractor Density was found, $F < 1$. Only the main effect for Prime Type proved to be significant, with $F(1,53) = 14.5$, $MSE = 4899$, $p < .001$, showing a medium effect, $\eta^2 = .081$, indicating that while there were negative priming effects, these did not differ for the two Prime Distractor Densities. When the Target's Density was LD, no significant interaction between Distractor Density and Prime Type $F(1,\ 53) = 2.04$, $MSE = 4263$, $p = .159$, $\eta^2 = .011$, nor a significant main effect for Distractor Density or for Prime Type was found, $F < 1$. This indicates that there appeared to be no differences in negative priming effects associated with either ld or hd distractors accompanying LD Targets, as neither negative priming effect was significant. Contrary to what was expected, the amount of suppression applied to a prime distractor did not depend on the distractor's density but on the target's density as demonstrated by the significant negative priming effect when the Prime Target is HD, but no evidence of negative priming when the Prime Target is LD.

Error rates Another four-way, mixed design ANOVA was used to analyse error rate patterns across picture names in HD and LD neighbourhoods for these factors: Target Density, Distractor Density, Prime Type and Participant Group. Mean error rates (%) and standard deviations across conditions as well as for the priming effects can be found in Table 4.7. The results of the analysis are summarised in Table 4.8.

Table 4.7: Mean Error Rates (%) and Standard Deviations (in parentheses) in the Control and DT Probe Trials across all Target Density$_{prime}$ (HD vs. LD) x Distractor Density$_{prime}$ (hd vs. ld) Combinations in the Monolingual Group

Target Density$_{prime}$	HD		LD	
Distractor Density$_{prime}$	hd	ld	hd	ld
Control	11.9 (11.9)	12.2 (12.3)	9.46 (10.4)	14.2 (11.6)
DT	12.6 (12.6)	13.6 (11.6)	11.1 (11.9)	13.2 (11.6)
Priming Effect	-0.7	-1.4	-1.64	1
Probe Combination	HDhd	LDhd	HDld	LDld

There was no significant three-way interaction between Target Density, Distractor Density and Prime Type, $F(1,\ 53) = 1.61$, $MSE = 50.2$, $p = .21$, $\eta^2 = .002$. Neither a significant interaction involving Prime Type, nor a significant main effect for Prime Type was found, so it seems that the difference between Control and DT trials did not influence error rates. The significant main effect for Distractor Density will be discussed in section 4.2.7.

Table 4.8: Results of the Four-Way, Mixed Design ANOVA for the Monolingual Group

	$F(1,53)$	p	η^2
1. $\text{Distractor}_{prime}$ or Target_{probe} Density	8.09**	.006	.013
2. Target_{prime} or $\text{Distractor}_{probe}$ Density	0.71	.404	.001
3. Prime Type	0.98	.326	.001
1 x 2	1.39	.242	.006
1 x 3	0.52	.473	.001
2 x 3	0.30	.584	.000
1 x 2 x 3	1.61	.210	.002

Note. **$p < .01$

Consequently, only looking at HD targets, no significant interaction between Distractor Density and Prime Type, nor main effects for either factor were found, all Fs < 1. The same was the case when looking at LD targets only, all Fs < 1.

Low Proficient Bilinguals

Reaction times To investigate negative priming effects across picture names in HD and LD neighbourhoods defined by either the low proficient bilinguals' L1 or L2, two four-way, mixed-design ANOVAs were used to analyse these factors: Distractor Density (hd vs. ld), Target Density (HD vs. LD), Prime Type (Condition vs. DT) and Participant Group. Mean RTs (ms) and standard deviations across conditions plus the RT magnitude of priming differences can be found in Table 4.9.

The results of the analysis with density defined by the L1 are summarised in Table 4.10. There were no significant interactions or main effects and no effect sizes were of any significant magnitude apart from that associated with the three-way interaction. This interaction produced a small effect of $\eta^2 = .036$, with a p value just above .10, in conjunction with a very low observed power of .056. Together, these results suggested that there was not sufficient power for a four-way analysis, and so smaller analyses were required.

Again, two three-way mixed design ANOVAs were conducted to analyse the factors Distractor Density, Prime Type and Participants Group for each Prime Target Density.

Table 4.9: Mean RTs (ms) and Standard Deviations (in parentheses) in the Control and DT Condition across Density Defining Languages (L1 vs. L2) and all Target Density$_{prime}$ (HD vs. LD) x Distractor Density$_{prime}$ (hd vs. ld) Combinations in the Low Proficient Group

Density in	Target Density$_{prime}$	HD		LD	
	Distractor Density$_{prime}$	hd	ld	hd	ld
L1 (Ger/Ice)	Control	911 (171)	942 (162)	972 (133)	971 (149)
	DT	950 (191)	976 (171)	973 (187)	947 (187)
	Priming Effect	-39 (97.3)	-34 (113)	-1 (121)	24 (101)
	Probe Combination	HDhd	LDhd	HDld	LDld
	Target Density$_{prime}$	HD		LD	
L2 (English)	Distractor Density$_{prime}$	hd	ld	hd	ld
	Control	949 (151)	947 (168)	943 (188)	961 (147)
	DT	983 (188)	955 (183)	962 (180)	950 (174)
	Priming Effect	-34 (127)	-8 (112)	-19 (140)	11 (100)
	Probe Combination	HDhd	HDld	LDhd	LDld

Table 4.10: Results of the Four-Way, Mixed Design ANOVA with Density Being Defined by the L1 for the Low Proficient Bilingual Group

	$F(1,18)$	p	η^2
1. Distractor$_{prime}$ or Target$_{probe}$ Density	0.14	.707	.001
2. Target$_{prime}$ or Distractor$_{probe}$ Density	1.79	.174	.006
3. Prime Type	1.01	.315	.013
1 x 2	0.61	.447	.003
1 x 3	0.02	.902	.000
2 x 3	0.01	.974	.000
1 x 2 x 3	2.29	.112	.036

When the Target's Density was HD, no significant interaction between Distractor Density and Prime Type, or significant main effects for Prime Type or Distractor Density was found, all Fs < 1. When the Target's Density was LD, again no significant interaction between Distractor Density and Prime Type, or significant main effects for Prime Type or Distractor Density was found, all Fs < 1. Contrary to the hypotheses, no priming pattern was found when density was defined by the L1.

The four-way analysis was repeated with density defined by the L2. Results are summarised in Table 4.11. Once again, there was no significant three-way interaction between Target Density, Distractor Density and Prime Type. In fact this time there was no hint of an effect, where $F < 1$. Neither a significant interaction involving Prime Type, nor a significant main effect for Prime Type was found. The significant Target Density by Distractor Density interaction will be discussed in section 4.2.7 as it does not involve the Prime Type factor critical for measure inhibition.

Consequently, only looking at HD targets, no significant interaction between Distractor Density and Prime Type, nor main effects for either factor were found, all Fs < 1. The same was the case when looking at LD targets only, all Fs < 1.

Table 4.11: Results of the Four-Way, Mixed Design ANOVA with Density Being Defined by the L2 for the Low Proficient Bilingual Group

	$F(1,18)$	p	η^2
1. Distractor$_{prime}$ or Target$_{probe}$ Density	1.53	.233	.011
2. Target$_{prime}$ or Distractor$_{probe}$ Density	0.41	.530	.002
3. Prime Type	1.81	.195	.017
1 x 2	7.16*	.015	.019
1 x 3	0.37	.551	.003
2 x 3	2.13	.161	.009
1 x 2 x 3	0.03	.855	.000

Note. *$p < .05$

It appears as if there are no distinct priming patterns either when density was defined by the L2. Contrary to our hypotheses, no significant negative priming was found in any condition for low proficient bilinguals when density was defined by the L1 and when it was defined by the L2.

Error rates To investigate error patterns across picture names in HD and LD neighbourhoods defined by either the low proficient bilinguals' L1 or L2, another two four-way, mixed-design ANOVAs were used to analyse these factors: Distractor Density, Target Density, Prime Type and Participant Group. Mean error rates (%) and standard deviations across conditions as well as for the priming effects can be found in Table 4.12. The results of the analysis with density defined by the L1 are summarised in Table 4.13.

Table 4.12: Mean Error Rates (%) and Standard Deviations (in parentheses) in the Control and DT Condition across Density Defining Languages (L1 vs. L2) and all Target Density$_{prime}$ (HD vs. LD) x Distractor Density$_{prime}$ (hd vs. ld) Combinations in the Low Proficient Group

Density in	Target Density$_{prime}$	HD		LD	
	Distractor Density$_{prime}$	hd	ld	hd	ld
	Control	10.8 (11.5)	13.9 (11)	8.63 (19.4)	11.8 (12.4)
L1 (Ger/Ice)	DT	10.3 (16.3)	12.8 (16.2)	8.25 (10.7)	10.9 (13.3)
	Priming Effect	0.5	1.1	0.38	0.9
	Probe Combination	HDhd	LDhd	HDld	LDld
	Target Density$_{prime}$	HD		LD	
	Distractor Density$_{prime}$	hd	ld	hd	ld
	Control	11.5 (11.2)	9.24 (8.27)	11.6 (10.6)	10.8 (12.5)
L2 (English)	DT	11.4 (12.5)	8.18 (13.3)	11.2 (12.8)	10 (11.9)
	Priming Effect	0.1	1.06	0.4	0.8
	Probe Combination	HDhd	HDld	LDhd	LDld

Table 4.13: Results of the Four-Way, Mixed Design ANOVA with Density Being Defined by the L1 for the Low Proficient Bilingual Group

	F(1,18)	p	η^2
1. Distractor$_{prime}$ or Target$_{probe}$ Density	1.43	.248	.011
2. Target$_{prime}$ or Distractor$_{probe}$ Density	7.52*	.013	.019
3. Prime Type	0.88	.359	.006
1 x 2	0.53	.476	.002
1 x 3	0.24	.633	.001
2 x 3	0.01	.932	.000
1 x 2 x 3	0.39	.546	.003

Note. $*p < .05$

When density was defined by the L1, neither a significant interaction involving Prime Type, nor a significant main effect for Prime Type was found, so it seems that the difference between Control and DT trials did not influence error rates. The significant main effect for Target Density will be discussed in section 4.2.7.

The results of the analysis with density defined by the L2 are summarised in Table 4.14. No significant effects were found.

Table 4.14: Results of the Four-Way, Mixed Design ANOVA with Density Being Defined by the L2 for the Low Proficient Bilingual Group

	F(1,18)	p	η^2
1. Distractor$_{prime}$ or Target$_{probe}$ Density	3.02	.090	.012
2. Target$_{prime}$ or Distractor$_{probe}$ Density	0.07	.797	.000
3. Prime Type	0.58	.458	.004
1 x 2	0.18	.679	.002
1 x 3	0.86	.365	.004
2 x 3	0.38	.547	.003
1 x 2 x 3	0.43	.519	.001

Note. *$p < .05$

High Proficient Bilinguals

Reaction times Another two four-way, mixed-design ANOVAs were used to analyse the following factors across picture names in HD and LD neighbourhoods defined by either the high proficient bilinguals' L2 or L1: Target Density, Distractor Density, Prime Type, and Participant Group. Mean RTs (ms) and standard deviations across conditions plus the RT magnitude of priming differences can be found in Table 4.15.

Table 4.15: Mean RTs (ms) and Standard Deviations (in parentheses) in the Control and DT Condition across Density Defining Languages (L2 vs. L1) and all Target Density$_{prime}$ (HD vs. LD) x Distractor Density$_{prime}$ (hd vs. ld) Combinations in the High Proficient Group

Density in	Target Density$_{prime}$	HD		LD	
L2 (English)	Distractor Density$_{prime}$	hd	ld	hd	ld
	Control	903 (138)	887 (139)	899 (139)	927 (140)
	DT	879 (145)	872 (125)	901 (154)	911 (159)
	Priming Effect	24 (138)	15 (114)	-2 (113)	16 (143)
	Probe Combination	HDhd	LDhd	HDld	LDld
	Target Density$_{prime}$	HD		LD	
L1 (Ger/Ice)	Distractor Density$_{prime}$	hd	ld	hd	ld
	Control	925 (162)	942 (158)	890 (148)	881 (112)
	DT	891 (127)	916 (160)	883 (159)	864 (149)
	Priming Effect	34 (143)	26 (105)	7 (137)	17 (151)
	Probe Combination	HDhd	HDld	LDhd	LDld

The results of the analysis with density defined by the participants' L2 are summarised in Table 4.16. Neither a significant interaction involving Prime Type, nor a significant main effect for Prime Type was found. However, the interaction between Distractor Density and Prime Type was the closest effect to significance, $F(1, 20) = 3.02$, $MSE = 5183$, $p = .098$, $\eta^2 = .006$.

Table 4.16: Results of the Four-Way, Mixed Design ANOVA with Density Being Defined by the L2 for the High Proficient Bilingual Group

	$F(1,20)$	p	η^2
1. Distractor$_{prime}$ or Target$_{probe}$ Density	5.52	.028*	.025
2. Target$_{prime}$ or Distractor$_{probe}$ Density	1.12	.302	.006
3. Prime Type	0.05	.823	.001
1 x 2	0.17	.681	.001
1 x 3	3.02	.098	.006
2 x 3	0.08	.778	.000
1 x 2 x 3	0.59	.452	.002

Note. *$p < .05$

When the Target's Density was HD, neither the interaction between Distractor Density and Prime Type, nor the main effects for Distractor Density or Prime Type were significant, all Fs <1. The same was found when the Target's Density was LD, all Fs < 1. This does not support the hypothesis that Targets with either hd or ld distractors should show greater negative priming effects when density was defined by the L2. The significant main effect for Distractor Density will be discussed in section 4.2.7.

The results of the analysis with density defined by the participants' L1 are summarised in Table 4.17. Once again, neither a significant interaction involving Prime Type, nor a significant main effect for Prime Type was found. No negative priming seems to have taken place. Contrary to our hypotheses, no significant negative priming was found in any condition both when density was defined by the L2 and when it was defined by the L1. The significant main effect for Target Density will be discussed in section 4.2.7.

Error rates To investigate error patterns across picture names in HD and LD neighbourhoods defined by either the high proficient bilinguals' L2 or L1, another two four-way, mixed-design ANOVAs were used to analyse these factors: Distractor Density, Target Density, Prime Type and Participant Group. Mean error rates (%) and standard deviations across conditions as well as for the priming effects can be found in Table 4.18. The results of the analysis with density defined by the L2 are summarised in Table 4.19.

Table 4.17: Results of the Four-Way, Mixed Design ANOVA with Density Being Defined by the L1 for the High Proficient Bilingual Group

	F(1,20)	p	η^2
1. Distractor$_{prime}$ or Target$_{probe}$ Density	0.10	.748	.000
2. Target$_{prime}$ or Distractor$_{probe}$ Density	9.98**	.004	.051
3. Prime Type	1.16	.292	.014
1 x 2	1.91	.181	.010
1 x 3	0.01	.957	.000
2 x 3	1.06	.313	.002
1 x 2 x 3	0.11	.740	.001

Note. **p < .01

There was a significant interaction effect between Distractor Density, Target Density and Prime Type, $F(1{,}20) = 6.30$, $MSE = 93.8$, $p < .05$, showing a small effect, $\eta^2 =$ .033.

Table 4.18: Mean Error Rates (%) and Standard Deviations (in parentheses) in the Control and DT Condition across Density Defining Languages (L2 vs. L1) and all Target Density$_{prime}$ (HD vs. LD) x Distractor Density$_{prime}$ (hd vs. ld) Combinations in the High Proficient Group

Density in	Target Density$_{prime}$	HD		LD	
	Distractor Density$_{prime}$	hd	ld	hd	ld
L2 (English)	Control	14.2 (11.7)	10.8 (13.5)	9.21 (8.81)	14.2 (14.1)
	DT	7.64 (10.2)	6.71 (8.18)	11.9 (10.7)	13 (12.3)
	Priming Effect	6.56	4.09	-2.69	1.20
	Probe Combination	HDhd	LDhd	HDld	LDld
	Target Density$_{prime}$	HD		LD	
	Distractor Density$_{prime}$	hd	ld	hd	ld
L1 (Ger/Ice)	Control	10.1 (9.81)	13.6 (13.4)	11.8 (8.96)	10.3 (11.4)
	DT	6.05 (8.79)	9.87 (8.86)	11.4 (12.2)	11.9 (10.6)
	Priming Effect	4.05	3.73	0.4	-1.6
	Probe Combination	HDhd	HDld	LDhd	LDld

As illustrated in Figure 4.3, it seems as if for HD targets, both hd and ld distractors did result in a positive priming effect. However, when the target was LD, hd distractors were associated with a slight negative priming effect, while ld distractors did not cause much difference.

It was therefore decided to explore the effects more closely by conducting two three-way mixed design ANOVAs for the factors Distractor Density, Prime Type and Participant Group for each of the two Target Densities. When the Target's Density was HD, there was a significant interaction between Distractor Density and Prime Type, with $F(1, 23) = 4.68$, $MSE = 86.8$, $p < .05$, showing a medium effect, $\eta^2 = .067$. As illustrated in

Table 4.19: Results of the Four-Way, Mixed Design ANOVA with Density Being Defined by the L2 for the High Proficient Bilingual Group

	$F(1,20)$	p	η^2
1. Distractor$_{prime}$ or Target$_{probe}$ Density	0.58	.453	.004
2. Target$_{prime}$ or Distractor$_{probe}$ Density	2.39	.138	.012
3. Prime Type	0.94	.344	.003
1 x 2	5.02*	.037	.029
1 x 3	0.39	.540	.001
2 x 3	4.17	.054	.019
1 x 2 x 3	6.30*	.021	.033

Note. *$p < .05$

Figure 4.4, pairwise contrasts revealed a significant positive priming effect of 6.59% when the Distractor's Density was hd ($p < .01$), but no significant priming effect when the Distractor's Density was ld ($p = .863$).

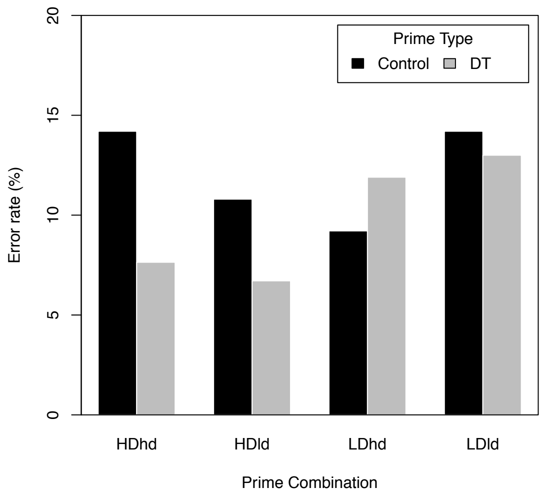

Figure 4.3: Mean error rates (%) across target and distractor densities and prime types for high proficient bilinguals in their L2.

When the Target's Density was LD, no significant interaction between Distractor Density and Prime Type, $F(1, 23) = 2.91$, $MSE = 65.4$, $p = .103$, $\eta^2 = .020$, or a significant main effect for Prime Type were found, $F < 1$. In contrast to when the Target's Density was HD, there did not appear to be any priming effect for either Distractor Density when

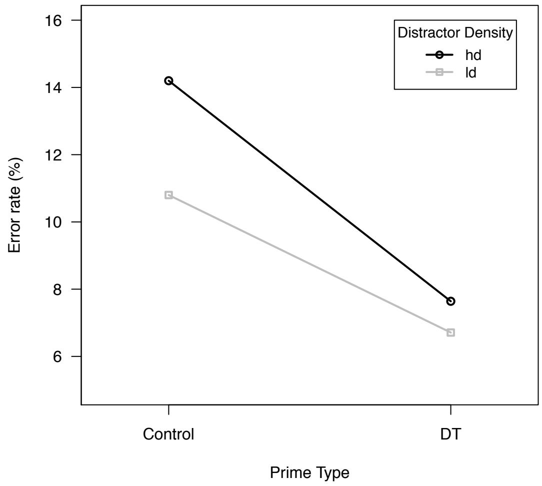

Figure 4.4: Interaction between distractor density and prime type for HD targets for high proficient bilinguals in their L2.

the Target's Density was LD. The results of the analysis with density defined by the L1 are summarised in Table 4.20. No significant effects were found.

Table 4.20: Results of the Four-Way, Mixed Design ANOVA with Density Being Defined by the L1 for the High Proficient Bilingual Group

	F(1,20)	p	η^2
1. Distractor$_{prime}$ or Target$_{probe}$ Density	1.76	.200	.006
2. Target$_{prime}$ or Distractor$_{probe}$ Density	1.07	.313	.005
3. Prime Type	0.91	.352	.004
1 x 2	0.28	.600	.001
1 x 3	0.03	.855	.000
2 x 3	2.65	.119	.020
1 x 2 x 3	0.08	.772	.000

4.2.6 Interim Summary: Negative Priming Effects

In the monolingual group, the aim was to see whether stronger hd distractors would induce greater negative priming effects after hd distractors proved to be the stronger distractors in the PPI paradigm. Contrary to the expectation, hd distractors were not inhibited more strongly than ld distractors. In fact, negative priming effects were dependent on target densities, with HD Targets showing priming effects regardless of the distractor's density and LD Targets showing no priming effects across distractor densities. It appears as if the target determines whether its distractors need to be inhibited.

In the low proficient bilingual group, the aim was also to see whether the density of distractors influenced priming strength and whether this was found when the L1 and not the L2 defined density. There were no priming effects found whatsoever, providing no support for the notion that one of the distractors should show greater priming effects. Also, no effects were found when either L1 or the L2 defined density, therefore it cannot be concluded which language determined density. Additionally, it was hypothesised that bilinguals would show greater negative priming effects than monolinguals as an indicator of advantages in cognitive control. The hypothesis was not confirmed, with low proficient bilinguals showing no negative priming effects.

In the high proficient bilingual group, the aim was also to see whether the density of distractors influenced priming strength and whether this was found when the L2 and not the L1 defined density. As in the monolingual group, no priming effects whatsoever were found, again providing no support for the prediction that one of the distractors, arguably the hd ones, should show a greater inhibition effect. Again, the absence of effects does not allow a conclusion whether the L2 or the L1 defines density. In contrast to the low proficient group, the error rates show effects when the L2 defined density hd distractors showed positive priming when the Target was HD, with fewer errors made on DT trials. All other combinations did not show any priming effect. With no other evidence to the contrary, this suggests that L2 determines neighbourhood density in high proficient bilinguals. With regards to the bilingual advantage in cognitive control, no priming effects were found in the bilingual group, so the hypothesis that there is an advantage evident in stronger inhibition compared to monolinguals is not confirmed for the high proficient group either.

4.2.7 Results: General Effects

Monolinguals

Reaction times The remaining non-Prime Type effects found when analysing the probe data were also examined. Mean RTs (ms) and standard deviations across conditions can be found in Table 4.5. The results of the analysis are summarised in Table 4.6, which indicated that the main effect for Distractor Density shows a trend towards significance, $F(1, 53) = 3.72$, $MSE = 3871$, $p = .059$, $\eta^2 = .007$. Probe targets with an hd distractor were named on average 26ms slower than targets with an ld distractor. This is in line with the monolingual RT findings in the PPI task.

Error rates Mean error rates (%) and standard deviations across conditions can be found in Table 4.7. The results of the analysis are summarised in Table 4.8, and show a significant main effect of Target Density, $F(1, 53) = 8.09$, $MSE = 68.1$, $p < .01$, showing a small effect, $\eta^2 = .023$. On average, 2.03% more errors were made when the probe target was LD compared to when it was HD, which is in line with previously reported error data for items differing in neighbourhood density (e.g., Vitevitch, 2002).

Low Proficient Bilinguals

Reaction times Mean RTs (ms) and standard deviations across conditions can be found in Table 4.9. The results of the analysis with density defined by the L1 are summarised in Table 4.10 and indicate no significant general effects.

The results of the analysis with density defined by the L2 are summarised in Table 4.11. There was a significant interaction between Target Density and Distractor Density, $F(1, 18) = 7.16$, $MSE = 2376$, $p < .05$ showing a small effect $\eta^2 = .019$. Pairwise comparisons revealed that, as illustrated in Figure 4.5, HD probe targets with an ld distractor were named 42ms more slowly than with an hd distractor, $p < .05$; in contrast, there was no difference in RTs between LD targets with an ld or an hd distractor, $p = .998$. It appears that, overall, HD targets were influenced by their distractor in a direction contrary to what was found for the monolinguals in the PPI paradigm.

Error rates Mean error rates (%) and standard deviations across conditions can be found in Table 4.12. The results of the analysis with density defined by the L1 are summarised in Table 4.13. There was only a significant main effect for Distractor Density, F (1, 18) = 7.52, $MSE = 57.1$, $p < .05$ showing a small effect $\eta^2 = .019$. When the probe distractor was ld, 3.66% fewer errors were made compared to when the distractor was hd.

The results of the analysis with density defined by the L2 are summarised in Table 4.14. No significant effects were found.

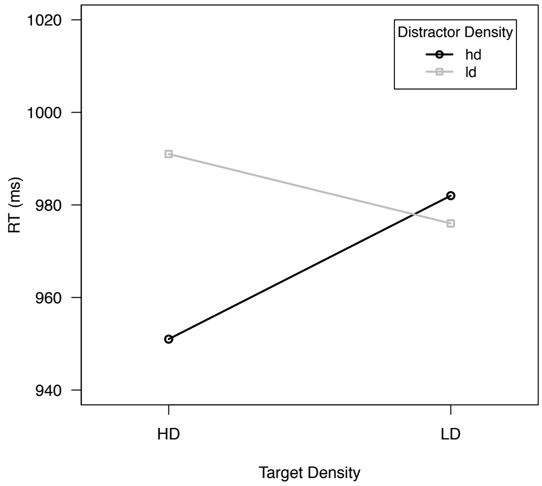

Figure 4.5: Mean RTs (ms) across target and distractor densities defined by the low proficient bilinguals' L2.

High Proficient Bilinguals

Reaction times Mean RTs (ms) and standard deviations across conditions can be found in Table 4.15. The results of the analysis with density defined by the participants' L2 are summarised in Table 4.16. There was a significant main effect for Target Density, F (1, 20) = 5.52, MSE = 5183, $p < .05$, showing a small effect, $\eta^2 = .025$. On average, LD targets were named 24ms more slowly than HD targets. It appears that only the probe target's density and not the probe distractor's density influenced naming time in a direction seen in previous simple naming studies (Vitevitch, 2002).

The results of the analysis with density defined by the participants' L1 are summarised in Table 4.17. There was a significant main effect for Distractor Density F (1, 20) = 9.98, MSE = 7393, $p < .01$, showing a small effect, $\eta^2 = .051$. Regardless of Target Density, targets with an ld distractor were named 39ms faster than targets with an hd distractor. In contrast to when the L2 defined density, it appears that distractor density instead of target density has an influence on RTs.

Error rates Mean error rates (%) and standard deviations can be found in Table 4.18. The results of the analysis with density defined by the L2 are summarised in Table 4.19; no general effects were found. The results of the analysis with density defined by the L1 are summarised in Table 4.20 showing no significant effects.

4.2.8 Interim Summary: General Effects

Given that the monolinguals showed solid negative priming effects, no other general effects were found for RT time. However, monolinguals showed general error rate effects, with LD Targets showing more errors than HD targets. This is in line with previously observed error rate effects in picture naming studies (Vitevitch, 2002).

In the absence of priming effects, in the low proficient bilingual group when density was defined by the L2, overall HD probe targets were named more slowly when the probe distractor was ld compared to when the distractor was hd. This contrasts with what has been found in the monolingual group in the PPI, where hd distractors interfered more with target naming. The question is, however, whether the results from the overall negative priming paradigm can be considered equivalent or comparable to the results from the PPI, which depends on whether Prime Type interacts with the other factors and, in itself, shows an effect. This RT effect does not support the prediction that the L1 still defines density in low proficient bilinguals because an expected effect only happens when L2 defines density. However, contrary to the RT effects, error rate effects have been found when density was indeed defined by the L1. When the L1 defined density, fewer errors were found for targets with ld distractors compared to targets with hd distractors. This is contrary to what was found for the monolinguals where target density influenced error rates. From this it seems that both the L1 and the L2 might have an influence in density coding.

The influence of L1 and L2 density is further complicated in high proficient bilinguals. For these individuals, when density was defined by the L2, target density influenced RTs with HD probe targets being named faster, as found in simple naming studies (Vitevitch, 2002). In contrast, when density was defined by the L1, there was also a significant effect. In this situation, distractor density influenced naming time, where targets with an ld distractor named faster than targets with a hd distractor. Again, it seems as if both L1 and L2 densities influence density coding.

4.2.9 Results: Comparing Performance Across Groups

Given the difference in response patterns across the three language groups, two 2-way ANOVAs were conducted to compare overall RTs and error rates across the factors Language Group and Participant Group. For this, density was always defined by the bilinguals' L2 English, which was the monolinguals' L1. Mean RTs and error rates and their associated standard deviations across the three groups can be found in Table 4.21.

Table 4.21: Overall Mean RTs (ms) and Error Rates (%) and their Standard Deviations (in parentheses) across the Three Language Groups

	RT	Error rate
Monolinguals	810 (102)	12.3 (7.06)
Low Proficient Bilinguals	955 (150)	10.5 (7.30)
High Proficient Bilinguals	897 (120)	10.9 (6.50)

Reaction Times

There was a significant effect for Language Group, $F(2, 91) = 11.2$, $MSE = 14444$, $p < 001$, with a small effect, $\eta^2 = .040$. Orthogonal contrasts revealed that monolinguals responded on average 166ms faster than low proficient and high proficient bilinguals, $p < .001$. Also, low proficient bilinguals responded 58ms more slowly than high proficient bilinguals, $p = .052$. This finding distinguishes well between the two proficiency groups. Also, given that low proficient bilinguals overall were the slowest to respond, this might have contributed to the fact that no priming effects were evident in this group. The difference between recognising a not previously seen target, and an inhibited target might not be big enough to display the slight priming effect.

Error Rates

Investigating overall differences in error rates across the three language groups, no significant effect for Language Group was found, $F < 1$. As illustrated in Table 4.21, unlike the RTs, there was no significant difference in error rates across the three groups.

4.3 Experiment 5

After finding negative priming effects in the monolingual, but not in the bilingual groups, the question is whether cognitive control advantages, as indicated by greater negative priming effects, is possibly a function of general cognitive processes. Therefore, the flanker task was repeated using digits that had to be named in the participants' L1 as a more general measure of cognitive inhibition.

4.3.1 Method

Participants

See Experiment 4

Materials and Procedure

The stimuli used in this experiment consisted of the digits 1 to 6, which had to be named in the participants' L1; native English speaking participants named the digits in English (one, two, three, four, five, six), native German speaking participants named the digits in German (eins, zwei, drei, vier, fünf, sechs), and native Icelandic speaking participants named the digits in Icelandic (einn, tveir, þrír, fjórir, fimm, sex).

This experiment was similar to the previous Experiment 4 except that now digits instead of pictures had to be named. On each trial, two digits, one green and one red, were presented with 50% overlap, as illustrated in Figure 4.6.

Figure 4.6: Overlay digit example.

Participants were instructed to name the green digit while ignoring the red digit. So for the digits presented in Figure 4.6, the correct response would be “three/drei/þrír”. The procedure of the picture-naming paradigm was the same as for the pictures described in Experiment 4 and illustrated in Figure 4.1. After eight practice prime and probe trials, each participant completed 36 experimental prime and probe trials. Participants completed this task at the end of their respective experimental session, with the oportunity to have a break beforehand.

Apparatus

See Experiment 4.

4.3.2 Results

It was hypothesised that if late bilinguals have general cognitive control advantages like early bilinguals (e.g., Bialystok, 2007; Bialystok et al., 2004), high and low proficient late bilinguals should show greater negative priming effects than monolinguals, the converse of what was found in Experiment 4. Additionally, if those advantages are related to proficiency, high proficient bilinguals were expected to show greater priming effects than low proficient bilinguals.

Reaction Times

To compare negative priming effects across monolinguals, low proficient bilinguals, and high proficient bilinguals, a two-way mixed design ANOVA was used to analyse these factors: Language Group (monolinguals vs. low proficient bilinguals vs. high proficient bilinguals) and Prime Type (Control vs. DT). Only probe trial responses were analysed, with mean RTs (ms) and standard deviations across the Group by Prime Type conditions and subsequent priming effects provided in Table 4.22.

There was no Group by Probe Type interaction, $F < 1$. There was, however, a main effect of Prime Type, $F(1, 98) = 24.6$, $MSE = 999$, $p < .001$, showing a large effect with $\eta^2 = .198$. As illustrated in Table 4.22, on average, and regardless of the Group, DT probe trials were responded to more slowly than Control probe trials, showing a reliable

Table 4.22: Mean RTs (ms) and Standard Deviations (in parentheses) across Probe Type (Control vs. DT) and Trial Type (Prime vs. Probe) for Monolingual, Low Proficient Bilingual and High Proficient Bilingual Participants

	Monolinguals	
	Prime	Probe
Control	501 (59.9)	483 (59.6)
DT	503 (66.7)	505 (66.9)
Priming Effect		-22 (19.8)
	Low Proficient Bilinguals	
	Prime	Probe
Control	533 (89.1)	587 (144)
DT	536 (144)	619 (168)
Priming Effect		-32 (68.3)
	High Proficient Bilinguals	
	Prime	Probe
Control	558 (88.9)	564 (119)
DT	560 (95.1)	581 (156)
Priming Effect		-17 (54.5)

negative priming effect of 23ms. Contrary to the hypothesis that expected a difference in the magnitude of negative priming between the three groups, the lack of an interaction indicates a consistent priming effect with no differences between groups.

A main effect for Group was also found, $F(2, 98) = 9.67$, $MSE = 11915$, $p < .001$, showing a large effect with $\eta^2 = .165$. Orthogonal contrasts showed a significant difference in overall RT between monolinguals (494ms) and the bilinguals (595ms), $p < .001$, but there was no difference in overall RT between low (603ms) and high proficient (570ms) bilinguals, $p = 335$. As also highlighted in Experiment 4, overall bilinguals were slower to respond than monolinguals.

Contrary to the expectation that there would be a difference in negative priming patterns between the groups as found in Experiment 4, this was not supported as all Groups showed reliable, but also comparable, priming effects. The only difference between the Groups was that bilinguals were slower to respond to target digits than monolinguals.

Error Rates

To investigate error rate patterns, another two-way mixed design ANOVA was used to analyse the factors Language Group and Prime Type. Mean error rates (%) and standard deviations across conditions and for the priming effects can be found in Table 4.23. As for the RTs (Table 4.22), the error rates for prime trials are shown as well, while in the analysis only the difference between the Control probe trial and the DT probe trial is considered.

There was no significant Group by Prime Type interaction, where $F < 1$. The main effect for Prime Type was also not significant, where $F(1,\ 98) = 1.34$, $MSE = 454$, $p = .250$, showing a small effect with $\eta^2 = .013$. Only the main effect for Group was significant, $F(2,\ 98) = 3.59$, $MSE = 3.8$, $p < .05$, showing a medium effect with $\eta^2 = .091$.

Table 4.23: Mean Error Rates (%) and Standard Deviations (in Parentheses) across Prime Type (Control vs. DT) and Trial Type (Prime vs. Probe) for Monolingual, Low Proficient Bilingual and High Proficient Bilingual Participants

	Monolinguals	
	Prime	Probe
Control	0.00 (0.00)	0.00 (0.00)
DT	0.11 (0.77)	0.21 (1.10)
Priming Effect		-0.21 (1.10)
	Low Proficient Bilinguals	
	Prime	Probe
Control	0.70 (1.89)	1.42 (2.53)
DT	0.94 (2.07)	0.92 (4.53)
Priming Effect		0.50 (4.18)
	High Proficient Bilinguals	
	Prime	Probe
Control	0.00 (0.00)	1.53 (4.36)
DT	0.93 (2.13)	0.70 (1.89)
Priming Effect		0.83 (4.40)

Orthogonal contrasts revealed a significant difference in overall error rates between monolinguals (0.11%) and bilinguals (1.15%), $p < .01$, but there was no difference in overall error rates between low (1.18%) and high proficient (1.12%) bilinguals, $p < .915$. Unlike in Experiment 4 when there were no differences in error rates between the three language groups, for digit naming bilinguals made 1.04 % more errors than monolinguals. Given that monolinguals were also faster to respond, this does not reflect a speed-accuracy trade-off.

4.4 Discussion

The aim of this study was to investigate how L2 words are accessed in word production. The first goal was to examine whether lexical selection is a competitive or non-competitive process in order to infer how late bilinguals keep their two languages apart. The second aim was to examine whether reports of early bilingual advantages in cognitive control (e.g., Bialystok, 2007; Bialystok et al., 2004) would extend to late bilinguals as well. This was done in light of the fact that the advantage has often been linked to the process of keeping the two languages apart. Third, the last aim was to further the findings in Chapter 3 concerning whether for low and high proficient bilinguals coding of L2 neighbourhoods was done according to their L1 or their L2.

4.4.1 Competitive Versus Non-Competitive Selection

The monolingual PPI paradigm results support the view that lexical selection is competitive. In this group, hd prime distractors delayed prime target naming significantly in comparison to ld distractors. Competitive lexical selection (see Levelt et al., 1999) assumes that selection depends on the activation of a target relative to the activation of non-target words. According to this approach, hd distractors interfere more because they are activated more strongly than ld distractors. This way, they are a stronger competitor to the target as they raise the amount activation the target has to compete against. The finding does not align with a previous PWI study in which low frequency distractors interfered more with target naming than high frequency words and suggested a non-competitive approach to selection (Miozzo & Caramazza, 2003).

The difference between frequency and neighbourhood density is that frequency is frequently attributed to the lemma, while neighbourhood density is attributed to the lexeme (Goldrick & Rapp, 2007). Some models of word production propose a strict separation between the lemma and the lexeme (to which neighbourhood density has been attributed) lexical entries, and add that only the lemma is activated during lexical selection (Levelt et al., 1999). However, given the influence exerted by neighbourhood density in the monolingual group in the PPI paradigm, it seems more plausible that the separation is not as strict as assumed (see also Caramazza, 1997; Dell, 1986). On the other hand, this also leaves the possibility that the frequency effect and the neighbourhood effect still occurred at different stages, and it remains to be seen which is related to selection. Unfortunately, the results in the two bilingual groups do not allow for a conclusion regarding lexical selection as, in both cases, distractor density did not influence target naming, only error rates. This is not expected in either competitive or non-competitive selection. Only target density influenced naming times. HD targets were named faster than LD targets in both the high and the low proficient group. This finding is in line with what is usually found when LD and HD pictures are named in the absence of a distractor (Vitevitch, 2002), arguably because HD targets are more readily available because of effective coding and or higher activation.

4.4.2 The Role of Cognitive Control

The question is why distractors did not have an influence in the two bilingual groups as they clearly did in the monolingual group. One possible explanation is the advantage bilinguals show when it comes to dealing with interference (e.g., Bialystok, 2007; Costa et al., 2009, 2008; Rodriguez-Fornells, Balaguer, & Munte, 2006), which could have led them to inhibit the distractor before it could have had any influence.

A possible bilingual advantage with regards to interference control using cognitive inhibition has been examined in the negative priming paradigm in Experiment 4. It was hypothesised that stronger distractors, such as hd distractors shown in the monolingual case, should show greater negative priming effects. Additionally, it was hypothesised that bilinguals should show greater negative priming as a result of their greater cognitive inhibition (see Treccani et al., 2009). Neither hypothesis was fully confirmed.

The monolingual group did show negative priming effects, however, these effects did not entirely differ for targets with hd and ld distractors. Only LDld items did not show any negative priming effects, and interestingly both their RTs in the control and the DT condition were comparably slow. It is therefore unclear whether hd distractors were inhibited more strongly, as HDld items were comparable to HDhd and LDhd items, while LDld items were not. Neither the low proficient bilinguals, nor the high proficient bilinguals showed any priming effects. In both groups, only target effects were found, comparable to effects on a PPI task. However, given that these results were averaged across two different trials (the DT probe has a relationship to the DT prime, whereas the control probe is not related to the control prime), it is not clear whether the effects could be interpreted as simple naming effects. HD targets were named faster than LD targets which at least would fit with results previously reported in the literature (Vitevitch, 2002).

Against the prediction that bilinguals should show an advantage with regards to cognitive inhibition as manifested by greater negative priming effects (Treccani et al., 2009), no negative priming effects were found in the low or the high proficient bilingual group. However, given that in the PPI paradigm no distractor influence on naming was found, it could be argued that the bilinguals were able to ignore the distractor on the prime trial in other ways than by inhibiting it so that when the prime distractor came back as a target on DT trials, it was available right away because it never was inhibited in the first place. Notably, the late bilinguals also did not show greater negative priming effects on the digit naming negative priming paradigm in which digits had to be named in the participants' L1 as a less language-dependent version of the negative priming paradigm. Therefore, the previously reported advantage in cognitive control (Bialystok, 2006; Bialystok, Craik, et al., 2005; Bialystok et al., 2008, 2004; Bialystok & DePape, 2009; Costa et al., 2009, 2008; Emmorey et al., 2008; Luk & Bialystok, 2008), did not extend to late bilinguals in a less language-dependent negative priming paradigm.

4.4.3 The Influence of L1 and L2 Neighbourhoods

Lastly, to link back to Chapter 3 investigating whether the L2 neighbourhood of late bilinguals was influenced by L1 or L2 coding, it was hypothesised that all effects for low proficient bilinguals would be found when density was defined by the L1, whereas for high proficient bilinguals effects would be found when density was defined by the L2. This hypothesis was only partly supported. In the case of low proficient bilinguals, all RT effects were found when density was defined by the L2. Only an error effect in the negative priming paradigm was found when density was defined by the L1.

For high proficient bilinguals, most effects were found when density was defined by the L2, including faster naming times for HD items compared to LD items on the PPI task. Curiously, in the negative priming paradigm, LD probe targets were named more slowly than HD targets when density was defined by the L2, but then ld distractors significantly slowed down target naming compared to hd distractors when density was defined by the L1. How can there be an effect for both the L1 and the L2 determining density? Unfortunately, given the close relationship between the three languages, many items correspond in terms of their neighbourhood, so some of the effects might occur when density is defined by the L2, while others occur when density is defined by the L1. Unlike in the last chapter, and with this experiment's complicated design, it was impossible to analyse items even further, (e.g., looking at items that were HD in one language, but LD in the other). That said, given that the high bilinguals again show the robust effect of HD targets being named faster than LD targets when density was defined by the L2, one could conclude that in line with the findings in the previous chapter, L2 items are mostly coded according to the L2 in the high proficient group. Regarding the low proficient group, whereas the previous chapter's results pointed in the direction of the L1, overall, low proficient bilinguals' coding seemed to lie between the L1 and the L2. In this study, low proficient bilinguals also showed the robust effect of HD targets being named faster than LD targets when defined by the L2 in the PPI task, indication that in this group too, coding seems to be more and more influenced by the L2.

4.4.4 Late Bilingual Word Production

What conclusions regarding late bilingual word production can be drawn from the results found? First of all, the monolingual data suggest that lexical selection is, after all, a competitive process. Even though Finkbeiner, Gollan, and Caramazza (2006) claim that the issue of keeping two languages apart is an easy issue to solve given that lexical access is not competitive is very simple, the findings of this study do not support their basic assumption which turns the proposal into a hard problem again. While other suggestions regarding the regulation of two languages in word production (Costa & Caramazza, 1999; Costa et al., 1999; Green, 1998; La Heij, 2005) cannot account for all the evidence provided so far (Finkbeiner, Almedeida, et al., 2006; Finkbeiner, Gollan, & Caramazza, 2006), they do assume competitive selection. Unfortunately, the results in our bilingual group do not tell us much more about whether selection is competitive or not. So far we can only infer this from our monolingual group.

Assuming that lexical selection is competitive, this allows for the possibility for a mechanism like the one proposed by Green (1998) IC model to regulate selection using cognitive inhibition. This mechanism has been linked to bilingual advantages in cognitive control in the past (e.g., Bialystok et al., 2008; Emmorey et al., 2008; Festman et al., 2010). One aim of this study was to investigate whether an advantage was also found in late bilinguals, as reported by Festman et al. (2010). No advantage was found for the bilingual groups on the digit naming task, which was less language-dependent. It is curious, however, that in the L2 picture naming priming paradigm, bilinguals showed some kind of interference control in that no negative priming was found whatsoever after distractors seemed to be easily ignored in the prime trials as indicated by the PPI task. One possible explanation of this finding is that the bilinguals did not inhibit the item itself, but the processing of whatever was shown in black (i.e., the distractor cue). For instance, it has been found that when the 'target task' in a negative priming paradigm (e.g., name the red picture) is too cognitively demanding, the distractor is not processed properly and rather 'ignored' on the basis of a perceptual feature, for example, colour or spatial location (Lavie & Fox, 2000). In that case, bilinguals did not show an advantage controlling interference, but had to simply direct all their capacity onto completing the main task at hand.

4.4.5 Limitation

A limitation of this study is that since both German and Icelandic bilinguals were combined to increase power in the analyses, again the items could not be analysed as neighbourhood density did not fully correspond between German and Icelandic. In this way, it is not known whether the item effects support the subject effects or whether some items performed worse than others.

4.4.6 Conclusion

To conclude, this study has indicated that lexical selection seems to be a competitive process in monolinguals involving lexical entries that consist of both the lemma and the lexeme. It can only be inferred from the monolingual results and previous studies that selection is possibly also competitive in bilinguals. If that is the case, Experiment 4 would support bilingual theories of word production that assume competitive lexical selection. This then highlights the question of how competition is resolved in bilingual word production. Looking at cognitive inhibition as one mechanism to resolve competition, it was, however, found that the task was too demanding for the late bilinguals and, as a result, the distractor was not inhibited but rather simply rejected on the basis of its colour properties. If using the L2 appears too demanding for the late bilinguals in certain contexts, the involvement of inhibition to keep the languages apart should be questioned. Lastly, this study has confirmed that both L2 and L1 influence the representation of L2 in bilinguals, with, however, more influence of the L2 in the high and partly in the low proficient group.

Chapter 5

Discussion

5.1 The Development and Organisation of L2 Phonological Word Forms

The experiments within this thesis sought to address a number of questions. The first question is: How are L2 phonological word forms developed and organised? Previously it has been argued that at least in the beginning stages of L2 acquisition, the L2 will be integrated into the L1 lexicon, because unlike in the case of L1 acquisition, when late bilinguals acquire an L2 there is already a lexicon that can accommodate new words (Jiang, 2000; Singleton, 1999). It has also been proposed that in late bilinguals, L2 lexical entries are closely linked to their L1 translation equivalents before they can establish their own connection with the concept they express as the late bilingual becomes more proficient (Kroll et al., 2010; Weinreich, 1953).

The findings in Experiment 3 indicated that L2 phonological word form representations are indeed not encoded and then organised in isolation: L1 neighbourhood density influenced the degree of form priming of L2 phonological word forms. In monolinguals, the observation that the degree of form priming decreases as the numbers of word neighbours increases has been attributed to the need for additional discrimination in high density neighbourhoods, which leads to reduced overlap with form primes and results in reduced form priming (Castles et al., 2007; Forster & Taft, 1994). Therefore, in Experiment 3 it appears that the L2 phonological word forms must have been in contact with related L1 forms and their neighbourhoods.

The only other study known to the author that also looked at the influence of L1 forms on the organisation of L2 word forms (orthographical in this case) was conducted by Van Heuven et al. (1998). They found that in an L2 lexical decision task, reaction times of mid to high proficient late bilinguals were influenced by the L1 neighbourhood of the L2 items.

While these findings indicate that the two languages must have been in contact with each other, the fact that an influence of the L1 can be seen in L2 retrieval does not necessarily mean that they still are in contact. Either there is an integrated lexicon where both L1 and L2 words combine in the same form-based neighbourhoods, or L2 words have migrated into a newly formed L2 lexicon. In that case, once a recoding occurs in the old lexicon, it is retained in the new (hence the continued indirect influence of L1 neighbourhoods). Consequently, this would mean that new L2 items that are acquired after the separation of lexicons will not reflect L1 neighbourhood density.

5.2 The Role of Proficiency in the Developing Lexicon

Another critical issue in the bilingual literature is whether the influence of the L1 and the integration between the two languages changes as the proficiency of the late bilingual increases. It has been proposed that as more L2 word forms are acquired and the L1 and the L2 are used in separate contexts, subsets in an integrated lexical space may form in which links with entries are established that are used in the same context or have the same properties (e.g., being an L2 word, being an L1 word), while links to entries that are not used together or have a different property decay (e.g., Hulstijn, 1997; Paradis, 2004).

In Experiment 3 it was shown that the L2 starts to play a bigger role in high proficient bilinguals compared to low proficient bilinguals; words from L2 high density neighbourhoods also showed reduced form priming compared to words from an L2 low density neighbourhood. Additionally, in Experiment 4 it was mostly L2 density which influenced naming times in both high and low proficient bilinguals.

The idea that the influence of the L1 decreases and the L2 phonological lexicon becomes self-contained can be seen as analogous to the proposal that as proficiency increases the organisation of the bilingual lexicon changes from a reliance on links between translation equivalents to having L2 entries directly linked to the concept (Kroll et al., 2010; Weinreich, 1953). Research indeed indicated that when bilinguals had to decide whether two words were translation equivalents (e.g., L2: silla – L1: cadira [chair]) or not, low proficient bilinguals were more likely to treat them as translation equivalents where the L1 word was only form related to the L2 word (e.g., silla – cadena [chain; similar to cadira - chair], while high proficient bilinguals were more susceptible to semantic incorrect pairs when the L1 word was semantically related to the L2 word (e.g., silla – buttaca [armchair]). This indicates a change from L2's reliance on L1 forms to a reliance on concepts.

So, do the two languages split into separate lexicon(s) at some stage? Most models regarding the organisation of the bilinguals' languages propose that once the bilingual becomes more proficient, lexical entries of the two languages are kept separate (Kroll et al., 2010; Weinreich, 1953).

The findings in Experiment 3 and 4 concern L1 and L2 phonological word forms, only. Experiment 3 and 4 show that, while especially in high proficient bilinguals the L2 environment has a greater influence on L2 word form processing than the L1 environment, there is nonetheless influence of the L1 lexicon (e.g., as seen in error rate effects). Therefore, while forms in the two languages might start to separate over time as they are used in different contexts and as the amount of L2 entries grows, it is difficult to say whether the lexicons will completely 'split up' at some stage. On the other hand, as mentioned previously it could also be the case that they have already split and just display a cross-language influence due to cross-language encoding.

Another question is whether other aspects of a lexical entry, such as L1 and L2 syntactic or morphological information, are integrated or (functionally) separate. With regards to syntactic and morphological information, it has been shown that the L1 also influences the acquisition of grammatical features such as grammatical gender (Sabourin, Stowe, & De Haan, 2006). In fact, in Dutch, the acquisition of specific gender marking rules and morphological changes according to these rules was found to be very much dependent on the similarity to gender marking in the L1. German-Dutch late bilinguals, whose L1's gender marking rules are very similar to the Dutch ones, performed best judging noun-relative pronoun agreement in Dutch. Romance-Dutch late bilinguals, whose L1 features some abstract syntactic gender features, performed second best, but significantly worse than the Germans. English-Dutch late bilinguals, whose L1 does not feature grammatical gender, performed worst at chance level (Sabourin et al., 2006). In this case, it seems that an integration of L1 features is necessary for optimal L2 usage. Also, it seems that the possibility of the integration is very much dependent on the similarity between the L1 and the L2.

Therefore, the question of whether a late bilingual's lexicon will separate (functionally) appears to be too simple. Rather, it seems that integration between languages can vary within each level (i.e., phonology, morphology, syntax), depending on proficiency, as demonstrated in Experiment 3 and 4, or depending on language similarity, as demonstrated by Sabourin et al. (2006). Likewise, the amount of integration can then vary for different aspects of the lexical entry, for instance presenting integration at the syntactic or morphological level (Sabourin et al., 2006), but increasing separation at the form level (see Experiment 3 and 4; Kroll et al., 2006, for a similar position).

5.3 L2 Processing in Late Bilinguals

If the two or more languages used by a bilingual are integrated across various types of information, the question then is: How are the two languages kept apart for production? To answer this question we should first take a step back and consider whether language selection is competitive or non-competitive. This is important because the answer will inform as to whether there is pre-access interference between the two languages that needs to be regulated. While most models of bilingual language production assume competitive lexical selection (Costa & Caramazza, 1999; Costa, Caramazza, & Sebastián-Gallés, 2000; Green, 1998; La Heij, 2005), it has been found that distractors that should be stronger competitors assuming competitive selection, in this case high frequency items, did not cause greater interference as expected by that assumption (Miozzo & Caramazza, 2003).

In Experiment 4 it was found that distractors from a high density neighbourhood did cause greater interference for target retrieval. According to a competitive assumption, this should be the case due to greater activation or faster availability compared to distractors from a low density neighbourhood. However, this was only found to be the case in the monolingual group. In the bilingual group the distractors did not have any influence at all. Does this mean that in monolinguals other words compete with a target for selection while in bilinguals there is no competition during lexical access?

Looking at the findings throughout Chapter 4, it rather seems as if the absence of any effects in the bilingual group is due to a different issue: the difficulty of the overlay task. The overlay task could have been particularly difficult for the late bilinguals because not only did they have to name low frequency pictures in their L2, like in Experiment 2, but now they were also told to ignore the distractor.

Looking at the picture-picture interference results in Experiment 4 both low and high proficient bilinguals named the pictures as if the distractor was not there. The distractor had no influence on naming times which were comparable to those in a simple picture naming task (Vitevitch, 2002). Then looking at the negative priming results, also in Experiment 4, no negative priming effects (i.e., evidence of interference) were found for either low or high proficient bilinguals. If the distractor was inhibited in the prime trial leading to facilitation of target naming in a competitive lexical environment, then there should have been negative priming effects when analysing the probe trials. However, no negative priming effects were found. It appears as if late bilinguals did not process the distractor at all.

One reason for not processing the distractor could have been the demands of the task. Research has found that if the target related task in a negative priming paradigm has a high cognitive load, irrelevant processing of the distractor is decreased, resulting in decreased or no negative priming (Lavie & Fox, 2000). In Experiment 4 it may be that the distractor was simply not processed. It could possibly have been rejected on the colour cue before the specific item could be processed to free up processing space for the target.

Another reason for the lack of distractor processing could be the fact that in late bilinguals, L2 processing is still not sufficiently automatic. In the past, interference effects have been attributed to greater automatic processing (Tzelgov & Kadosh, 2009). It has been found in late bilinguals that the Stroop effect (i.e., the interference present when saying what colour ink a word is written in, while the word itself names another colour [e.g., the word 'red' written in blue ink]) is greater when participants are required to respond with their L1 relative to L2 responses (Tzelgov, Henik, & Leiser, 1990). This suggests that greater automaticity is associated with the L1 lexical entries.

From this it could be concluded that L2 processing in Experiment 4 was possibly not automatic. Additionally, in Experiment 5 in which participants completed the digit-naming negative priming paradigm in their L1, equivalent negative priming effects were found across mono- and bilinguals in line with the L1 Stroop effects found by Tzelgov et al. (1990), supporting the assumption that interference would result in inhibition.

What does this suggest regarding cognitive control in late bilinguals? In the past, the cognitive control advantages found in early bilinguals (e.g., Bialystok, 2007)(Costa et al., 2009, 2008; Rodriguez-Fornells et al., 2006) have been linked to the involvement of cognitive inhibition to keep the two languages apart during production (Green, 1998). However, as described above, for the late bilinguals in this study, L2 processing might not have happened in a completely automatic fashion and if control is linked to automatic processing, no control should be expected as a mechanism to keep the languages apart. This fits in with criticism regarding switching costs as evidence for inhibitory control in late bilingual production. In language switching paradigms it has been found that the switch from the L2 to the L1 takes longer than from the L1 to the L2 (Meuter & Allport, 1999). The longer switching time has been attributed to the recovery of the L1 from prior inhibition. However, an alternative explanation has been that the automatic L1 response is available too fast after the previous L2 responses were much slower (not automatic) and that the fast L1 response is simply 'flagged' as being suspicious (Finkbeiner, Almedeida, et al., 2006). Non-language switching evidence for this alternative comes from a monolingual switching task where bigger switching cost were associated with changing from a difficult task to an easier one (see Finkbeiner, Almedeida, et al., 2006), where 'suspicion' of a fast answer possible led to lagged processing time.

It is not entirely evident whether lexical selection in late bilinguals is competitive or non-competitive. From the monolingual results it could be inferred that it most likely is competitive. If lexical selection in bilinguals is competitive, however, the results in Experiment 4 and 5 indicate that cognitive control involving inhibition, such as that suggested by the IC model (Green, 1998), is probably not involved in keeping the two languages apart. L2 processing does not seem to be automatic and so does not require the type of control associated with mechanisms such as inhibition.

5.4 Conclusion

The results throughout this thesis indicate that the L1 and L2 mental lexicons of late bilinguals are integrated at least at the level of phonological form. The degree of integration appears to change as the late bilingual becomes more proficient. For very proficient late bilinguals, the lexicon might even become functionally separated. Research looking at other features of word representation (e.g., morphology) also indicates that the L1 and the L2 are integrated, at least in the beginning. It remains to be seen to what extent each set of lexical features varies in terms of integration and development. Given the evidence that there is some integration of L2 properties with those of L1, there are a number of possibilities regarding how the languages are kept apart during production. One means of achieving language specific access is to inhibit lexical entries in the non-target language. However, no evidence for such a control mechanism was found in Chapter 4. The L2 overlay picture naming task in Experiment 4 seemed to be too demanding for the late bilinguals to be able to process L2 items automatically. As a result, no negative priming indicating the involvement of inhibition was found. Active control mechanisms were simply not required. It seems as if in late bilinguals both the organisation and processing of the L2 are still constantly developing and changing and, for the participants studied in the experiments reported, had not reached a level of automaticity witnessed in L1 production, leaving open the question of inhibition as a means of achieving language specific access in this group.

5.5 Limitations

There are two main limitations associated with the research presented throughout this thesis which are very much interrelated: the inability to analyse the two language groups separately and the inability to analyse item effects. While German and Icelandic are fortunately quite similar in their degree of similarity to English, and while the German and Icelandic participants were also very similar in the L2 acquisition history, it was certainly unfortunate that both groups had to be combined to increase power for the analyses. If there had been more participants it would have been useful to confirm effects for the two language groups separately. After all, it is not known if there are subtle differences between the two language groups that resulted in null effects once the languages were collapsed. One major issue that combining the groups created was the inability to analyse item effects in Chapter 3 and Chapter 4 as densities varied between German and Icelandic. This is especially problematic as the item selection was very much restricted to items in the standardised picture set which was further restricted by the requirement of using low frequency pictures to achieve clearer neighbourhood effects. Without an item analysis it is not known to what degree this picture selection has influenced the presence and, most of all, the absence, of effects. In subsequent studies more participants are certainly desirable.

Additionally within this thesis, cross-language neighbours were calculated by the researcher herself, following the rules for calculating the PLD20 within languages. To calculate cross-neighbourhood density, German and Icelandic dictionaries that included IPA transcriptions were used. Both dictionaries were far from exhaustive, only allowing a crude estimate of neighbourhood density across languages. To include more exhaustive word lists one could automatically transcribe entries into the IPA relying on orthography and transcription rules (see Marian, Bartolotti, Chabal, & Shook, 2012). However, this does not work very well for languages that have a deep orthography (i.e., weak grapheme to phoneme correspondence) like English. Therefore to calculate the PLD20 across languages, more resources, such as language databases including verified IPA transcriptions for pronunciation, are needed. This is important if one wants to build upon the study in Chapter 3 by looking for effects in languages as close as and, most importantly, more distant to English than German and Icelandic.

5.6 Future Directions

Given the finding that the L1 influences neighbourhood organisation of the L2, one interesting direction that this research could take is an investigation of how the L2 in turn influences L1 organisation. This would require adapting the form priming paradigm using L1 word forms for which the L1 and the L2 neighbourhood is calculated.

It would also be useful to characterise the organisation of neighbourhoods in early bilinguals as well to see whether their language experience has led them to a different or similar system as the one seen in late bilinguals. Additionally, it would be interesting to see whether the promising findings of Chapter 3 would also be found using languages that are more distant to English as this may have a great influence on the integration of the L2 into the L1 neighbourhood. If two languages do not possess many cross-language neighbours, there should arguably be less influence of the L1 on the L2.

Given the differences between late and early bilinguals with regards to cognitive control and the finding that in late bilinguals L2 processing might not yet be automatic, it would be beneficial to look at whether and under which circumstances (e.g., degree of proficiency, context of L2 use) automatic processing in late bilinguals can be found and also whether these bilinguals then show cognitive control advantages.

5.7 Finally - Zum Schluss - Loksins

In recent times, the interest in bilingualism has grown, partly because current technology allows for an exchange between people from different language backgrounds in an instant, and also partly because of possible cognitive advantages that bilingualism might bestow. There are a vast number of differences between bilinguals. Many manage to function very well in two languages or possibly even more. Others may be less successful in the acquisition of their second language and consider themselves blessed if they can order a coffee when on vacation. And while it is important to stress those differences in investigation, no matter how proficient or competent someone in contact with more than one language is and no matter what the cognitive advantage associated is, what counts in the end is that:

> "One language sets you in a corridor for life. Two languages open every door along the way."
>
> - Frank Smith

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Appendix A

Questionnaires

A.1 Monolingual Demographic Questionnaire

Participant No. ___________

Before we start with the experiment we would like to ask you a few basic details:

1) How old are you?

___________ years

2) Gender (tick the box)

_____ male _____ female

3) What's your occupation?

____

4) Are you right- or left-handed? (tick the box)

_____ right-handed _____ left-handed

5) Do you speak (an)other language(s)? (tick the box)

_____ yes _____ no

If you indicated "yes" at question 5, please continue:

6) Which language(s) do you speak?

____

____

____

____

7) How proficient do you consider yourself in the other language(s)?

(Please specify per language)

____

____

____

____

8) How often do you speak the other language(s)?

(Please specify per language)

____

____

____

____

A.2 Bilingual Demographic Questionnaire

Participant No. __________

Before we start with the experiment we would like to ask you a few basic details:

1) How old are you?

__________ years

2) Gender (tick the box)

_____ male _____ female

3) What's your occupation?

____

4) Are you right- or left-handed? (tick the box)

_____ right-handed _____ left-handed

5) Is German your native language?

_____ yes _____ no

6) How proficient do you consider yourself in English? (tick the box)

_____ native like - _____ proficient - _____ more or less proficient - _____ not very proficient - _____ not proficient at all

When did you start learning English?

_____ years ago

7) How often do you speak English?

____

____

____

____

8) Did you ever spend some time in an English speaking country? (tick the box)

_____ yes _____ no

9) If you indicated "yes" at question 8: Which country did you visit and why? How much time did you spend in that country?

____

____

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____

10) Do you speak (an)other language(s)? (tick the box)

_____ yes _____ no

If you indicated "yes" at question 10, please continue:

11) Which other language(s) do you speak?

____

____

____

____

12) How proficient do you consider yourself in the other language(s)?

(Please specify per language)

____

____

____

____

13) How often do you speak the other language(s)?

(Please specify per language)

____

____

____

____

That's it! Thank you!

Appendix B

Words Used in the Experiments Throughout the Thesis

Table B.1: Words Used in the Monolingual Experiments

Word	Unrelated Prime	Related Prime	Frequency (HAL)	No. of Letters	No. of Phonemes	No. of Syllables	English PLD20	Neighbourhood Group
beard	blump	beord	3173	5	4	1	1	HD
bell	brot	belf	24815	4	3	1	1	HD
belt	buop	beft	10820	4	4	1	1	HD
bone	baig	bune	16063	4	3	1	1	HD
bowl	boft	buwl	10720	4	3	1	1	HD
bride	bount	brife	3676	5	4	1	1.2	HD
cake	coul	cale	6250	4	3	1	1	HD
clock	coite	clofk	24496	5	4	1	1.15	HD
comb	curo	cemb	1614	4	3	1	1	HD
deer	dilt	daer	4911	4	3	1	1	HD
doll	dasu	dolk	5685	4	3	1	1.25	HD
duck	dant	dulk	6829	4	3	1	1	HD
fork	flup	firk	11253	4	4	1	1.15	HD
goat	gomp	geat	2562	4	3	1	1	HD
grave	gults	greve	7527	5	4	1	1	HD
hook	hult	hoak	11610	4	3	1	1.2	HD
hose	huft	hote	3874	4	3	1	1	HD
kite	koft	kile	2346	4	3	1	1	HD
lamp	lult	lemp	6657	4	4	1	1.35	HD
leaf	luct	leof	7051	4	3	1	1.05	HD

Word	Unrelated Prime	Related Prime	Frequency (HAL)	No. of Letters	No. of Phonemes	No. of Syllables	English PLD20	Neighbourhood Group
mouse	miket	meuse	37838	5	3	1	1.45	HD
nail	nuef	nuil	4603	4	3	1	1	HD
paint	pelte	pailt	15964	5	4	1	1.25	HD
peach	prolt	peuch	1812	5	3	1	1.25	HD
pear	pizt	poar	971	4	3	1	1	HD
pipe	prak	pepe	12205	4	3	1	1.25	HD
plate	poumf	plafe	10419	5	4	1	1.25	HD
purse	pogth	porse	1862	5	3	1	1.35	HD
rope	radu	rofe	6358	4	3	1	1	HD
sheep	skoll	sheup	7524	5	3	1	1	HD
shell	sieph	sholl	37174	5	3	1	1	HD
shoe	slif	shae	5209	4	2	1	1	HD
slide	spack	slibe	10004	5	4	1	1.15	HD
sock	spal	solk	1146	4	3	1	1	HD
swing	shult	sweng	7716	5	4	1	1.1	HD
tent	tolf	tont	3187	4	4	1	1	HD
vase	vuil	vese	540	4	3	1	1.2	HD
vest	vuls	vust	1238	4	4	1	1.15	HD
wing	wogh	weng	15248	4	3	1	1	HD
worm	waft	wolm	4110	4	3	1	1.45	HD
barrel	buthaf	barkel	6836	6	5	2	1.65	LD
basket	bebnil	bosket	2815	6	6	2	1.7	LD
bench	bahat	bonch	5360	5	4	1	1.7	LD
branch	bupple	brinch	13544	6	5	1	1.75	LD
bucket	bafdad	bulket	3329	6	5	2	1.85	LD
button	blafis	bitton	30330	6	4	2	1.7	LD
carrot	cessum	calrot	1435	6	5	2	1.65	LD
clown	capol	clowt	2761	5	4	1	1.7	LD
crib	caek	crob	1280	4	4	1	1.8	LD
desert	dafeld	dusert	17569	6	5	2	2.65	LD
donkey	dwanpe	dinkey	2629	6	5	2	1.95	LD
drawer	dolket	drewer	2480	6	4	1	1.65	LD
frog	fiet	freg	3126	4	4	1	1.7	LD
globe	gurth	glube	5452	5	4	1	1.65	LD
guitar	golees	goitar	24781	6	5	2	2.65	LD
hammer	huffli	hamfer	6714	6	4	2	1.55	LD
jacket	joulig	jucket	10208	6	5	2	2	LD
lemon	latif	lumon	4015	5	5	2	1.7	LD
magnet	miflup	mugnet	2236	6	6	2	2.05	LD

Word	Unrelated Prime	Related Prime	Frequency (HAL)	No. of Letters	No. of Phonemes	No. of Syllables	English PLD20	Neighbourhood Group
monkey	malghu	molkey	4882	6	5	2	1.7	LD
needle	naufik	needke	5047	6	4	2	1.65	LD
nurse	namti	nerse	6640	5	3	1	1.65	LD
onion	olfam	onuon	2587	6	5	2	2.2	LD
orange	olsemp	otange	13483	6	5	2	1.95	LD
pencil	poutka	pefcil	3021	6	5	2	1.8	LD
pillow	prasuf	piklow	2110	6	4	2	1.65	LD
rabbit	rogfeg	rabgit	5751	6	5	2	1.8	LD
robot	raeld	robet	10880	5	5	2	2.1	LD
scarf	sompl	scamf	826	5	5	1	1.85	LD
screw	salfo	scriw	9543	5	4	1	1.65	LD
shovel	safki	shivel	1017	6	4	2	1.8	LD
skirt	segla	slirt	4928	5	4	1	1.75	LD
snail	suro	snaul	10191	5	4	1	1.65	LD
spider	shutol	spuder	6953	6	5	2	1.8	LD
statue	sholfu	stalue	7801	6	5	2	2.15	LD
toilet	trumpa	toulet	5523	6	5	2	2.15	LD
trophy	tulgai	triphy	2193	6	5	2	1.95	LD
turkey	thampa	tarkey	13802	6	4	2	1.75	LD
turtle	tafka	tartle	4483	5	4	2	1.7	LD
zebra	ziolk	zebna	915	5	5	2	2.7	LD

Table B.2: Words Used in the Bilingual Experiments

Word	Unrelated Prime	Related Prime	Frequency (HAL)	No. of Letters	No. of Phonemes	No. of Syllables	English PLD20	German PLD20	Icelandic PLD20	English N Group	German N Group	Icelandic N Group
arrow	atlam	arfow	7324	5	3	2	1.1	3.2	2.9	HD	LD	0
barn	bels	baln	2575	4	4	1	1.35	2.8	3	HD	0	LD
belt	buop	beft	10820	4	4	1	1	1.85	2	HD	HD	HD
bowl	boft	buwl	10720	4	3	1	1	2	3	HD	HD	LD
bread	blomp	bruad	9063	5	4	1	1.2	3	3	HD	LD	LD
broom	blaen	broam	600	5	4	1	1.45	3.45	2.9	HD	LD	0
cake	coel	cale	6250	4	3	1	1	2	2.05	HD	HD	HD
cloud	chemp	cload	6301	5	4	1	1.4	2.75	3	HD	HD	LD
coat	cump	coet	10295	4	3	1	1	1.95	2	HD	HD	HD
comb	curp	cemb	1614	4	3	1	1	1.95	2.75	HD	HD	HD
corn	clep	cern	4988	4	4	1	1	2	2	HD	HD	HD

Word	Unrelated Prime	Related Prime	Frequency (HAL)	No. of Letters	No. of Phonemes	No. of Syllables	English PLD20	German PLD20	Icelandic PLD20	English N Group	German N Group	Icelandic N Group
deer	dilt	daer	4911	4	3	1	1	1.95	1.9	HD	HD	HD
doll	dasu	dolk	5685	4	3	1	1.25	1.95	2.4	HD	HD	HD
duck	dant	dulk	6829	4	3	1	1	1.9	2	HD	HD	HD
fence	flaum	fince	5277	5	4	1	1.5	2.05	1.95	HD	HD	HD
flute	foani	flite	3491	5	4	1	1.4	1.95	2.15	HD	HD	HD
fork	flup	firk	11253	4	4	1	1.15	2	1.65	HD	HD	HD
goat	gomp	geat	2562	4	3	1	1	1.95	2.9	HD	HD	0
harp	henf	horp	1667	4	4	1	1.5	2.8	2.5	HD	0	HD
kite	koft	kile	2346	4	3	1	1	1.1	1.75	HD	HD	HD
ladder	loppaf	lodder	2970	6	4	2	1	4	3.25	HD	LD	LD
lamp	lult	laup	6657	4	4	1	1.35	2.2	2.3	HD	HD	HD
leaf	luct	leof	7051	4	3	1	1.05	1.5	2.2	HD	HD	HD
nail	nuef	nuil	4603	4	3	1	1	2	2.8	HD	HD	HD
nose	nunt	nuse	13919	4	3	1	1	2.8	2.95	HD	0	LD
peach	prolt	peuch	1812	5	3	1	1.25	2.35	2.75	HD	HD	HD
pear	pizt	poir	971	4	3	1	1	1.9	1.95	HD	HD	HD
pipe	prak	pepe	12205	4	3	1	1.25	1.9	2	HD	HD	HD
seal	scof	seol	6421	4	3	1	1	1.85	2	HD	HD	HD
sheep	scoll	sheup	7524	5	3	1	1	1.5	2.9	HD	HD	0
shirt	segla	slirt	8155	5	3	1	1.5	2	2.95	HD	HD	LD
snake	shuli	snoke	5217	5	4	1	1.4	2.95	3	HD	LD	LD
sock	spal	solk	1146	4	3	1	1	2	2	HD	HD	HD
spoon	steol	spoan	2624	5	4	1	1.45	3.15	2.75	HD	LD	HD
stool	sketa	staol	1234	5	4	1	1.3	2.9	2.45	HD	LD	HD
swing	shult	sweng	7716	5	4	1	1.1	3	2.85	HD	LD	HD
truck	tolft	trock	10203	5	4	1	1.5	2.6	1.95	HD	HD	HD
vase	vuil	vese	540	4	3	1	1.2	1.9	1.95	HD	HD	HD
vest	vuls	vust	1238	4	4	1	1.15	1.9	1.8	HD	HD	HD
wrench	wutums	wronch	1389	6	4	1	1.45	3	2.15	HD	LD	HD
anchor	aflupt	anchir	2766	6	4	2	1.55	4	2.8	LD	LD	HD
barrel	buthaf	barkel	6836	6	5	2	1.65	3	3.65	LD	LD	LD
beetle	baghof	bettle	1026	6	4	2	1.7	2.7	2.65	LD	HD	HD
blouse	barkut	bloise	1685	6	4	1	1.85	2.1	3	LD	HD	LD
brush	blemp	brosh	5701	5	4	1	1.65	2.85	3	LD	LD	LD
camel	conth	cumel	3375	5	4	2	1.75	2	3	LD	HD	LD
cannon	cullem	cannou	7579	6	5	2	1.8	2.85	2.95	LD	LD	LD
carrot	cessum	calrot	1435	6	5	2	1.65	3	2.8	LD	LD	HD
cherry	cinlup	chorry	4370	6	4	2	1.7	3.6	3.95	LD	LD	LD
chisel	cynfum	chosel	2697	6	4	2	1.9	3.75	4	LD	LD	LD
cigar	clumn	cigor	1240	5	5	2	2.35	3.75	2.4	LD	LD	HD

Word	Unrelated Prime	Related Prime	Frequency (HAL)	No. of Letters	No. of Phonemes	No. of Syllables	English PLD20	German PLD20	Icelandic PLD20	English N Group	German N Group	Icelandic N Group
clown	capol	clowt	2761	5	4	1	1.7	2.6	2.95	LD	HD	LD
desk	dugh	dask	13624	4	4	1	1.75	2.55	2.35	LD	HD	HD
donkey	dalami	denkey	2629	6	5	2	1.95	2.95	4	LD	LD	LD
dress	douct	driss	12384	5	4	1	1.65	2.8	2.6	LD	0	HD
eagle	efkih	eggle	6845	5	3	2	1.7	2.8	3.95	LD	0	LD
flower	fuchal	fluwer	6288	6	4	1	1.7	2.65	2.95	LD	HD	LD
frog	fiet	freg	3126	4	4	1	1.7	2.75	2.55	LD	HD	HD
glove	guant	glave	2355	5	4	1	1.75	2.7	2.95	LD	HD	LD
hammer	huffli	hamfer	6714	6	4	2	1.55	3.45	2.95	LD	LD	LD
jacket	joulig	jucket	10208	6	5	2	2	3.4	4.35	LD	LD	LD
lemon	latif	lumon	4015	5	5	2	1.7	2.95	2.95	LD	LD	LD
lion	leat	luon	7671	4	4	1	1.55	2	2.9	LD	HD	0
mitten	muckat	motten	139	6	4	2	1.65	2.4	2.7	LD	HD	HD
monkey	malghu	molkey	4882	6	5	2	1.7	3	3.45	LD	LD	LD
needle	naufik	needke	5047	6	4	2	1.65	2.75	4	LD	HD	LD
onion	olfam	onuon	2587	5	5	2	2.2	3.9	3	LD	LD	LD
orange	olsemp	otange	13483	6	5	2	1.95	4	3.7	LD	LD	LD
pencil	poutka	pefcil	3021	6	5	2	1.8	3.8	3.1	LD	LD	LD
pepper	plomfa	pupper	5324	6	4	2	1.65	3.15	2.95	LD	LD	LD
rabbit	rogfeg	rabgit	5751	6	5	2	1.8	3.8	3	LD	LD	LD
screw	salfo	scriw	9543	5	4	1	1.65	3.7	2.65	LD	LD	HD
skirt	shoft	skert	4928	5	4	1	1.75	3	2.35	LD	LD	HD
skunk	slomt	skunt	885	5	5	1	1.75	3.25	2.65	LD	LD	HD
snail	surog	snaul	10191	5	4	1	1.65	3	3	LD	LD	LD
spider	shutol	spuder	6953	6	5	2	1.8	4	3.65	LD	LD	LD
tiger	thomp	tuger	5393	5	4	2	1.55	2.95	3	LD	LD	LD
turtle	tafkan	tartle	4483	6	4	2	1.7	3.85	3.5	LD	LD	LD
wagon	whult	wigon	3687	5	5	2	1.95	3.6	4	LD	LD	LD
zebra	ziolk	zebna	915	5	5	2	2.7	2.95	4	LD	LD	LD

Appendix C

Latin Squares

C.1 Latin Square Distribution in the Monolingual Group

Table C.1: Latin Square Distribution in the Monolingual Group

	Set 1		DT				Control			
Group 1			Target	Distractor	T-Item	D-Item	Target	Distractor	T-Item	D-Item
	Condition 1	Prime	H2	H1	2	1	H4	H5	4	5
		Probe	H1	H3	1	3	H1	H3	1	3
	Condition 2	Prime	H2	L1	2	6	H4	L5	4	10
		Probe	L1	H3	6	3	L1	H3	6	3
	Condition 3	Prime	L2	H1	7	1	L4	H5	9	5
		Probe	H1	L3	1	8	H1	L3	5	7
	Condition 4	Prime	L2	L1	7	6	L4	L5	9	10
		Probe	L1	L3	6	8	L1	L3	6	8

			DT				Control			
Group 2			Target	Distractor	T-Item	D-Item	Target	Distractor	T-Item	D-Item
	Condition 1	Prime	H2	H1	1	5	H4	H5	3	4
		Probe	H1	H3	5	2	H1	H3	5	2
	Condition 2	Prime	H2	L1	1	10	H4	L5	3	9
		Probe	L1	H3	10	2	L1	H3	10	2
	Condition 3	Prime	L2	H1	6	2	L4	H5	8	4
		Probe	H1	L3	5	7	H1	L3	5	7
	Condition 4	Prime	L2	L1	6	10	L4	L5	8	9
		Probe	L1	L3	10	7	L1	L3	10	7

			DT				Control			

Group 3			Target	Distractor	T-Item	D-Item	Target	Distractor	T-Item	D-Item
	Condition 1	Prime	H2	H1	5	4	H4	H5	2	3
		Probe	H1	H3	4	1	H1	H3	4	1
	Condition 2	Prime	H2	L1	5	9	H4	L5	2	8
		Probe	L1	H3	9	1	L1	H3	9	1
	Condition 3	Prime	L2	H1	10	4	L4	H5	7	3
		Probe	H1	L3	4	6	H1	L3	4	6
	Condition 4	Prime	L2	L1	10	9	L4	L5	7	8
		Probe	L1	L3	9	6	L1	L3	9	6

			DT				Control			
Group 4			Target	Distractor	T-Item	D-Item	Target	Distractor	T-Item	D-Item
	Condition 1	Prime	H2	H1	4	3	H4	H5	1	2
		Probe	H1	H3	3	5	H1	H3	3	5
	Condition 2	Prime	H2	L1	4	8	H4	L5	1	7
		Probe	L1	H3	8	5	L1	H3	8	5
	Condition 3	Prime	L2	H1	9	3	L4	H5	6	2
		Probe	H1	L3	3	10	H1	L3	3	10
	Condition 4	Prime	L2	L1	9	8	L4	L5	6	7
		Probe	L1	L3	8	10	L1	L3	8	10

			DT				Control			
Group 5			Target	Distractor	T-Item	D-Item	Target	Distractor	T-Item	D-Item
	Condition 1	Prime	H2	H1	3	2	H4	H5	5	1
		Probe	H1	H3	2	4	H1	H3	2	4
	Condition 2	Prime	H2	L1	3	7	H4	L5	5	6
		Probe	L1	H3	7	4	L1	H3	7	4
	Condition 3	Prime	L2	H1	8	2	L4	H5	10	1
		Probe	H1	L3	2	9	H1	L3	2	9
	Condition 4	Prime	L2	L1	8	7	L4	L5	10	6
		Probe	L1	L3	7	9	L1	L3	7	9

C.2 Latin Square Distribution in the Bilingual Group

Table C.2: Latin Suqare Distribution of Items across Conditions

		Control			DT		
HD	Same	C1	H2	H3	C5	H2	H1
			H1	H4		H1	H4
	Diff	C2	L2	H3	C6	L2	H1
			H1	L4		H1	L4
LD	Same	C3	L2	L3	C7	L2	L1
			L1	L4		L1	L4
	Diff	C4	H2	L3	C8	H2	L1
			L1	H4		L1	H4

Table C.3: Latin Square Group 1.

	Control/Same C1&3			Control/Diff C2&4			DT/Same C5&7			DT/Diff C6&8	
	Target	Distractor		Target	Distractor		Target	Distractor		Target	Distractor
1	H2	H3	2	L32	H23	5	H42	H41	6	L72	H61
1	H1	H4	2	H21	L34	5	H41	H44	6	H61	L74
1	H3	H4	2	L33	H24	5	H43	H42	6	L73	H62
1	H2	H5	2	H22	L35	5	H42	H45	6	H62	L75
1	H4	H5	2	L34	H25	5	H44	H43	6	L74	H63
1	H3	H6	2	H23	L36	5	H43	H46	6	H63	L76
1	H5	H6	2	L35	H26	5	H45	H44	6	L75	H64
1	H4	H7	2	H24	L37	5	H44	H47	6	H64	L77
1	H6	H7	2	L36	H27	5	H46	H45	6	L76	H65
1	H5	H8	2	H25	L38	5	H45	H48	6	H65	L78
1	H7	H8	2	L37	H28	5	H47	H46	6	L77	H66
1	H6	H9	2	H26	L39	5	H46	H49	6	H66	L79
1	H8	H9	2	L38	H29	5	H48	H47	6	L78	H67
1	H7	H10	2	H27	L40	5	H47	H50	6	H67	L80
1	H9	H10	2	L39	H30	5	H49	H48	6	L79	H68
1	H8	H1	2	H28	L31	5	H48	H41	6	H68	L71
1	H10	H1	2	L40	H21	5	H50	H49	6	L80	H69
1	H9	H2	2	H29	L32	5	H49	H42	6	H69	L72
1	H1	H2	2	L31	H22	5	H41	H50	6	L71	H70
1	H10	H3	2	H30	L33	5	H50	H43	6	H70	L73
3	L12	L13	4	H22	L33	7	L52	L51	8	H62	L71
3	L11	L14	4	L31	H24	7	L51	L54	8	L71	H64
3	L13	L14	4	H23	L34	7	L53	L52	8	H63	L72
3	L12	L15	4	L32	H25	7	L52	L55	8	L72	H65
3	L14	L15	4	H24	L35	7	L54	L53	8	H64	L73
3	L13	L16	4	L33	H26	7	L53	L56	8	L73	H66
3	L15	L16	4	H25	L36	7	L55	L54	8	H65	L74

	Control/Same C1&3			Control/Diff C2&4			DT/Same C5&7			DT/Diff C6&8	
	Target	Distractor		Target	Distractor		Target	Distractor		Target	Distractor
3	L14	L17	4	L34	H27	7	L54	L57	8	L74	H67
3	L16	L17	4	H26	L37	7	L56	L55	8	H66	L75
3	L15	L18	4	L35	H28	7	L55	L58	8	L75	H68
3	L17	L18	4	H27	L38	7	L57	L56	8	H67	L76
3	L16	L19	4	L36	H29	7	L56	L59	8	L76	H69
3	L18	L19	4	H28	L39	7	L58	L57	8	H68	L77
3	L17	L20	4	L37	H30	7	L57	L60	8	L77	H70
3	L19	L20	4	H29	L40	7	L59	L58	8	H69	L78
3	L18	L11	4	L38	H21	7	L58	L51	8	L78	H61
3	L20	L11	4	H30	L31	7	L60	L59	8	H70	L79
3	L19	L12	4	L39	H22	7	L59	L52	8	L79	H62
3	L11	L12	4	H21	L32	7	L51	L60	8	H61	L80
3	L20	L13	4	L40	H23	7	L60	L53	8	L80	H63

Table C.4: Latin Square Group 2.

	Control/Same C1&3			Control/Diff C2&4			DT/Same C5&7			DT/Diff C6&8	
	Target	Distractor		Target	Distractor		Target	Distractor		Target	Distractor
1	H62	H63	2	L12	H3	5	H22	H21	6	L52	H41
1	H61	H64	2	H1	L14	5	H21	H24	6	H41	L54
1	H63	H64	2	L13	H4	5	H23	H22	6	L53	H42
1	H62	H65	2	H2	L15	5	H22	H25	6	H42	L55
1	H64	H65	2	L14	H5	5	H24	H23	6	L54	H43
1	H63	H66	2	H3	L16	5	H23	H26	6	H43	L56
1	H65	H66	2	L15	H6	5	H25	H24	6	L55	H44
1	H64	H67	2	H4	L17	5	H24	H27	6	H44	L57
1	H66	H67	2	L16	H7	5	H26	H25	6	L56	H45
1	H65	H68	2	H5	L18	5	H25	H28	6	H45	L58
1	H67	H68	2	L17	H8	5	H27	H26	6	L57	H46
1	H66	H69	2	H6	L19	5	H26	H29	6	H46	L59
1	H68	H69	2	L18	H9	5	H28	H27	6	L58	H47
1	H67	H70	2	H7	L20	5	H27	H30	6	H47	L60
1	H69	H70	2	L19	H10	5	H29	H28	6	L59	H48
1	H68	H61	2	H8	L11	5	H28	H21	6	H48	L51
1	H70	H61	2	L20	H1	5	H30	H29	6	L60	H49
1	H69	H62	2	H9	L12	5	H29	H22	6	H49	L52
1	H61	H62	2	L11	H2	5	H21	H30	6	L51	H50
1	H70	H63	2	H10	L13	5	H30	H23	6	H50	L53
3	L72	L73	4	H2	L13	7	L32	L31	8	H42	L51
3	L71	L74	4	L11	H4	7	L31	L34	8	L51	H44
3	L73	L74	4	H3	L14	7	L33	L32	8	H43	L52
3	L72	L75	4	L12	H5	7	L32	L35	8	L52	H45

	Control/Same			Control/Diff			DT/Same			DT/Diff	
	C1&3			C2&4			C5&7			C6&8	
	Target	Distractor		Target	Distractor		Target	Distractor		Target	Distractor
3	L74	L75	4	H4	L15	7	L34	L33	8	H44	L53
3	L73	L76	4	L13	H6	7	L33	L36	8	L53	H46
3	L75	L76	4	H5	L16	7	L35	L34	8	H45	L54
3	L74	L77	4	L14	H7	7	L34	L37	8	L54	H47
3	L76	L77	4	H6	L17	7	L36	L35	8	H46	L55
3	L75	L78	4	L15	H8	7	L35	L38	8	L55	H48
3	L77	L78	4	H7	L18	7	L37	L36	8	H47	L56
3	L76	L79	4	L16	H9	7	L36	L39	8	L56	H49
3	L78	L79	4	H8	L19	7	L38	L37	8	H48	L57
3	L77	L80	4	L17	H10	7	L37	L40	8	L57	H50
3	L79	L80	4	H9	L20	7	L39	L38	8	H49	L58
3	L78	L71	4	L18	H1	7	L38	L31	8	L58	H41
3	L80	L71	4	H10	L11	7	L40	L39	8	H50	L59
3	L79	L72	4	L19	H2	7	L39	L32	8	L59	H42
3	L71	L72	4	H1	L12	7	L31	L40	8	H41	L60
3	L80	L73	4	L20	H3	7	L40	L33	8	L60	H43

Table C.5: Latin Square Group 3.

	Control/Same			Control/Diff			DT/Same			DT/Diff	
	C1&3			C2&4			C5&7			C6&8	
	Target	Distractor		Target	Distractor		Target	Distractor		Target	Distractor
1	H42	H43	2	L72	H63	5	H2	H1	6	L32	H21
1	H41	H44	2	H61	L74	5	H1	H4	6	H21	L34
1	H43	H44	2	L73	H64	5	H3	H2	6	L33	H22
1	H42	H45	2	H62	L75	5	H2	H5	6	H22	L35
1	H44	H45	2	L74	H65	5	H4	H3	6	L34	H23
1	H43	H46	2	H63	L76	5	H3	H6	6	H23	L36
1	H45	H46	2	L75	H66	5	H5	H4	6	L35	H24
1	H44	H47	2	H64	L77	5	H4	H7	6	H24	L37
1	H46	H47	2	L76	H67	5	H6	H5	6	L36	H25
1	H45	H48	2	H65	L78	5	H5	H8	6	H25	L38
1	H47	H48	2	L77	H68	5	H7	H6	6	L37	H26
1	H46	H49	2	H66	L79	5	H6	H9	6	H26	L39
1	H48	H49	2	L78	H69	5	H8	H7	6	L38	H27
1	H47	H50	2	H67	L80	5	H7	H10	6	H27	L40
1	H49	H50	2	L79	H70	5	H9	H8	6	L39	H28
1	H48	H41	2	H68	L71	5	H8	H1	6	H28	L31
1	H50	H41	2	L80	H61	5	H10	H9	6	L40	H29
1	H49	H42	2	H69	L72	5	H9	H2	6	H29	L32
1	H41	H42	2	L71	H62	5	H1	H10	6	L31	H30
1	H50	H43	2	H70	L73	5	H10	H3	6	H30	L33
3	L52	L53	4	H62	L73	7	L12	L11	8	H22	L31

	Control/Same			Control/Diff			DT/Same			DT/Diff	
	C1&3			C2&4			C5&7			C6&8	
	Target	Distractor		Target	Distractor		Target	Distractor		Target	Distractor
3	L51	L54	4	L71	H64	7	L11	L14	8	L31	H24
3	L53	L54	4	H63	L74	7	L13	L12	8	H23	L32
3	L52	L55	4	L72	H65	7	L12	L15	8	L32	H25
3	L54	L55	4	H64	L75	7	L14	L13	8	H24	L33
3	L53	L56	4	L73	H66	7	L13	L16	8	L33	H26
3	L55	L56	4	H65	L76	7	L15	L14	8	H25	L34
3	L54	L57	4	L74	H67	7	L14	L17	8	L34	H27
3	L56	L57	4	H66	L77	7	L16	L15	8	H26	L35
3	L55	L58	4	L75	H68	7	L15	L18	8	L35	H28
3	L57	L58	4	H67	L78	7	L17	L16	8	H27	L36
3	L56	L59	4	L76	H69	7	L16	L19	8	L36	H29
3	L58	L59	4	H68	L79	7	L18	L17	8	H28	L37
3	L57	L60	4	L77	H70	7	L17	L20	8	L37	H30
3	L59	L60	4	H69	L80	7	L19	L18	8	H29	L38
3	L58	L51	4	L78	H61	7	L18	L11	8	L38	H21
3	L60	L51	4	H70	L71	7	L20	L19	8	H30	L39
3	L59	L52	4	L79	H62	7	L19	L12	8	L39	H22
3	L51	L52	4	H61	L72	7	L11	L20	8	H21	L40
3	L60	L53	4	L80	H63	7	L20	L13	8	L40	H23

Table C.6: Latin Square Group 4.

	Control/Same			Control/Diff			DT/Same			DT/Diff	
	C1&3			C2&4			C5&7			C6&8	
	Target	Distractor		Target	Distractor		Target	Distractor		Target	Distractor
1	H22	H23	2	L52	H43	5	H62	H61	6	L12	H1
1	H21	H24	2	H41	L54	5	H61	H64	6	H1	L14
1	H23	H24	2	L53	H44	5	H63	H62	6	L13	H2
1	H22	H25	2	H42	L55	5	H62	H65	6	H2	L15
1	H24	H25	2	L54	H45	5	H64	H63	6	L14	H3
1	H23	H26	2	H43	L56	5	H63	H66	6	H3	L16
1	H25	H26	2	L55	H46	5	H65	H64	6	L15	H4
1	H24	H27	2	H44	L57	5	H64	H67	6	H4	L17
1	H26	H27	2	L56	H47	5	H66	H65	6	L16	H5
1	H25	H28	2	H45	L58	5	H65	H68	6	H5	L18
1	H27	H28	2	L57	H48	5	H67	H66	6	L17	H6
1	H26	H29	2	H46	L59	5	H66	H69	6	H6	L19
1	H28	H29	2	L58	H49	5	H68	H67	6	L18	H7
1	H27	H30	2	H47	L60	5	H67	H70	6	H7	L20
1	H29	H30	2	L59	H50	5	H69	H68	6	L19	H8
1	H28	H21	2	H48	L51	5	H68	H61	6	H8	L11
1	H30	H21	2	L60	H41	5	H70	H69	6	L20	H9
1	H29	H22	2	H49	L52	5	H69	H62	6	H9	L12

	Control/Same C1&3			Control/Diff C2&4			DT/Same C5&7			DT/Diff C6&8	
	Target	Distractor		Target	Distractor		Target	Distractor		Target	Distractor
1	H21	H22	2	L51	H42	5	H61	H70	6	L11	H10
1	H30	H23	2	H50	L53	5	H70	H63	6	H10	L13
3	L32	L33	4	H42	L53	7	L72	L71	8	H2	L11
3	L31	L34	4	L51	H44	7	L71	L74	8	L11	H4
3	L33	L34	4	H43	L54	7	L73	L72	8	H3	L12
3	L32	L35	4	L52	H45	7	L72	L75	8	L12	H5
3	L34	L35	4	H44	L55	7	L74	L73	8	H4	L13
3	L33	L36	4	L53	H46	7	L73	L76	8	L13	H6
3	L35	L36	4	H45	L56	7	L75	L74	8	H5	L14
3	L34	L37	4	L54	H47	7	L74	L77	8	L14	H7
3	L36	L37	4	H46	L57	7	L76	L75	8	H6	L15
3	L35	L38	4	L55	H48	7	L75	L78	8	L15	H8
3	L37	L38	4	H47	L58	7	L77	L76	8	H7	L16
3	L36	L39	4	L56	H49	7	L76	L79	8	L16	H9
3	L38	L39	4	H48	L59	7	L78	L77	8	H8	L17
3	L37	L40	4	L57	H50	7	L77	L80	8	L17	H10
3	L39	L40	4	H49	L60	7	L79	L78	8	H9	L18
3	L38	L31	4	L58	H41	7	L78	L71	8	L18	H1
3	L40	L31	4	H50	L51	7	L80	L79	8	H10	L19
3	L39	L32	4	L59	H42	7	L79	L72	8	L19	H2
3	L31	L32	4	H41	L52	7	L71	L80	8	H1	L20
3	L40	L33	4	L60	H43	7	L80	L73	8	L20	H3