

EYETRACKING AND INTERLINGUAL HOMOGRAPHS

Mariko Nakayama & John Archibald
University of Calgary

A fundamental question of bilingual language processing asks whether bilinguals have separate lexicons for each language they command, or have a unified lexicon that represents two languages and one language is activated independently of the other. Past studies have not agreed upon whether bilinguals activate the representation of both languages in parallel, or whether only one lexicon is activated at a time. More recent studies are leaning toward the conclusion that the bilinguals possess a unified lexicon and their two languages are connected with one another. Our study further investigated the non-selective account of bilingual lexical processing in reading and the bilingual lexical processes in context.

The eye movement patterns of the bilinguals showed that reading of the interlingual targets was significantly influenced by the between-language lexical overlaps, indicating the representation of both languages was activated even when the bilinguals are reading English sentences. These results suggested the strong role of an automatic and bottom-up activation in nonselective lexical processing. Theoretical implications for the current models of the bilingual lexicon are discussed.

Our approach to study the selective versus nonselective lexical activation was to investigate how bilinguals process interlingual homophones and homographs. Interlingual homographs are words from different languages that are spelled identically but are different in their pronunciation or meaning. For example, *ANGEL* is an interlingual homograph between English and Dutch (pronounced [ɑŋəl], meaning a hook). Interlingual homophones are words from different languages that are pronounced similarly, but are different in their spelling or meaning. For example, *LEAF* and *LIEF* (meaning dear, lovable) are both pronounced [li:f], and are interlingual homophones between English and Dutch.¹

1. Experiment 1: Dutch-English bilinguals

The aim of the current study is to investigate bilingual lexical processes in context. In the study, bilinguals were asked to read English sentences for comprehension while their eye movements were recorded. As various past monolingual studies have shown that eye movements are sensitive measures of lexical processing (e.g., Duffy, Kambe, & Rayner, 2001; see Rayner & Juhasz, 2004 for a recent review), it was assumed that they would also be sensitive to bilingual lexical processing. The English sentences presented to participants

¹ *Proceedings of the 2005 annual conference of the Canadian Linguistic Association*
© 2005 Mariko Nakayama and John Archibald

occasionally contained Dutch-English interlingual homographs and homophones. The participants were not told about the bilingual nature of the critical words, but were only told to read the sentences for comprehension. Because the participants were asked to simply read the sentences, it was expected that their eye movements would reflect natural on-line lexical processes.

Eye movements are generally divided into two classes of qualitatively different processes: first pass processes and second pass processes. First-pass processes include the first fixation duration (initial fixation on a target word) and the gaze duration (the sum of fixations made on a target word before the eyes leave the word). Second-pass reading time include regressions (re-fixations on a target word that are made after the eyes have left the word). First-pass processes are associated with initial lexical retrieval processes, and second-pass processes are associated with advanced reading process past the initial lexical retrieval, such as text integration (e.g., Avital, Frost, Pollatsek, & Rayer, 2005).

If bilingual lexical processing is language non-selective in reading, then the first-pass reading time should reflect different eye movement patterns on interlingual targets from “monolingual” English words. Based on the findings by Dijkstra et al. (1999), in which the interlingual homographs were responded to significantly faster and interlingual homophones were responded to significantly slower, in this study, the interlingual homographs were predicted to be fixated on shorter amount of time relative to the English controls, suggesting the facilitatory lexical retrieval from the orthographic overlap. On the other hand, the interlingual homophones would be fixated on for a longer amount of time relative to the control words, suggesting the inhibitory lexical retrieval from the phonological overlap.

1.1 Method

Participants. Fourteen Dutch-English Bilinguals participated in the study. The majority of participants were faculty members of University of Calgary, or were Dutch immigrants recruited from a local Dutch church group. Table 1 details the demographic information.

Table 1: Demographic information of Dutch-English bilinguals in Experiment 1 (standard deviations)

Sex	9 males & 5 females
Age	43.14 (17.94)
Years lived in English speaking countries	22.00 (16.72)
Years lived in the Netherlands	22.54 (8.55)
Age at which first studied English	10.67 (1.45)
Years of formal English education in the Netherlands	6.79 (2.92)
Comprehension of words used in English newspapers	95 % or more: 11/14 bilinguals = 79%, 90 % - 95 %: 3/14 bilinguals = 21%
Comprehension of words used in Dutch news papers	95 % or more: 12/14 bilinguals = 86 % 90-95%: 1 bilingual = 7 % 80%: 1 bilingual = 7 %

Stimuli. Because we hoped to attribute any differences in effects that may be observed to the paradigms (single word presentation vs. reading), the stimuli for the current study were selected from Dijkstra et al. (1999). Fifteen interlingual homographs and 15 interlingual homophones and their respective control words were taken from Dijkstra et al. (1999). All words were nouns and adjectives and were three to five letters in length. For orthographic false friends, the average English word frequency was 40.2 occurrences per million and Dutch word frequency was 27.4 occurrences per million according to CELEX database (Baayen, Piepenbrock, & VanRijin, 1993). For interlingual homophones, the average English word frequency was 41.7 occurrences per million and Dutch word frequency was 29.1 occurrences per million. The average word frequency for control words was 40.4 occurrences per million for the orthographic condition and 41.9 occurrences per million for the phonological condition. In Dijkstra et al. (1999), the interlingual targets (orthographic false friends) had been rated by Dutch – English bilinguals with regard to their lexical similarities. The interlingual homographs were rated as identical in orthography (7.0/7.0) but not similar in semantics (1.6/7.0) or in phonology (2.6/7.0). Likewise, the interlingual homophones (phonological false friends) were rated as very similar in phonology (6.0/7.0) but not similar in semantics (1.2/7.0) or in orthography (2.8/7.0). (For further stimuli descriptive, please refer to Dijkstra et al., 1999.)

Thirty short sentence frames were created in order to embed the test words (interlingual homographs or interlingual homophones) and their matched English controls. All sentences were under 70 characters long. The sentence frames were created in such a way that the context made sense whether a test word or a control word was accommodated. The critical words (pairs of test words or control words) were embedded in varying positions within the sentence frame; a third of critical pairs appeared in the first third region of the sentence, a third in the middle region of the sentence and a third in the last third region of the sentence. Thirty filler sentences were also created. These distracter sentences contained only English words. The filler sentences were presented so that the bilingual nature of the test words would be less salient, which would strongly bias the language context toward English.

Previous eye movement studies reported (e.g., Drieghe, Brysbaert, Desmet, Baecke, 2004; Kliegel, Grabner, Rolfs, & Engbert, 2004) that a word tends to be fixated on for a shorter period of time or skipped more often when the context of a sentence made the word easily predictable. Therefore, care was taken in creating the sentence frames so that the context would be as neutral as possible. In addition, a group of 20 English-speaking students, who did not participate in the current study, rated how well both the false friends and their matched control words “fit” in their sentence frames from a scale of one to seven. Only words that were placed in the middle and the last of the sentences were rated, as the context should not affect the fast pass fixation of the words that were placed at the beginning of the sentence. As a result, the interlingual homographs had a “fit” rating of 4.9 / 7.0, and the control words had a rating of 5.2 / 7.0, $t(9) = -1.05$, $p > 0.3$. The interlingual homophones had a “fit” rating of 5.1 / 7.0 and their control words had a rating of 4.8 / 7.0, $t(9) = .68$, $p > 0.5$.

Thus, any statistical difference in the first pass fixations between the test words and control words should not be attributed the context of sentence frame biasing toward one word or another.

Fifteen sentence frames for the homograph condition were then divided into two groups (7 and 8 items each). Each group embedded only test words or only control words. Word type (test or control) was alternated for the groups, resulting in 2 stimulus lists. Likewise, fifteen sentence frames for homophone condition also yielded 2 stimulus lists. As a result, 4 lists of critical stimulus were created. The filler sentences were then added to these stimulus files. Each of the original stimulus files was then processed with Randomizer (SR research), producing two files with different item presentation sequences. Thus, in total 8 stimuli files were created.

Apparatus. The eye movements were recorded by SR research, Inc. EYELINK I system (Ontario, Canada) with a sampling rate of 250 Hz. The gaze eye position resolution is .005° (20 seconds of arc, with an average error of 0.5° to 1.0°). Detection and analysis of saccades, fixations and blinks occur in real time. Presentation of the stimuli was controlled by a Pentium II class computer at the refresh rate of 60 Hz with 800 x 600 resolutions. Each sentence was presented in a single line on the center of the 17-inch View Sonic (E90) monitor in size-16 Times New Roman font.

Procedure. Participants were tested individually. Participants sat at a distance of approximately 60 cm from the monitor and their eyes were calibrated. The initial calibration process took approximately 5-10 minutes. Except for the first 5 participants, the participants' eyes were re-calibrated after 30 sentences to ensure a good calibration quality.

After the calibration was the completed, participants were told that they were going to be presented with a series of short English sentences. They were asked to silently read each sentence for comprehension. When they finished reading a sentence they were told to look down and press the escape key, which cleared the sentence display. When the participants were ready to read the new sentence, they fixated on the fixation dot on the center of the screen. As the experimenter confirmed that the participants properly fixated on the dot, the new sentence was presented. Occasionally (15-25% of the time), the participants were asked a simple question about the sentence they have just read (e.g., "Where did Ken want to go?"). The participants answered every question with no difficulty. They were given eight practice sentences before the experimental sentences were presented. Throughout the task, participants were never told about the bilingual property of words that appeared in some of the sentences.

Subsequent to the reading task, participants were asked to fill out an information questionnaire, (presented in Table 1) which asked their background information about Dutch and English language education along with demographic information. They also completed the Nelson-Denny vocabulary test, which objectively measures their level of knowledge of English words. Lastly, the participants were debriefed on the purpose of the study. Prior to the debriefing, hardly any participant had noticed that some sentences contained a word that was visually identical to a Dutch word (i.e. interlingual homographs),

or sounded similar to a Dutch word (i.e. interlingual homophones). Quite a few participants commented that they “switch” language depending on an environmental/task at hand, so they never read the interlingual words as Dutch words. The majority of the participants had to be shown the test words again to be convinced with the bilingual nature of the critical words.

1.2 Results

The raw data were trimmed prior to the data analyses. First, the mean and the standard deviation of the fixation durations were calculated for each participant. The fixation durations that exceeded 2.5 standard deviations of the participant were treated as outliers and removed from the analyses (2.38 % of the data). The gaze durations that were longer than 1 second were also considered outliers and removed from the analyses (0.48 % of the data).

The fixations on words that were either initially skipped by participants or not fixated on at all were not included in the analyses (17.14 % of the data). The remaining data were submitted to 2 (condition: orthography vs. phonology) \times 2 (word status: test vs. control) repeated measures ANOVA. Separate analyses were conducted 1) for the first fixation duration and 2) the gaze duration. Consistent with Dijkstra et al. (1999), only the subject analyses were conducted, as these items “form nonrandom and almost exhaust selection of the item population, *pp.* 504” and therefore using different stimuli would be virtually impossible.

First fixation duration. The main effect of condition was not significant, $F(1,13) = 1.22$, $p > .20$, nor the main effect of word type, $F(1, 13) < 1$. However, there was a significant interaction between condition and word type $F(1, 13) = 9.36$, $p < .05$. The descriptive statistics suggested that this interaction stemmed from interlingual homographs being fixated for a shorter period of time than their controls, and interlingual homophones being fixated on for a longer period of time than their controls. Two paired comparisons were conducted to follow up this significant interaction. On the basis of the results by Dijkstra et al (1999), we had general predictions as to the direction of the effects. For that reason, statistical significance was assessed by one-tailed tests. Interlingual homographs were fixated on significantly shorter (212 ms) relative to their control words (239 ms), $t(13) = -3.34$, $p < .05$. On the other hand, interlingual homophones were fixated on longer (242 ms) relative to their control words (223 ms), $t(13) = 1.69$, $p = .06$; the effect was marginally significant.

Gaze duration. The main effect of condition was not significant, $F(1, 13) < 1$. The main effect of word type was not significant, $F(1, 13) < 1$. As in the first fixation duration, there was a significant interaction between condition and word type in gaze duration, $F(1, 13) = 16.21$, $p < .05$. Post-hoc paired comparisons revealed that the interlingual homographs were fixated significantly shorter (255 ms) than their controls (284 ms), $t(13) = -2.66$, $p < .05$, and the interlingual homophones were fixated significantly longer (280 ms) relative to their controls (239 ms), $t(13) = 3.01$, $p < .05$.

Table 2: Average first fixation duration and gaze duration of Dutch-English Bilinguals (ms)

	<u>Interlingual homograph</u>		<u>Interlingual homophones</u>	
	Test (<i>ANGEL</i>)	Control (<i>ELBOW</i>)	Test (<i>LEAF</i>)	Control (<i>FAIR</i>)
First Fixation	212	239	242	223
Gaze Duration	255	284	280	239

1.3 Discussion

The aim of the current study was to explore whether bilinguals' eye movements reflect the language nonselective activation when reading English text. Both the first fixation and the gaze duration eye movements captured the different lexical retrieval processes associated with the reading of interlingual words and with the reading of monolingual English words. Moreover, there was a significant interaction between the condition (interlingual homographs vs. interlingual homophones) and the word type (test vs. control). The first-pass fixation durations on interlingual homographs were significantly shorter than English controls, indicating that the lexical retrieval of homographs was facilitated. On the other hand, the first-pass fixations on interlingual homophones were significantly slower than the English controls, indicating that the lexical retrieval of homophones was inhibited. These results replicated Dijkstra et al (1999), and lend additional support to the language non-selective view of bilingual word recognition.

On average, the bilinguals in the present study had lived in Canada for more than two decades, and were very proficient in English language. The patterns of the data obtained in Experiment 1 suggest that neither a strong environmental context (the participants are immersed in an English speaking society) nor very high proficiency in the second language is sufficient to override the language non-selective activation. In addition, the fact that almost none of the participants had any awareness of the bilingual nature of interlingual homographs and homophones give further support to the automatic, bottom-up nature of the bilingual lexical processes.

2. Experiment 2: Monolingual English speakers

Could it be possible that the results of Experiment 1 were in fact due to some uncontrolled factors about the words, the sentence frames or the interaction of the two? Although Dijkstra et al. (Experiment 3, 1999) showed that a group of English speakers did not treat the interlingual words and control words any differently in a lexical decision task², these possibilities had to be addressed before any important theoretical implications are discussed, as we employed a different paradigm, and also introduced a new variable – sentence frames.

² Response latencies to interlingual homophones (497 ms) were not significantly different from their control words (496 ms); however, the error rates were significantly higher for the false friends (7.0 %) than for the control words (2.7 %).

In Experiment 2, a group of monolingual English speakers read the same sentences while their eye movements were monitored. A monolingual English speaker was defined as a native English speaker who does not speak Dutch; the participants were not necessarily limited to pure monolinguals who do not speak any other language. If the results observed in Experiments 1 were due to some unmatched characteristics of the stimuli, then the English monolinguals should show eye movement patterns that are comparable to the bilingual participants. On the other hand, if the results were indeed due to the activation of Dutch lexical representation influencing the reading of English text, then the English speakers, who do not speak Dutch, should not behave with any similarity to the bilinguals.

More specifically stated, the predictions of Experiment 2 are as follows. If the findings of Experiment 1 truly support the language nonselective view of initial lexical activation, then the monolinguals' first-pass fixation durations on interlingual homographs should not differ from these fixation durations on English controls. Likewise, the first-pass fixation durations on interlingual homophones should not differ from the fixation durations on their controls.

2.1 Method

Participants. Nineteen students at the University of Calgary participated in the study in exchange for a bonus credit toward a psychology course. All were native speakers of English. None of the participants spoke Dutch.

Apparatus and Procedure. The same apparatus as Experiment 1 was used in Experiment 2. The procedure was identical to Experiment 1, except that Nelson Denny vocabulary test and demographic information questionnaire were not assigned to participants.

2.2 Results

As in Experiment 1, the raw data were trimmed prior to the data analyses. First, the mean and the standard deviation of the fixation durations were calculated for each participant. The fixation durations that exceeded 2.5 standard deviations for each participant were treated as outliers and removed from the analyses (2.25 % of the data). There was no gaze duration that was longer than 1 second. The fixations on words that were either initially skipped by participants or not fixated on at all were not included in the analyses (20.37 % of the data).

The remaining data were submitted to 2 (condition: orthography vs. phonology) x 2 (word status: test vs. control) repeated measures ANOVA. Separate analyses were conducted for 1) the first fixation duration and 2) the gaze duration. The remaining data were submitted to 2 (condition: orthography vs. phonology) x 2 (word status: test vs. control) repeated measures ANOVA. Separate analyses were conducted for 1) the first fixation duration and 2) the gaze duration.

First fixation duration. The main effect of condition was not significant, $F(1,18) < 1$; nor the main effect of word type, $F(1, 18) < 1$. There was a no

significant interaction between condition and word type $F(1, 18) = 1.15, p > .25$. Two paired comparisons showed that the average first fixation duration on interlingual homographs (225 ms) were not any shorter than the average first fixation duration on English controls (235 ms), $t(18) = -1.65, p > .05$. Likewise, the first fixation duration on interlingual homophones were not any longer (233 ms) than the average first fixation on English controls (231ms), $t(18) < 1$.

Gaze duration. The main effect of condition was not significant, $F(1, 18) = 2.17, p > .15$. The main effect of word type was not significant, $F(1, 18) = 1.11, p > .30$. There was no interaction between condition and word type, $F(1, 18) < 1$. A paired comparison revealed that the average gaze durations on interlingual homographs was not any shorter (260 ms) than the average gaze durations on their controls (249 ms), $t(18) < 1$. The average gaze durations on interlingual homophones was not any longer (250 ms) than their controls (241 ms), $t(18) < 1$.

Discussion

A group of English monolinguals participated in Experiment 2 in order to ascertain that the results of Experiment 1 were not due to some preexisting differences between the interlingual words and English controls. The results of Experiment 2 clearly ruled out the possibility of such confounding. For both first fixation durations and gaze durations, the monolinguals did not fixate on interlingual homographs any shorter than the English controls, nor did they fixate on interlingual homophones any longer than the English controls.

Curiously, the overall first fixation durations of monolinguals (231 ms) were not any faster than for the bilinguals (228 ms), despite that fact that English was the second language for the bilinguals, and also the fact the bilinguals were on average much older than the monolinguals. The gaze durations were shorter for the monolinguals (250 ms) than for the bilinguals (264 ms), however, this 14 ms difference was not statistically significant, $t(130) = 1.45, p > .10$. These relatively short fixation durations of the bilinguals are probably due to their very high proficiency in English.

Table 3. Average first fixation duration and gaze duration of English monolinguals (ms)

	<u>Interlingual homograph</u>		<u>Interlingual homophones</u>	
	Test (<i>ANGEL</i>)	Control (<i>ELBOW</i>)	Test (<i>LEAF</i>)	Control (<i>FAIR</i>)
First Fixation	225	235	233	231
Gaze Duration	260	249	250	241

3. General Discussion

The present study investigated the bilingual lexical processes in reading, especially with regards to the selective versus nonselective account of bilingual lexical activation. With the Dutch-English bilinguals, Experiment 1 observed that the bilinguals' fixation patterns on interlingual words were significantly different from those on monolingual English words, even when the participants were reading English text. With the English monolinguals, the null effects in

Experiment 2 confirmed that the results from Experiment 1 were indeed caused by the bilinguals' knowledge of Dutch language.

The eye movements of the bilinguals suggested that despite the strong contextual cue given to the participants, the representation of English was not selectively activated, but rather the representation of both English and Dutch was activated in parallel, influencing their reading of English text. Given the relative ineffectiveness of contextual (i.e. top-down) cues, the initial lexical activation of bilinguals appears to be heavily dependent on perceptual (i.e. bottom-up) input.

Further, replicating Dijkstra et al (Experiment 1, 1999), the present study observed that the between-language overlap in orthographic information and phonological information had opposite effects on bilinguals' first-pass fixation durations. The overlap in orthography had a facilitating effect in word recognition, while the overlap in phonology had an inhibitory effect in word recognition.

The results of the present study can be interpreted in terms of Bilingual Interactive Activation models of bilingual word recognition (Dijkstra & VanHeuven, 1998; 2002). The BIA models assume that in a lexical system, there are four layers of abstract representations of units: feature, letter, word and language. The units within layers are linked via inhibitory connections, whereas the units between layers are linked via excitatory connections. A word is recognized when the activation of the word unit exceeds the recognition threshold. The critical assumptions of the BIA models are that the two languages are stored in an integrated lexicon, and the initial lexical activation is a bottom up, nonselective process. The language nodes in the BIA models work as a language tag (or a guide to which language a word belongs) and does not itself influence the bottom-up lexical activation occurring at lower layers. The newer version of the BIA model, the BIA+ model (Dijkstra & Van Heuven, 2002), incorporates the phonological and the semantic representation into the original orthographic representation-only model in an inter-connected manner.

According to the BIA models (as well as Dijkstra et al., 1999), the perfect overlap in orthography of interlingual homographs can produce stronger lexical activation to the word unit, resulting in faster lexical retrieval for bilinguals. On the other hand, the phonology in interlingual homophones almost never has perfect overlap because of the presence of language-specific phonemes. As a result, the imperfect overlap produces momentary phonological competition. Because the phonological conflict must be resolved before the lexical retrieval occurs, word identification of the interlingual homophones is consequently delayed.

The BIA models also predict that lexical activation will be nonselective even when the bilinguals are reading English sentences. This is because the models assume a strong role of bottom-up processes and a relatively little role of the contextual information (top-down) in initial lexical processing. The results of the present study were indeed consistent with this prediction.

Although the BIA models nicely explain the present results, there are some major problems with the models' architecture that have to be addressed.

The BIA+ models incorporate lexical orthography units, lexical phonology units, and semantics that are activated in an interactive manner. However, it is not clear how it is possible for orthographic, phonological, and semantic unit to be individually activated when a word is represented in a localized unit as a whole. In addition, the models do not provide a clear explanation as to why the homographs processing are facilitated; especially as to why the overlap in orthography should result in greater lexical activation to begin with.

Alternatively, the same results can also be explained by Parallel Distributed Processing type models of lexical representation (e.g., Plaut, McClelland, Seidenberg, and Patterson, 1996). For example, the inhibition effect of interlingual homographs can be explained by the feedback inconsistency hypothesis proposed by Pexman, Lepker, and Reggin (2002). The feedback inconsistency hypothesis is based on the assumption of the PDP type models of lexical representation; the lexical representation is distributed, with orthographic, phonological and semantic units intimately linked via feed-forward and feed-backward connections. In monolingual studies employing a lexical decision task, homophones are normally responded to significantly slower than their control words. According to the feedback inconsistency hypothesis, such inhibition to homophonic words comes from the mismatch between the orthographic code of a presented target (e.g., “maid”), and the representation of the orthographic code (e.g., “made”) that was fed back from the phonological unit (e.g., “[meid]”) activated by the target (e.g., “maid” – “[meid]”). Because the feedback from phonology strongly activates the orthographic code of the higher frequency homophone (either by its higher resting levels or stronger feedback goes to more familiar word, or both) which causes momentary competition between two orthographic codes.

Assuming that the bilinguals possess unified and mutually connected representations, the feedback inconsistency should also arise upon the reading of interlingual homophones. For bilinguals, it is reasonable to assume that words in their first language are more familiar than words in their second language. If the activated phonological representation from English pair of the homophone feeds back to the Dutch spelling – this momentum conflict can cause longer fixation durations on the interlingual homophones.

Would the feed back hypothesis be able to explain the facilitation effect of interlingual homographs? It is also possible to explain the effect if the homographs receive richer feedback from semantics, which is equivalent to the polysemy effect in monolingual studies (Hino & Lupker, 1996). In monolingual studies, words with multiple meanings (e.g., “BANK”) are normally responded to faster than words with only one meaning. According to the feedback hypothesis (Hino & Lupker, 1996; Pexman et al. 2002), the facilitation effect is because the polysemic words receive enhanced feedback from semantic units to orthographic units. For bilinguals, interlingual homographs are analogous to polysemic words for monolinguals. Again, given the unified and interconnected bilingual lexical representation, the facilitation of interlingual homographs can

be attributed to the richer semantic feedback from the interlingual homographs, via the dual activation of English and Dutch meaning^{3,4}.

One apparent disadvantage of applying the feedback hypothesis (more like the PDP models) to bilingual lexical processing is that currently there is no language unit implemented in the model. Without abstract language representation, it would be extremely hard for bilinguals to discriminate a word from one language to another. However in reality bilinguals perform such a task with no difficulty, suggesting the existence of some form of language “unit”.

In the present study, the bilinguals’ eye movement patterns on interlingual homographs and homophones showed that bilingual lexical activation is nonselective in reading. The study also suggested that the lexical activation is strongly affected by bottom-up processes. Neither the strong monolingual context, nor the high language proficiency of the bilinguals eliminated the nonselective lexical activation. The question that is yet to be answered is whether the context of the sentence that is strongly biased toward one of the homograph meanings would reduce the nonselective lexical activation. The present study did not address this issue, as the sentence frames used in the present study were relatively neutral.

Theoretically, it is extremely important for further studies to investigate the validity of the models of bilingual word recognition. Unfortunately, there are currently many gaps in our knowledge about how bilinguals process two languages. These knowledge gaps may in fact be almost too large to completely implement the BIA+ or any other bilingual word recognition model to be built (Dijkstra & Van Heuven, 2002, pp195). In addition, there remain the large discrepancies between the nature of findings reported by cognitive neuroscience, and those reported by cognitive studies, each of them direct toward opposite theoretical interpretations. When we have more information, models can be refined and improved, providing us with better understanding of the true nature of the bilingual lexicon. It is hoped that this piece of empirical evidence will contribute to advancing the understanding of bilingual lexical processing.

³ In order to accept the hypothesis that the richer semantic feedback to orthographic codes facilitated the reading of the interlingual homographs, the role of phonology must be deemphasized (for example, by emphasizing on the use of the “direct” orthography to semantic route), or it must be assumed that the bilinguals only used English grapheme-phoneme rules to retrieve phonological representations, thus activating only one phonological representation. This is because in monolingual studies, homographs produce slower response latencies or null effects relative to non-homographic controls, which are associated with the conflicting phonological information of the homographic words.

⁴ Although both BIA model and the feedback ward hypothesis can nicely explain the obtained results, it is important to note that they commonly predict that the direction of orthographic and phonological effects are not absolute, but rather interact with the task demands, especially with regard to a response code that is required in the task. For example, Jared and Szucs (2002) reported the inhibitory effect of interlingual homographs in naming (e.g., “PAIN” meaning bread in French). This was most likely due to the fact that the resolution of phonological inconsistency is critical in order for the response to be made, which is not so critical in a lexical decision task and in a perceptual identification task.

Appendix A

Critical sentences in Experiment 1 and 2

Orthographic Condition (test word / control word)

1. The (stage/mouth) has a complex structure.
2. The (lover/entry) of the castle was very bright.
3. An (angel/elbow) can be damaged easily.
4. The (sage/flea) surprised the people in the crowd.
5. The (roof/sale) was more impressive than I thought.
6. Robert's son was a (boon/hero) to him.
7. Bob was very fond of the (boot/acre) his father gave him.
8. Mary didn't expect the (fee/mud) to be so annoying.
9. Linda is quite a (shy/rug) collector.
10. I don't like the (steel/rough) furniture that they bought.
11. It looks like Bob's (glad/coat).
12. One of Larry's birthday gifts was a (tube/lion).
13. I put a bean in the child's (lap/jar).
13. Sometimes soldiers can be (brave/crude).
15. That's not Martha's mother's favourite (brand/gown).

Phonological Condition (test word / control word)

1. The (leaf/fair) was a sigh that autumn had come.
2. The (lake/holy) relics are in decay.
3. A cruel, corporate (pace/fate) will be the end of him.
4. The (ray/bee) bounced off the window.
5. The (stale/alley) atmosphere left something to be desired.
6. It was (aid/odd) that the United Nations left for Zambia.
7. The garbage you find in the (lane/wire) is problematic.
8. The girl didn't expect a (cow/gap) in the story.
9. A little bit of (scent/mercy) can go a long way.
10. She never got the (dose/fame) she deserved.
11. Stacy was sorry to see that Jeff left the (note/army).
12. I was surprised to receive her (mail/pity).
13. We made structural changes to the (core/cage).
14. Tim had never seen a single (oar/oat) before.
15. Kate thinks the problem is the (lack/duty) of others.

References

- Baayen, R.H., Piepenbrock, R., & Rijn, H. van (1993). *The CELEX Lexical Database* (Release 1) [CD-ROM]. Philadelphia PA: Linguistic Data Consortium, University of Pennsylvania [Distributor].

- Brybaert, M., Van Dyck, G. & Van de Poel, M. (1999). Visual word recognition in bilinguals: Evidence from masked phonological priming. *Journal of Experimental Psychology: Human Perception and Performance*, 25, 137-148.
- De Bruijn, E., Dijkstra, A., Chwilla, D.J., & Schriefers, H.J. (2001). Language context effects on interlingual homograph recognition: Evidence from event-related potentials and response times in semantic priming. *Bilingualism: Language and Cognition*, 4, 155-168.
- De Groot, A. M. B., & Nas, G. L. (1991). Lexical representation of bilinguals: cognates and noncognates in compound bilinguals. *Journal of Memory & Language*, 30, 90-123.
- Dehaene S, Dupoux E, Mehler J, Cohen L, Paulesu E, Perani D. (1997). Anatomical variability in the cortical representation of first and second language. *Neuroreport*, 8, 3809–3815.
- Deutsch, A., Frost, R., Pollatsek, A., & Rayner, K. (2005). Morphological parafoveal preview benefit effects in reading: Evidence from Hebrew. *Language and Cognitive Process*, 20, 341-371.
- Dijkstra, A., & Van Heuven, W. J. B (1998). The BIA model and bilingual word recognition. In J. Grainger & A. Jacobs (Eds.), *Localist Connectionist Approaches to Human Cognition* (pp. 189-225). Hillsdale, NJ: Erlbaum.
- Dijkstra, A., & Van Heuven, W.J.B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition*, 5, 175-197.
- Dijkstra, A.F.J., Van Jaarsveld, H.J., & Ten Brinke, S. (1998). Interlingual homograph recognition: Effects of task demands and language intermixing. *Bilingualism: Language and Cognition*, 1, 51-66.
- Dijkstra, T., Grainger, J., & Van Heuven, W. J. B (1999). Recognition of cognates and interlingual homographs: The neglected role of phonology. *Journal of Memory and Language*, 41, 496-518.
- Drieghe, D., Brybaert, M., Desmet, T., & de Baecke, C. (2004). Word skipping in reading: On the interplay of linguistic and visual factors. *European Journal of Cognitive Psychology*, 16, 79-103.
- Eviatar, Z., Leikin, M., & Ibrahim, R. (1999) Phonological Processing of Second Language Phonemes: A selective deficit in a bilingual aphasic. *Language Learning*, 49, 121-141.
- Fabbro, F. (1999). *The Neurolinguistics of Bilingualism: An Introduction*. Hove, UK: Psychology Press.
- Gerard, L.D., & Scarborough, D.L. (1989). Language-specific lexical access of homographs by bilinguals. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 15, 305–313.
- Gollan, T. H., Forster, K. I., & Frost, R. (1997). Translation priming with different scripts: Masked priming with cognates and noncognates in Hebrew-English bilinguals. *Journal of Experimental Psychology-Learning Memory and Cognition*, 23, 1122-1139.
- Grainger, J., & Jacobs, A.M. (1996). Orthographic processing in visual word recognition: A multiple read-out model. *Psychological Review*, 103, 518–565.
- Hino, Y., & Lupker, S. J. (1996). The effects of polysemy in lexical decision and naming: An alternative to lexical access accounts. *Journal of Experimental Psychology: Human Perception and Performance*, 22, 1331–1356.
- Jackson, G. M., Swainson, R., Mullin, A., Cunnington, R., & Jackson, S.R. (2004). ERP correlates of a receptive language-switching task. *The Quarterly Journal of Experimental Psychology*, 57, 223-240.

- Jared, D., & Kroll, J. F. (2001). Do bilinguals activate phonological representations in one or both of their languages when naming words? *Journal of Memory and Language*, *44*, 2-31.
- Jared, D., & Szucs, C. (2002). Phonological activation in bilinguals: Evidence from interlingual homograph naming. *Bilingualism: Language and Cognition*, *5*, 225-239.
- Jiang, N., & Forster, K. I. (2001). Cross-language priming asymmetries in lexical decision and episodic recognition. *Journal of Memory and Language*, *44*, 32-51.
- Kambe, G., Rayner, K., & Duffy, S. (2001). Global context effects of processing lexically ambiguous words: Evidence from eye fixations. *Memory & Cognition*, *29*, 363-372.
- Kliegl, R., Grabner, E., Rolfs, M., & Engbert, R. (2004). Length, frequency, and predictability effects of words on eye movements in reading. *European Journal of Cognitive Psychology*, *16*, 262-284.
- Lambert, W.E.(1969). Psychological studies of the interdependencies of the bilingual's two languages. In Puhvel J (Ed.), *Substance and structure of language*. Los Angeles: University of California Press.
- Marian, V., Spivey, M., & Hirsch, J. (2003). Shared and separate systems in bilingual language processing: Converging evidence from eyetracking and brain imaging. *Brain & Language*, *8*, 70-82.
- Meuter R. F. I., Allport A. (1999) Bilingual language switching in naming: asymmetrical costs of language selection. *Journal of Memory and Language*, *40*, 25–40.
- Pexman, P. M., Lupker, S. J., & Reggin, L. D. (2002). Phonological effects in visual word recognition: Investigating the impact of feedback activation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*, 572-584.
- Plaut, D. C., McClelland, J. L., Seidenberg, M. S., and Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review*, *103*, 56-115.
- Rayner, K., & Juhasz, B. J. (2004). Eye movements in reading: Old questions and new directions. *European Journal of Cognitive Psychology*, *16*, 340-352.
- Rodriguez-Fornells, A., Rotte, M., Heinze, H-J., Nosselt, T., & Munte, T.F. (2002). Brain potential and functional MRI evidence for how to handle two languages with one brain. *Nature*, *415*, 1026-1029.
- Sanchez-Casas, R.M., Davis, C.D., & Garcia-Albea, J.E. (1992). Bilingual lexical processing: Exploring the cognate/noncognate distinction. *European Journal of Cognitive Psychology*, *4*, 293–310.
- Schulpen, B.J.H., Dijkstra, A.F.J., Schriefers, H. J., & Hasper, M. (2003). Recognition of interlingual homophones in bilingual auditory word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *29*, 1155-1178.
- Schwartz, A. I. (2004). The nature of cross-language lexical activation in sentence context: A psycholinguistic investigation. (Doctoral dissertation, The Pennsylvania State University, 2003). *Dissertation Abstracts International*, *65*, 460.
- Tzelgov, J., Henik, A. & Leiser, D. (1990). Controlling Stroop interference: Evidence from a bilingual task. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *16*, 760-771
- Van Heuven, W. J. B., Dijkstra, T., & Grainger, J. (1998). Orthographic neighborhood effects in bilingual word recognition. *Journal of Memory and Language*, *39*, 458-483.