Inhibitory Interaction:

The Effects of Experience and Distractor Lexicality

on a Lexical Decision Task

by

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Abstract

The research tests the prediction of the inhibitory-interaction hypothesis (Wey, Cook, Landis, Regard, & Graves, 1993) that experience alters the pattern of interhemispheric communication during reading and tests whether this pattern is altered by the lexicality of a peripheral stimulus. Right-handed undergraduate students are presented letter strings, one-at-a-time, to the centre visual field for lexical decision. The letter strings are familiar words, orthographically correct pseudowords, or orthographically incorrect non-words. In Experiment I, each letter string is accompanied by a blinking lexical (M) or non-lexical (light) distractor presented to the left or right visual field, or not at all. In Experiment II, letter strings are accompanied by a blinking lexical distractor (HAT) or non-lexical distractor (light). Results from Experiment I support our predictions, that experience alters hemispheric processing, leading to a left hemisphere advantage. In addition, distracting the right hemisphere with a lexical distractor slowed response time to pseudowords, and it was more costly to distract the right hemisphere with a non lexical distractor in the nonword condition, compared to a lexical one. Results for Experiment II also offer support for our predictions. The pattern of asymmetry increased with experience leading to suppression of the non dominant hemisphere, which was clear with common words, less so with pseudowords, and not present with nonwords. The lexicality of a distractor affected processing for common words, as it was more costly to present a lexical distractor to either visual field, compared to conditions when both were free to engage.

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Lateralization of function in the brain refers to the differences in processing capabilities between the right and left hemispheres of the brain (Beeman & Chiarello, 1998; Bryden, 1982; Bouma, 1990; Gazzaniga, 2000; Reuter-Lorenz, & Miller, 1998; Wey, Cook, Landis, Regard, & Graves, 1993). Research on individuals with damage localized in their left hemisphere revealed severe language impairments that were not characteristic of damage localized to the right hemisphere (Beeman & Chiarello, 1998). However, more recent research reveals that damage to the right hemisphere also results in language and speech impairments, which led to the belief that the hemispheres operate in a collaborative fashion, rather than the left monopolizing the processing of language (Beeman & Chiarello, 1998).

People suffering from a severe form of epilepsy are sometimes treated through the severing of the corpus callosum, with the result that the hemispheres are isolated from each other. The corpus callosum is a white matter pathway that connects the left and right hemispheres and is responsible for the transfer of information between the two hemispheres (Reuter-Lorenz & Miller, 1998).

In order to test the extent of asymmetry of language processing after split-brain surgery, researchers use lateralized displays of lexical information presented to the left or right visual field. Due to the contralateral organization of the brain, visual information presented to the left visual field travels to the right hemisphere first, and visual information presented to the right visual field is sent directly to the left hemisphere (Bouma, 1990).

Studies of asymmetry of language processing in split-brain individuals consistently displayed a right visual field advantage, which suggests that the left hemisphere is dominant for this type of processing (Reuter-Lorenz & Miller, 1998). This type of research offers robust evidence for the asymmetrical functioning of the right and left hemispheres because the hemispheres are isolated from each other in the split brain (Reuter-Lorenz & Miller, 1998). However, evidence from split-brain studies is not necessarily predictive of processing that occurs in the intact brain because the hemispheres are not isolated from each other in the intact brain. Several theorists have attempted to address how functioning is divided between the right and left hemisphere in the intact brain.

The inhibitory-interaction hypothesis is a theory based on the contention that collaboration occurs between the hemispheres in order to process language (Wey, et al., 1993). The inhibitory-interaction hypothesis proposes that the dominant hemisphere will inhibit identical processing by the non dominant hemisphere, and that experience will alter the pattern of hemispheric interaction. This means that as the dominant hemisphere becomes stronger, the inhibitory effect over identical processing will also become stronger. Accordingly, it is important to identify the processing strategies used when processing written material.

There are two strategies involved in the brain’s processing of written material: a lexical and a non lexical strategy (Zaidel & Peters, 1981). The lexical strategy involves matching a letter string as a whole to a representation in memory, while the non lexical strategy involves the sounding out of a letter string that is unfamiliar to the reader. Evidence suggests that the lexical strategy is available to the left and right hemispheres, while the non lexical strategy is available to the left hemisphere only. It follows from the inhibitory-interaction hypothesis that common words should invoke a lexical strategy by both hemispheres, and thus should result in callosal inhibition of the non dominant hemisphere. On the other hand, less inhibition should be apparent for unfamiliar letter strings because they invoke different processing by both hemispheres, lexical by the left and non lexical by the right. A common paradigm that is used to test the asymmetrical processing of written material is the lexical decision task.

Rutherford and Lutz (2004) used a lexical decision task to test the predictions of the inhibitory-interaction hypothesis. Letter strings (words, pseudowords, nonwords) were centrally presented for lexical decision, and were accompanied by a blinking rectangle (light) distractor in the right visual field, the left visual field, or not at all. According to Cowan (1995) the presentation of a blinking distractor to either the left or right visual field will temporarily capture the attention of the opposite hemisphere, thus disengaging it from the central decision task. Comparing reaction time in conditions in which both hemispheres are free to engage (no distractor) to conditions in which one or the other hemisphere is disengaged (left visual field distractor or right visual field distractor) provides evidence for the degree of involvement that each hemisphere exhibits in different letter string conditions.

Rutherford and Lutz’s (2004) results were consistent with the inhibitory-interaction hypothesis. Common words should evoke lexical processing by both the right and left hemispheres, and left hemisphere dominance for lexical processing should lead to the inhibition of the right. Indeed, reaction time in the word condition was slowest when the left hemisphere was disengaged. In addition, participants were equally fast when both hemispheres were engaged in processing compared to when the right hemisphere was distracted, which suggests that the left hemisphere was suppressing the right when both were free to engage in the task. According to their findings there is a cost to disengaging the left hemisphere, but no cost to disengaging the right hemisphere.

Rutherford and Lutz's (2004) results in the nonword condition also support the prediction of the inhibitory-interaction hypothesis. Since neither hemisphere has experience with orthographically incorrect nonwords, there should be little suppression. They found that reaction time in the nonword condition was slowest when both hemispheres were engaged, compared to when one or the other was disengaged. This suggests that presentation of a distractor reduced the conflict between the hemispheres, and thus led to improved reaction time in these conditions.

Rutherford and Lutz's (2004) results for letter strings that spelled orthographically correct pseudowords supported the prediction of the inhibitory interaction hypothesis that experience will alter the pattern of asymmetry between the hemispheres. In block 1, reaction time resembled the nonword condition, and in block 4 it resembled the common word condition. This effect is due to pseudowords matching the rules of spelling for English, which makes them somewhat common to readers, thus allowing for practice effects to occur and left hemisphere dominance to develop.

The current research replicated the procedure used by Rutherford and Lutz (2004), with the exception that there were two types of distractors. In Experiment I, letter strings were presented with a non lexical distractor (light) or a lexical distractor (M). In Experiment II, letter strings were accompanied by a non lexical distractor (light) or a lexical distractor (HAT).

The purpose of the current study is to test the predictions of the inhibitory interaction hypothesis that the dominant hemisphere suppresses the non dominant hemisphere when they are both engaged in identical processing and that experience alters the pattern of hemispheric communication (Wey, et al., 1993). It follows that processing common words should result in a strong inhibitory effect of the dominant hemisphere on the non dominant one, suppression should weaken for pseudowords, and should not be present for nonwords.

It is also predicted that a lexical distractor (M or HAT) will have a negative effect on reaction time compared to a non lexical distractor (light). This prediction follows from the submission of the inhibitory-interaction hypothesis that inhibition occurs when both hemispheres engage in identical processing. In trials where there is a lexical distractor (M or HAT), both hemispheres will be engaged in language processing, one with the distractor and the other with the letter string. Accordingly, this should result in an increased reaction time as well as more inhibition because the distractor engages processing similar to what is used for processing the letter string. Notwithstanding the increase in reaction time, the pattern of asymmetry should not shift across the letter string conditions.

Experiment I

The first experiment aimed to test the predictions that experience would alter the pattern of interhemispheric communication between the left and right hemispheres, and that lexicality of a peripheral distractor would increase reaction time compared to a non lexical one. A repeated measures design was used, in that each participant was presented a lexical distractor (M) some of the time and a non lexical distractor (light) some of the time. According to the assumptions of the inhibitory-interaction hypothesis, reaction time measures should reflect the occurrence of suppression of the dominant hemisphere on the non dominant one for letter strings that people have had experience with (Wey, et al., 1993). Accordingly, there should be more suppression for common words, less for pseudowords and even less for nonwords. Lexicality of a distractor should not affect the pattern of asymmetry, but we expect that a non lexical distractor (light) will require less processing and thus affect reaction time less compared to a lexical distractor (M).

Method

Participants

Participants were 32 undergraduate students (8 male, 24 female), who were right-handed, phonologically able, with normal or corrected to normal vision, and reported English to be their first language. At the time of participation they were not taking prescription medication, other than those for hormonal control.

Participants were informed that participation was strictly voluntary, and that they could withdraw from the procedure at any time. They were also informed that their data would be coded with a participant number rather than their name, in order to ensure anonymity. A payment of $10.00 was issued to each participant for their time.

Materials

Three tasks were incorporated into the study of hemispheric interaction during reading: the Annette (1970) handedness questionnaire; the Word Attack subtest of the Woodcock-Johnson Revised Tests of Acheivement; and a lexical decision task performed on a computer.

Annette (1970) Handedness Questionnaire

The questionnaire is a list of 12 activities (e.g., to write a letter legibly), printed in black, 12 point font on a white sheet of 8.5 x 11 in. paper. Participants were asked to write an R (i.e., right), L (i.e., left), or E (i.e., either) beside each activity to identify which hand they habitually use to complete it. The researcher coded each response as follows: +1.00 for every R, -1.00 for every L, and 0 for every E. Total scores could range from +12.00 to -12.00, where a positive total deems an individual strongly right handed, and a negative total strongly left handed. Data from right-handed participants were included in the analyses.

Word Attack Subtest of the Woodcock-Johnson Revised Test of Achievement

Participants were presented a series of 32 orthographically correct nonsense words (e.g., loast) printed in black 12 point font on a sheet of white 8.5 x 11 in. paper. They were instructed to read each nonsense word out loud, one at a time. Each nonsense word was evaluated for correct pronunciation. The total score on this test was used to calculate the individual's percentile rank on phonological ability. A participant's data was excluded if he/she scored lower than the 25^{th} percentile on this measure.

Computer task

The computer task was completed using MEL software version 2.0, on an IBM compatible Pentium 1 computer. A fixation cross was presented centrally for 500 ms and was replaced by a letter string. Letter strings were 3-5 characters long, presented centrally in system 32 font against a black background. Half of the letter strings were words and half were not words, of the not words half were orthographically correct (i.e., pseudowords) and half were orthographically incorrect (i.e., non words).

A blinking distractor that was lexical (i.e., *M*) or non lexical (i.e., rectangle) the size of 1 dg visual angle was presented in light grey so that the lateral edge was 7 dg to the left or right of center screen, and blinked on and off in 50 ms intervals for 300 ms. There was equal probability of a display of a lexical (M) or a non lexical (light) distractor in the left visual field, the right visual field or not at all, in each letter string condition.

<u>Procedure</u>

Participants were tested individually in the cognitive science research area of University of British Columbia Okanagan. They were seated in a quiet room and were presented a consent form. If they agreed to participate, they were then administered the Annette (1970) Handedness Questionnaire, then the Word Attack test and lastly the computer task.

Participants were seated in front of a computer with their head stabilized in a chin rest situated 57 cm from the monitor. A central fixation cross was presented for 500 ms and then replaced by a letter string. Participants indicated if the letter string spelled a word or not. A positive response was indicated by pressing the f and j keys with the left and right index fingers, a negative response was indicated by pressing the d and k keys with the left and right middle fingers. Each trial terminated after 2 seconds or following a key press, whichever came first. Participants initiated the presentation of subsequent letter strings by pressing the space bar. Accuracy and response time were measured.

The procedure included one block of 30 practice trials, followed by 4 blocks of test trials. Each block of test trials consisted of 72 randomly presented letter strings (36 words, 18 non words, and 18 pseudowords). One third of each letter string was accompanied by a left distractor, one third a right distractor, and one third was not accompanied by a distractor. Furthermore, in trials that were accompanied by a distractor, half were lexical (M) and half were non lexical (rectangle).

Design

Due to the fact that there could not be a distractor type (light or M) in the no distractor condition, analyses were limited to the two distractor locations (left and right) where distractor type was manipulated. The resulting design was a 3 (string type: word, nonword, pseudoword) x 2 (distractor location: left or right) x 2 (distractor type: light or M) x 4 (test block number) repeated-measures design. Response time was measured.

Results

For the purpose of this study an alpha level of .05 was used for all statistical analyses using SPSS version 12.0. A separate repeated measures analysis of variance (ANOVA) was performed on reaction time measures based on block, distractor location (left visual field or right visual field), and distractor type (light or M) for each of the three letter string conditions (common words, pseudowords, nonwords).

Words

The analysis of reaction time to letter strings that spelled common words revealed a 2-way interaction between block and distractor location, [$F(3,29)=3.109, p=.042$], as shown in Figure 1. A separate ANOVA was conducted for each block of trials to identify where the interaction occurred. In block 1 a main effect of distractor location was found, [$F(1, 28)=13.003$, $p= .001$], due to a significantly longer mean reaction time to a left visual field distractor versus a right visual field distractor ($p=.001$). In blocks 2, 3, and 4 this difference disappeared. As can be seen in Figure 1, responses became steadily faster across blocks of trials when the distractor was to the left visual field, but did not do so when the distractor was to the right visual field**.** This suggests the left hemisphere benefits more from practice with common words than does the right, as would follow if the right hemisphere is normally suppressed by the left.

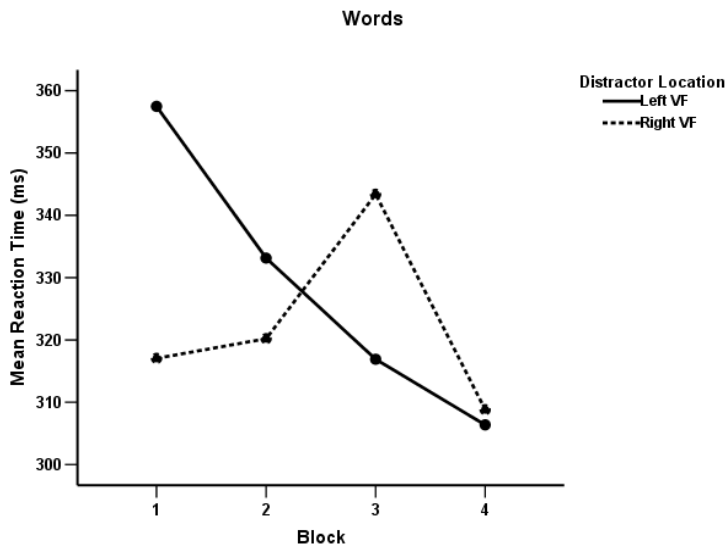

Figure 1. 2-Way interaction between block and distractor location for letter strings that spell common words.

Pseudowords

The analysis of orthographically correct pseudowords revealed a 2-way interaction between block and distractor location, [F(3,29)=3.174, *p*=.039], as shown in Figure 2. A separate ANOVA of each block of trials was conducted to reveal where the interaction occurred. In block 1 a significant main effect of distractor location was revealed, [F(1,28)=14.893, *p*=.001], due to longer mean reaction time to a left visual field distractor versus a right visual field distractor (*p*=.001). In blocks 2, 3, and 4, this difference disappeared. As can be seen in Figure 2, responses generally became faster across blocks of trials when the distractor was to the left visual field, but alternated between speeding and slowing to a right visual field distractor. This suggests the left hemisphere benefits more from practice with pseudowords than does the right.

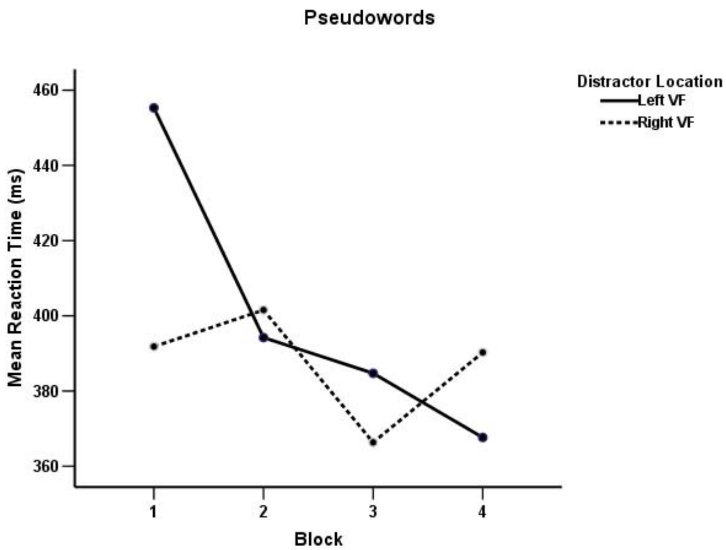

Figure 2. 2-way interaction between block and distractor location for letter strings that spell orthographically correct pseudowords.

The pseudoword analysis also revealed an interaction between block and distractor type, [F(3,29)=3.477, *p*=.029]. The separate analyses indicated that the main effect of distractor type occurred in block 3, [F(1, 28)=4.909, *p*=.035], due to longer mean reaction time to a lexical distractor (M) versus a non lexical distractor (light) (*p*=.035). The main effect of distractor type indicates there is more of a cost to displaying a lexical distractor (M) versus a non lexical distractor (light), perhaps because less processing is required for a light than an M. Moreover, the processing that a lexical distractor (M) evokes may be similar to that required for processing the letter string, and as a result increases the attentional load, thus increasing reaction time in this condition. No main effects of distractor type were found in blocks 1, 2, and 4.

Nonwords

The analysis of orthographically incorrect non words revealed an interaction between block and distractor location, [F(3,29)=3.332, *p*=.033], as shown in Figure 3. A separate analysis of each block of trials revealed that a main effect of distractor location occurred in block 4, [F(1, 28)=17.018, *p*=.000], which was due to longer mean reaction time to a left visual field distractor versus a right visual field distractor (*p*=.000). As can be seen in Figure 3, both hemispheres showed general speeding across the first 3 blocks of trials, but only the left continued to speed up in the final block of trials. The interaction suggests the right hemisphere benefits more from practice than does the left.

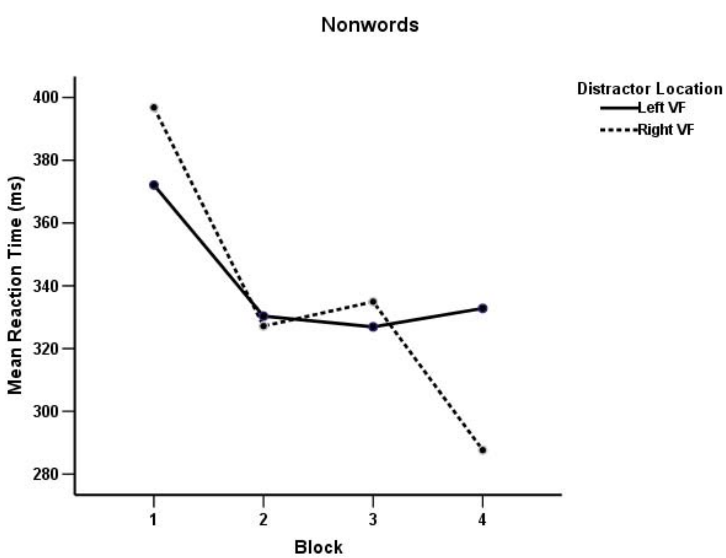

Figure 3. 2-way interaction between block and distractor location for letter strings that spell orthographically incorrect nonwords.

The analysis of non words also revealed an interaction between distractor location and distractor type, [F(1,31)=4.635, *p*=.039]. Separate analyses of distractor location revealed a main effect of distractor type for a left visual field distractor. This was due to longer mean reaction time to a non lexical distractor (light) presented to the left visual field compared to a lexical distractor (M) (*p*=.017). In the right visual field distractor condition, no main effect of distractor type was found. This evidence suggests that in the non word condition a non lexical distractor presented to the left visual field interferes more with processing than a lexical distractor does.

An overall analysis of non word letter strings revealed a main effect of block, [F(3,29)=5.596, *p*=.004] which was due to longer reaction time in block 1 compared to block 2 (*p*=.017), block 3 (*p*=.009), and block 4 (*p*=.002). The improvement of reaction time across blocks suggests the occurrence of practice effects.

Discussion

According to the inhibitory-interaction hypothesis the dominant hemisphere will suppress the non dominant hemisphere when both are engaged in identical processing, and that the inhibition increases with experience (Wey, et al., 1993). The results revealed the left hemisphere showed a practice effect which is likely due to previous experience processing common words. The argument for the differential practice effect for pseudowords could be built from previous research suggesting the hemispheres use different strategies (right lexical, left non lexical) when processing pseudowords, but with practice, the more efficient non lexical strategy of the left becomes more dominant. Accordingly, it follows that the right, which normally contributes less to the processing of pseudowords, should benefit less from practice than the left. On the other hand, given that adult readers have had little experience with nonwords, suppression has not had the opportunity to develop, so both should benefit from practice.

The main effect of distractor type was limited to the third block of trials for pseudowords, and was the result of a lexical distractor (M) increasing reaction time compared to a non lexical distractor (light). This effect is consistent with the idea that a lexical distractor increases the attentional load, and as a result increases reaction time compared to a non lexical distractor. The absence of this effect for words and nonwords suggests that the processing required for pseudowords requires more attentional capacity, and a lexical distractor interferes to a greater degree compared to a non lexical distractor.

The interaction between distractor location and distractor type was limited to nonwords, where a non lexical distractor (light) displayed in the left visual field increased reaction time compared to a lexical distractor (M). This effect is contrary to the prediction that a lexical distractor would increase reaction time compared to a non lexical distractor (light); however it speaks of the asymmetrical function of the hemispheres. The right hemisphere is more specialized in processing non lexical material, thus a distractor that taps this sort of processing should interfere more with processing the letter string compared to one that does not.

Taken together the results offer support for the prediction that experience alters the functional asymmetry between the hemispheres, as more experience with letter strings led to practice effects. However the lexicality of a distractor only exerted a differential effect on the processing of nonwords, but in favor or a non lexical distractor (light) rather than the predicted effect of a lexical distractor (M) inhibiting processing more.

Experiment II

The second experiment aimed to test the predictions that experience would alter the pattern of interhemispheric communication between the left and right hemispheres, and that a lexical distractor (HAT) would have a differential effect on reaction time compared to a non lexical one (light). Participants were divided into a lexical distractor (HAT) group, and a non lexical distractor (light) group. In other words, people were only exposed to one type of distractor across the lexical decision task. Based on the predictions of the inhibitory interaction hypothesis, we expect that patterns of asymmetry will be more pronounced for common words, less so for pseudowords, and should not be present for nonwords (Wey, et al., 1993). In addition, a lexical distractor (HAT) will increase reaction time compared to a non lexical distractor (light), as it requires similar processing to the lexical decision and divides attention across two lexical tasks.

Method

Participants

Participants were 72 undergraduate students (36 male, 36 female), who were right-handed, phonologically able, with normal or corrected to normal vision, and reported English to be their first language. At the time of participation they were not taking prescription medication, other than those for hormonal control.

Participants were informed that participation was strictly voluntary, and that they could withdraw from the procedure at any time. They were also informed that their data would be coded with a participant number rather than their name, in order to ensure anonymity. Participants had a choice of extra credit for introductory Psychology students or a payment of $10.00 for their time.

Materials

All materials were the same as Experiment I with two exceptions, letter strings were 3-7 characters long, and the distractor was either a lexical word (HAT) in System 32 font for half of the participants or a non lexical rectangle of 1 dg visual angle for the other half of the participants. In addition, the letter strings were 3-7 characters long. There was equal probability of each distractor occurring in the left visual field, right visual field or not at all, in each letter string condition (word, pseudoword, nonword).

Procedure

All procedures were identical to the procedures used in Experiment I.

Design

This was a 3 (letter string: word, pseudoword, nonword) x 3 (distractor location: no, left, and right) x 4 (test block number) repeated measures design with distractor type (light or HAT) as a between subjects variable. Response time was measured.

Results

Separate repeated measures ANOVA's were conducted for each string type (words, pseudowords, nonwords) to analyze response time measures based on block and distractor location for each of the letter string types (words, pseudowords, nonwords) with the between-subjects variable of group (light or "HAT").

Words

A 2-way interaction between distractor location and group was revealed in the analysis of letter strings that spelled words, [$F(2,69)=6.060$, $p=.004$]. A separate analysis was conducted for each group to identify the interaction. A main effect of distractor location was found in the lexical distractor (HAT) group, this effect was due to faster mean reaction time to no distractor compared to a left visual field distractor ($p=.000$) or a right visual field distractor ($p=.000$). Mean reaction time in the left visual field distractor condition was slightly faster compared to a right visual field distractor, but failed to reach significance ($p=.071$). This evidence indicates that there is a cost associated with distracting the left or right hemisphere with a lexical distractor (HAT), due to a division of attentional resources across two lexical tasks.

The analysis limited to the non lexical distractor (light) group revealed a main effect of distractor location, [F(2,34)=6.037, *p*=.006], as shown in Figure 4, which was due to faster reaction times to a non lexical distractor displayed to the left visual field compared to a right visual field distractor (*p*=.007). This effect indicates that there is a cost to distracting the left hemisphere away from the decision task, suggesting that the left hemisphere is contributing more to processing common letter strings. Mean reaction time in the no distractor condition was faster compared to the right visual field distractor (*p*=.011), but not significantly different than a left visual field distractor (*p*=1.00). This evidence lends support for the prediction of the inhibitory-interaction hypothesis (Wey, Cook, Landis, Regard, & Graves, 1993) that the dominant left hemisphere should inhibit processing by the right hemisphere when both are free to engage (no distractor condition).

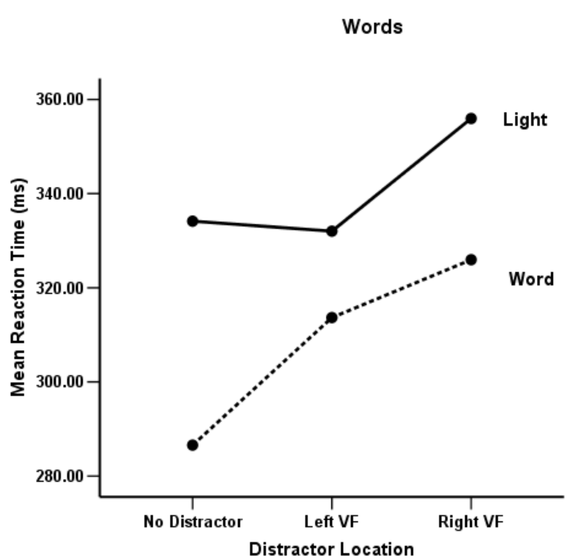

Figure 4. 2-Way interaction between group and distractor location.

The analysis of letter strings that spelled words revealed an interaction between block and distractor location, [F(6,65)=13.639, *p*=.000], as shown in Figure 5. In order to investigate the interaction a separate analysis of each block of trials was conducted. In block 1 a main effect of distractor location was found, [F(2,69)=18.785, *p*=.000], this effect was due to faster mean reaction time in the no distractor condition compared to left visual field distractor (*p*=.000) or a right visual field distractor (*p*=.002). Moreover, in trials where a left visual field distractor was displayed, reaction time was significantly slower compared to the right visual field distractor (*p*=.003), suggesting a cost to disengaging the left hemisphere from the decision task. In block 2, mean reaction time was faster in the left visual field distractor condition compared to a no distractor condition (*p*=.004), but not faster than the right visual field distractor (*p*=.266), suggesting the right hemisphere slows processing when it is free to engage in the no distractor condition. In blocks 3 and 4 there was a main effect of distractor location, [F(2,69)=9.774, *p*=.000] and [F(2,69)=34.121, *p*=.000], respectively. In block 3 this effect was due to faster mean reaction time in the no distractor and a left visual field distractor conditions compared to the right visual field distractor condition (*p*=.000). In block 4 this effect was similar to block 3, but reaction time in the no distractor condition was significantly faster compared to a left visual field distractor (*p*=.028) and the right visual field distractor (*p*=.000). Taken together, the effects in blocks 3 and 4 offer further evidence for the existence of asymmetry between the left and right hemispheres for common word strings, as there is a cost to presenting a distractor to the right visual field, which distracts the left hemisphere away from the lexical decision, but that distracting the right hemisphere has very little effect on reaction time.

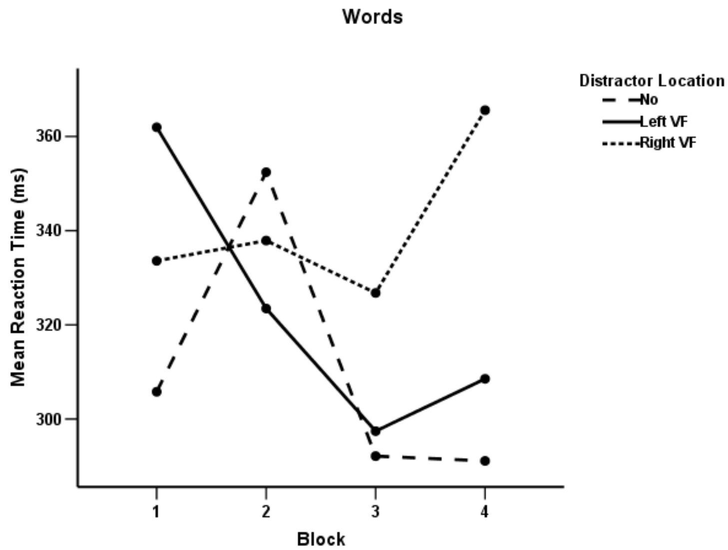

Figure 5. 2-Way interaction between block and distractor location for letter strings that spell common words.

Notwithstanding the block x distractor location interaction, there was a main effect of distractor location. This was due to reaction time being faster in the no distractor condition compared to a left distractor (p=.013) or a right distractor (p=.000). Participants were faster at reacting to common letter strings when both hemispheres were free to engage in processing compared to when one or the other was disengaged by a distractor.

The analyses revealed a significant main effect of block which was due to significantly faster reaction times in block 3 compared to block 1 (p=.001) and block 2 (p=.000), but not significantly different than block 4 (p=.072). The gradual improvement of reaction time across blocks of trials is evidence for the existence of practice effects for letter strings that spell common words.

Pseudowords

The analysis of orthographically correct pseudowords revealed a 2-way interaction between block and distractor location, [F(6,65)=5.881,p=.000], as shown in

Figure 6. A separate analysis was conducted for each block of trials to identify the differences in reaction time based on location of the distractor (left visual field, right visual field or not at all). In block 1 there was a significant effect of distractor location, [$F(2,69)=5.355$, $p=.007$]. Reaction time was significantly slower in the no distractor condition compared to a left visual field distractor ($p=.027$), or a right visual field distractor ($p=.002$), suggesting that initially the hemispheres use conflicting strategies when processing pseudowords. In block 2 and 3 there was not a significant effect of distractor location. There was a main effect of distractor location in block 4, [$F(2,69)=11.464$, $p=.000$], which was due to slower reaction time to a right visual field distractor compared to no distractor at all ($p=.000$), suggesting the left hemisphere contributes more to processing in the no distractor condition than the right hemisphere. An interaction between block and distractor location suggests that the pattern of hemispheric asymmetry shifts across blocks of trials with letter strings that spell orthographically correct pseudowords. Initially the pattern resembles that of orthographically incorrect non words, but by block 4 resembles the patterns for common word strings. This effect occurs because people have more experience with letter strings that do than do not match the rules of spelling for English. In other words, initially neither the right nor the left hemisphere is dominant for processing pseudoword strings; however, repeated exposure gradually builds left hemisphere dominance, leading to suppression of the right hemisphere when both are free to engage in processing. This evidence supports the prediction of the inhibitory interaction hypothesis that the strength of the inhibitory effect will increase with experience (Wey, et al., 1993).

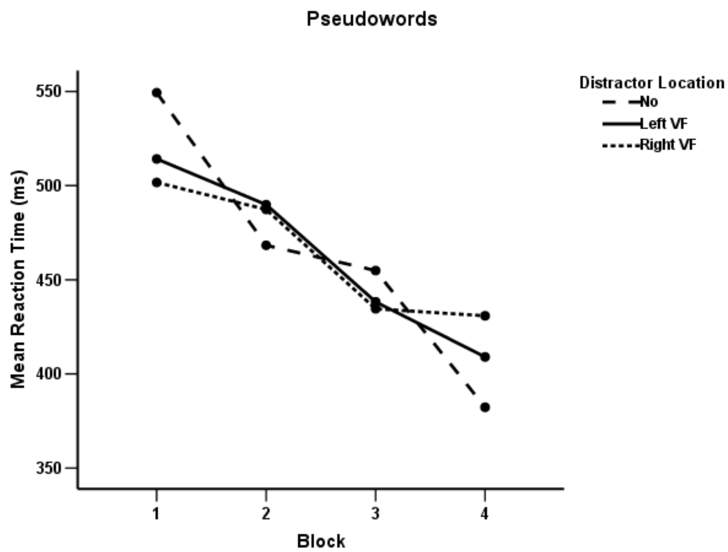

Figure 7. 2-Way interaction between block and distractor location for letter strings that spell orthographically correct pseudowords.

The pseudoword analysis revealed a significant main effect of block, [F(3,68)=30.186, *p*=.000], which was due to improved reaction time across blocks of trials. Block 1 was significantly slower compared to block 2 (*p*=.002), block 3 (*p*=.000), and block 4 (*p*=.000). The improvement in mean reaction time that is evident in the pseudoword condition is due to the development of practice effects. As participants gain more experience with orthographically correct pseudowords their reaction time improves.

Nonwords

Analysis of reaction time for letter strings that spell orthographically incorrect nonwords revealed a 2-way interaction between distractor location and group, [F(2,69)=3.439, *p*=.038]. A separate analysis of reaction time was conducted for the non lexical distractor (light) group and the lexical distractor (word) group. The non lexical distractor (light) analysis revealed a main effect of distractor location, [F(2,34)=12.118, *p*=.000]. This main effect was due to significantly slower reaction times in the no distractor condition compared to a left visual field distractor (*p*=.041) or a right visual field distractor (*p*=.000), with reaction times not differing between right visual field distractor and left visual field distractor conditions (*p*=.545). This effect is likely the result of neither hemisphere having experience with processing nonwords. As a result, asymmetry has not had the opportunity to develop. Moreover, the fact there is slowing when both are free to engage in the task suggests they use conflicting strategies.

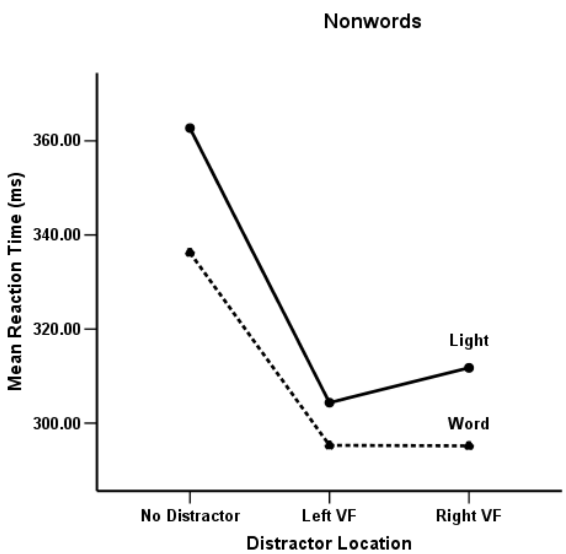

Figure 8. 2-Way interaction between group and distractor location for letter strings that spell orthographically incorrect nonwords.

The analysis of the lexical distractor (word) group revealed a significant effect for distractor location, [F(2,34)=4.746, *p*=.015], which was due to slower reaction times to a no distractor compared to a left visual field distractor (*p*=.011), but not a right visual field distractor (*p*=1.00). As was the case for the non lexical distractor, the finding suggests the hemispheres use conflicting strategies when processing nonwords which, in turn leads to a slowing of response time when both are free to engage in processing.

The analysis of mean reaction time to letter strings that are orthographically incorrect nonwords revealed a 2-way interaction between block and distractor location, [F(6,65)=2.427, *p*=.035]. As shown in Figure 9, separate analyses of each block were conducted to identify where the interaction occurred. A main effect of distractor location was evident in block 1, [F(2,69)=8.14, *p*=.001], block 2, [F(2,69)=20.501, *p*=.000], and block 4, [F(2,69)=3.210, *p*=.046], where reaction time was slower when both hemispheres were free to engage, compared to when one or the other was disengaged. As Figure 9 shows, the left and right hemispheres are fairly equal in processing nonword strings on their own and this effect is consistent across all four blocks of trials. In the no distractor condition there was speeding of response time across the first 3 blocks, and slowing in block 4. Also, by block 4 reaction time in the no distractor condition is not significantly different compared to a left visual field distractor (*p*=.936). This suggests that initially when both hemispheres are free to engage conflict causes a slowing of response times, but with experience the left hemisphere develops an advantage and begins to monopolize the bulk of processing.

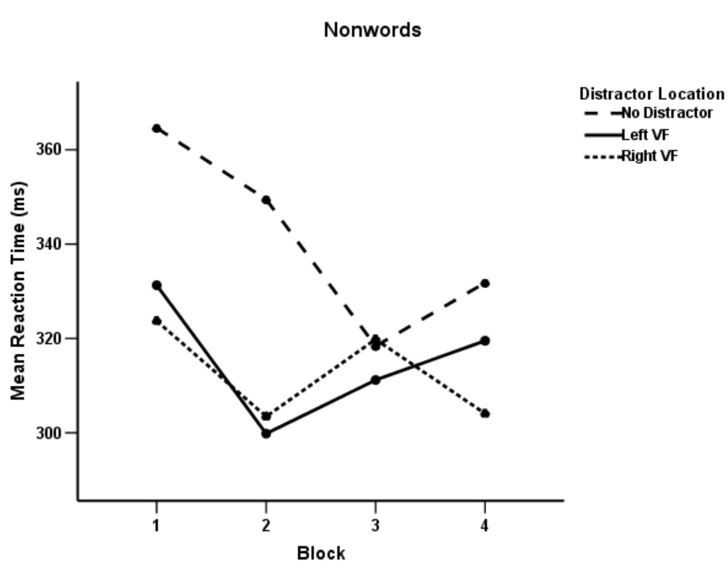

Figure 9. 2-Way interaction between block and distractor location for letter strings that spell orthographically incorrect nonwords.

Discussion

The results from Experiment II indicate a block by distractor location interaction in each letter string condition (words, pseudowords, nonwords), as well as a distractor by group interaction in the word and nonword conditions. The findings offer support for the assumptions of the inhibitory interaction hypothesis, that the dominant hemisphere will suppress identical processing by the non dominant one, and that the strength of inhibition will increase as experience is gained (Wey, et al., 1993).

Trends of speeding across blocks in right visual field distractor, and no distractor conditions, provides additional support for contention that the left hemisphere is dominant for familiar words compared to the right. Due to the degree of experience that people have for letter strings that spell common words, asymmetry has had the time to develop as was seen in the light condition where there was a cost to disengaging the left hemisphere but not the right hemisphere. Pseudowords are relatively unfamiliar strings and as a result asymmetry has not had the time to develop. These letter strings share features in common with words, and thus experience with these strings should benefit both hemispheres. The results support the benefit of experience as there is a significant speeding across blocks in conditions where both are engaged and one or the other is disengaged. Nonwords are highly unfamiliar, thus no asymmetry should be evident for these strings, and practice should have less of an effect on processing speed for either hemisphere. Speeding was limited to the no distractor condition, suggesting that the use of conflicting strategies initially slows reaction time, but experience with nonwords resulted in speeding across blocks 2 and 3. Reaction time in the block 4 is not significantly different between conditions in which both hemispheres are engaged to ones in which left hemisphere is engaged, suggesting that the hemispheres revert to the more developed strategies of the left hemisphere after some experience is gained.

The prediction that a lexical distractor (HAT) would increase reaction time compared to a non lexical distractor (light) was only supported in the common word condition. A lexical distractor (HAT) displayed in the left or right visual field was more costly compared to no distractor, suggesting that a lexical distractor evoked processing similar to that needed in the decision task and placed an additional load on attentional resources. A non lexical distractor (light) displayed in the right visual field was more costly compared to no distractor or a left visual field distractor, which supports the prediction of a left hemisphere advantage for common words, and is consistent with the inhibitory-interaction hypothesis (Wey, et al., 1993)

Reaction time to nonwords was faster when one or the other hemisphere was disengaged with either a lexical or non lexical distractor. Presentation of a distractor facilitates reaction time because it disengages one hemisphere, and as a result, reduces the conflict that exists in conditions when both are free to engage in processing. In other words, when processing unfamiliar letter strings, a distractor benefits reaction time because it reduces conflict.

The results from this experiment are consistent with Rutherford and Lutz’s (2004) findings and offer additional support for the predictions of the inhibitory-interaction hypothesis (Wey, et al., 1993).

General Discussion

The inhibitory-interaction hypothesis states that experience will alter the pattern of interhemispheric communication when people read, and suggests that the dominant hemisphere suppresses identical processing by the non dominant one (Wey, et al., 1993). The present study included two experiments to test the assumptions proposed by Wey et al. (1993) and the differential effect of presenting a lexical versus a non lexical distractor to either visual field. Experiment I used a centralized lexical decision task accompanied by a lexical distractor (M) or a non lexical distractor (light). The results indicated that experience does alter the functional imbalance between the left and right hemispheres, and that lexicality of a distractor exerts a negative effect when paired with an unfamiliar letter string. The results did not test the prediction that suppression will occur when both hemispheres are engaged in identical processing, because the data from the no distractor condition could not be compared to the two types of distractors in the left and right distractor conditions.

Experiment II used the same procedure as Experiment I, but the lexical distractor was the word HAT rather than the letter M, and an additional distractor location variable (no distractor) was analyzed to address what would happen if both hemispheres were engaged. The results from Experiment II are consistent with previous research (Rutherford & Lutz, 2004; Wey et al., 1993). Accordingly, experience with a letter string predicted the degree of hemispheric asymmetry, and that this asymmetry was likely the result of the inhibitory effects on the non dominant hemisphere. The lexicality of a peripheral distractor exerted a negative effect on processing for common words, by placing an additional load on attentional resources compared to a non lexical distractor.

This evidence is important because it offers insight into the role of practice on improving reading ability, thus can be used in developing new strategies to aid individuals who are inexperienced readers.

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Appendix A

The Annette Handedness Questionnaire

Handedness Questionnaire (Annett, 1970)

Which hand do you habitually use for the following tasks? Print left (L), right (R), or either (E) beside each question:

1. To write a letter legibly
2. To throw a ball to hit a target
3. To hold a racket in tennis, squash, or badminton
4. To hold a match whilst striking it
5. To cut with scissors
6. To guide a thread through the eye of a needle (or guide needle on to thread)
7. At the top of a broom while sweeping
8. At the top of a shovel when moving sand
9. To deal playing cards
10. To hammer a nail into wood
11. To hold a toothbrush while cleaning your teeth
12. To unscrew the lid of a jar

Appendix B

The Consent Form

Informed Consent

Brain Interhemispheric Communication And Reading

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Sponsor: Partial funding from an OUC Grant-In-Aid

Introduction:

The University of British Columbia-Okanagan subscribes to the ethical conduct of research and to the protection at all times of the interests, comfort, and safety of the study of subjects. The information provided in this form is being given to you for your own protection and full understanding of the procedures, risks and benefits associated with this research.

The consent form is only part of the process of informed consent. It should give you a basic idea of what the research is about and what your participation will involve. If you would like more details, feel free to ask the researcher presenting this form at any time. Please take the time to read this carefully and to understand any accompanying information.

Purpose Of The Study:

This study seeks to better understand how the hemispheres of the brain interact when people read.

Study Procedures:

You will be asked to engage in 3 tasks that will take about 1 hour of your time (including the time to debrief you):

(1) Handedness questionnaire: This asks which hand you habitually use to perform different tasks (e.g. writing, throwing a ball). It will take about 5 minutes to complete.

(2) Reading Aloud: You will be asked to read aloud a short list of “fake” words (e.g. blurp). This task will take about 5 minutes to complete.

(3) Computer task. You will be seated in front of a computer screen with your chin on a chinrest. A letter string will appear on the monitor. Your job is to decide whether or not the letters spell a word. You will press one or other of a pair of computer keys to indicate the decision. On some of the trials, a distractor located to one or other side of the letter string will blink on and off for a short period of time. This task will take about 30 minutes to complete.

Potential Risks And Benefits:

This project has been reviewed and granted a certificate of approval by the UBCO Research Ethics Board.

This research is important because it will increase our understanding of how the hemispheres of the brain interact when people read. In turn, the findings will be useful to the development of programs to better help those who struggle with reading.

You understand that any risk from participation in this research is minimal because the tasks are those normally associated with everyday living (e.g. filling out a form, speaking aloud, and sitting in front of a computer screen and pressing computer keys).

Confidentiality:

You understand that all data collected from you will be coded by a number and not your name; therefore, your identity will be kept confidential. The only people who will have access to the data are the principal investigator and designated research assistant(s). The data will be stored in a locked file cabinet and in a password-protected file on a computer in the psychology laboratory complex. All data will be destroyed 7 years after the findings have been published.

Remuneration/Compensation:

Introductory Psychology students at UBCO will receive a 1% course bonus credit/hour of research participation (up to a maximum of 4 credits). UBCO students who are either ineligible for bonus credits or do not wish to receive bonus credits may receive $10/hour research participation.

Contact For Information About The Study:

If you have any questions about the project, you may address them to Dr. Barbara Rutherford, at telephone number (250) 807-8734.

If you have any concerns about your treatment or rights as a research subject, you may contact the Chair, Research Ethics Board through the Office of Research Services at (250) 807-8150.

The results of the study will be presented at national/international conferences and published in a peer-reviewed journal in psychology. For details on the publication, contact Dr. Barbara Rutherford at telephone number (250) 807-8734 about 2 years following your participation. For other access to the findings, watch for posters on campus that advertise the time and place of a verbal presentation of the results.

Consent:

Your participation in the study is entirely voluntary and you may refuse to participate at any time during the testing session without consequence. Prior to leaving the testing session, you may instruct the researcher to destroy your data and watch while the computer file is deleted and the paper documents are shredded.

Your signature on this form indicates that you understand the information provided regarding this research project including all procedures and the personal risks involved. Your participation in this project is in no way related to your status as a student.

You understand that your identity and any identifying information will be kept confidential.

Your signature below indicates that you consent to participate in this study. You will receive a copy of this consent form for your own records.

Your name (Please print): ____

Your signature: ___________________________________ Date:____________

Investigator and/or Delegate's signature: __________________ Date:____________