Using Mental Set to Change the Size of Posner's Attentional Spotlight: Implications for how Words are Processed in Visual Space

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

The present thesis investigated how words are processed within the context of visual search. Both explicit and implicit measures were used to assess whether spatial attention is a prerequisite for words to undergo processing. In the explicit search task, subjects searched a display and indicated whether a word was present or absent among nonword distractors. In the implicit task, priming was employed to index word processing. Subjects viewed the same search displays that were used in the explicit task, however, the displays were presented briefly and were followed by a single target letter string to which subjects performed a lexical decision. In Experiments 3 through 6, in which the target was always presented at fixation, no priming was evident. In Experiments 7 and 8 when the location of the target moved from trial to trial, priming was observed. It is argued that attentional resources are narrowly allocated to a location in visual space when target location is certain but diffusely allocated when target location is uncertain. Furthermore, processing only occurs for words that fall within the suffusion of this strategically pliable attentional beam. The results are also interpreted within the domains of perceptual cuing and attentional capture.

Acknowledgements

This dissertation, the consummation of my graduate work at the University of Waterloo, reflects important relationships that have forever changed me. Relationships that have conferred knowledge, led to introspection and growth, and provided experiences that I take with me for the remainder of my life.

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Chapter 1: Introduction

Cognitive psychology literature is rife with theories and experiments that explore the phenomenon of visual search. Similarly, studies investigating word recognition are well represented within the pages of these journals. Yet, interestingly, there have been only a handful of experiments that have integrated these two areas of research. The present study does so by investigating how people process words within the context of visual search tasks. The purpose of the study is to gain a more complete understanding of the relation between spatial attention and word processing. For example, is spatial attention a prerequisite for word processing? Can the focus of spatial attention be strategically broadened and narrowed depending on task demands? By colouring a word in a display and making it a featural singleton, will processing of the word be enhanced? Put another way, can a featural singleton marshal the attentional resources necessary to process the identity of the featural carrier? At present, the role that spatial attention plays in the processing of words is controversial. This study seeks to help clarify that role.

One line of thought is that spatial attention must be brought to bear upon a stimulus before it is processed to the level of meaning. This account, dating back to the selective filter theory of Broadbent (1958), is referred to as an early selection account because it presupposes that spatial attention must be allocated early in the temporal processing stream before any meaningful processing begins. In contrast, contemporaries of Broadbent (e.g., Deutsch & Deutsch, 1963), argued that spatial attention is not necessary for meaningful identification. Proponents of this late selection account theorize that stimulus identification occurs in parallel across the visual field prior to attentional selection. In terms of lexical processing then, early selection accounts contend that spatial attention is necessary for lexical activation whereas late selection accounts argue that it is not.

Over the past fifty years many experiments have been conducted that have tested these competing viewpoints. The paradigm that has probably been employed more extensively than any other in this endeavor is the flanker task. Eriksen and Eriksen (1974) introduced this task to investigate whether letters can be processed in the absence of spatial attention. Since then, numerous studies have explored the flanker compatibility effect by asking participants to identify or categorize targets that are flanked by congruent or incongruent distractors. For example, in a study by Shaffer and LaBerge (1979), participants identified a target word by responding manually to the category of that target. Participants pressed one button if the word was from the category of metal or clothing, and another button if the word was from the category of furniture or trees. Above and below each target were category distractor words that were either paired with the same response button as the target or paired with the other response button. Their results showed that participants were slower when the distractors were paired with a response button different from that of the target. Shaffer and LaBerge argued that the distractor words must have been processed outside of spatial attention given that attention was focused upon the target word. Such conclusions are common with these types of experiments.

This conclusion, however, highlights the difficulty of studying spatial attention using such a paradigm. An alternative inference is that subjects simply moved their attention to the distractor items during the task. Indeed, a number of researchers have commented upon this problem, arguing that in experiments that investigate processing in the absence of attention, the "unattended stimuli" are not necessarily unattended. (e.g., Besner, Risko, & Sklair, 2005; Lachter, Forster, & Ruthruff, 2004; Yantis & Johnston, 1990). Lachter et al. (2004) discuss the difficulty of distinguishing between attended and unattended stimuli by underscoring Broadbent's (1958) concepts of leakage and slippage. Leakage occurs when unattended information is meaningfully processed. Thus, although attention may be allocated elsewhere, distractor information still undergoes processing that leads to identification. The idea is that extraneous information leaks through the attentional filter, which is designed to keep superfluous information from interfering with the uptake of preferentially selected information. Alternatively, slippage occurs when attention is initially focused upon preferentially selected information but briefly moves to the distractor items. The distractor items undergo processing but only after attention has been brought to bear upon them.

Unfortunately, within any given flanker experiment, assignment of whether slippage or leakage occurred can be made post hoc and with theoretical bias. For example, an early selection proponent might base her assessment of the slippage/leakage distinction upon the completed results. If the distractor items affect the response to the target then she ascribes the effect to slippage (and thus she concludes that there is no breach of the attentional filter through the process of leakage). In contrast, if the distractor items do not affect responses to the target then she argues that there was no slippage in this particular case (and thus, once again, she concludes that there is no breach of the attentional filter by the process of leakage).

It is clear that investigating spatial attention using varied approaches is important to eschew the slippage/leakage dilemma. One possibility is to present subjects a display of letter strings and allow them to move their attention in the display as they see fit. By manipulating factors such as task, the duration of the display, the number and types of items in the display, and the colour of items in the display, one can potentially investigate the requisite circumstances involved in processing words.

Chapter 2: Explicit Visual Search to Index Word Processing

Our first undertaking was to investigate word recognition within the context of an explicit visual search task. We used a straightforward paradigm typically found within the visual search literature (e.g., Duncan & Humphreys, 1989; Treisman, 1988; Treisman & Gelade, 1980; Wolfe 1994; Wolfe, Cave, & Franzel, 1989). Participants simply searched for a target among distractors and indicated whether the target was present or absent. The target was always a word and the distractors nonwords. The purpose of the experiment was to investigate whether the task would produce efficient search slopes (e.g., RT increases little as a function of set size) or inefficient search slopes (e.g., RT increases linearly as a function of set size). The explicit search task will provide a baseline for subsequent implicit tasks.

According to Treisman's feature integration theory (Treisman, 1988; Treisman & Gelade, 1980) efficient searches are associated with targets that can be discriminated from distractors at a preattentive stage. Within this preattentive stage, items in the display are processed in parallel and, accordingly, there is no need to identify the target item by using attention to "glue" constituent features, in order to make a discrimination between it and the distractors. In contrast, the hallmark of inefficient searches is that participants must focus spatial attention upon items in the display to synthesise constituent features, consequently enabling the target/distractor discrimination.

If words are processed regardless of whether attention is brought to bear upon the word, as argued by proponents of late selection accounts, then one might expect to see relatively flat search slopes in such a task. This is because independent of the number of distractors, the word should undergo processing and hence lead subjects to indicate that a word is indeed present (of course, it is one matter for a word to undergo meaningful processing and another for this processing to lead to an explicit response – this matter is addressed later in the thesis). Conversely, if a prerequisite for word processing is the allocation of spatial attention, then one might expect to see steep linear search slopes as participants move attention from one item in the display to another to make target/distractor discriminations.

Previous studies that have explored the task of searching for words among nonword distractors have typically reported inefficient search slopes. For example, Flowers and Lohr (1985) conducted a study in which participants searched for a predefined word (e.g., DOG) among nonwords that were visually similar (e.g., DCG). The task had a large number of trials as is common in the domain of psychophysics. They reported that there was no evidence for a *pop-out effect* and that the results were consistent with a serial self-terminating search. In other variations of visual search, experimenters have had participants search for words with high emotional content. For example, participants have searched for their own names among other names or word distractors. Interestingly, these results have been inconsistent. Mack and Rock (1998) reported that when participants searched for their own names there were very efficient search slopes suggestive of pop-out, whereas Harris, Pashler, and Colburn (2004) reported steep slopes consistent with serial search.

We wanted to conduct an explicit search task for words in our lab for two reasons. First, the results from these visual search experiments would set the stage for a series of implicit tasks examining how word processing is modulated by spatial attention. Second, we wanted to modify the methodology from that previously employed to further an understanding of how words are processed in visual space.

The target words in the task were not predefined, nor did they differ from distractors by a single letter. Rather, subjects were instructed to simply indicate whether a word was present or absent within a display. In addition, there were three types of distractors, which were manipulated between subjects: Unpronounceable nonwords (e.g., mnxb); pronounceable nonwords (e.g., nolp); and pseudohomophones, (nonwords that sound like words when pronounced, e.g., phir). If subjects employ a serial search when discriminating words from nonwords, then we would expect to find differential search slopes between the three types of distractors. For example, consider the following scenario: Subjects perform the task by moving spatial attention from one item in the display to another until they either find a word (and indicate yes) or search the entire display without encountering a word (and indicate no). If such a strategy were used, then for each item encountered in the display a decision must be made – *word* or *not a word*. In lexical decision, typically, differentiating a word from an Unpronounceable nonword (e.g., mnxb) is faster than differentiating a word from a pronounceable nonword (e.g., nolp), which in turn is faster than differentiating a word from a pseudohomophone nonword (e.g., phir). Thus, if the search task is tantamount to making numerous lexical decisions, we should not just see differences in the intercepts of the search slopes but also differences in the slopes themselves. Alternatively, if subjects perform the task using a different strategy (e.g., one that might utilize some type of holistic approach within the display), then we might not expect significant differences in the search slopes.

EXPERIMENT 1

Method

Participants

Seventy-two University of Waterloo undergraduate students took part in the experiment. All spoke English as their first language and all had normal or corrected-to-normal vision.

Design

The experiment consisted of a 4 (Set Size: 1 vs. 3 vs. 5 vs. 7) x 2 (Target Presence/Absence: Word-Present vs. Word-Absent) x 3 (Distractor Type: Unpronounceable Nonwords vs. Pronounceable Nonwords vs. Pseudohomophone Nonwords) mixed-subjects design. The factors of Set Size and Target Presence/Absence were within-subject and the factor of Distractor Type was between-subject.

Stimulus materials and list construction

The word stimuli consisted of 64 four- and five-letter words randomly selected from the Celex database (see Appendix A). A word was present on half of the trials and each word appeared equiprobably across all conditions. For each of the distractor conditions, there were 448 nonwords that were four or five letters in length. In the Unpronounceable nonword condition, there were no vowels in any of the nonwords but all consonants were equally likely to appear in each of the items (see Appendix B). The pronounceable nonwords are presented in Appendix C. In the pseudohomophone condition, the nonwords were constructed so that when they were pronounced, they sounded like a word (see Appendix D). Examples for each nonword distractor type, respectively, are *mnxb*, *nolp*, and *phir*. No items were displayed more than once for each participant.

Each participant saw only one distractor type throughout the entire experiment. Within each distractor type condition, all words and nonwords appeared equiprobably in all conditions, across subjects. Both words and nonwords were rotated through the four conditions formed by the two within-subjects factors of Target Presence/Absence (Word-Present vs. Word-Absent) and Set Size (1, 3 ,5, 7). There were 128 experimental trials in total.

Procedure

Subjects were tested individually, seated approximately 60 cm from the computer monitor. Subjects read through instructions that were displayed on the monitor. Afterwards, the experimenter recapitulated the instructions aloud. Subjects were instructed to respond *present* if a word was present in the display and *absent* if no word was present in the display. They were asked to respond as quickly and accurately as possible.

Stimuli were displayed on a standard 15-inch SVGA monitor controlled by Micro Experimental Laboratory (MEL) software (Schneider, 1988, 1990) implemented on a Pentium-IV (1,800 MHz) computer. Response accuracy and latency to the nearest millisecond were measured by MEL software.

Each trial began with a fixation cross (+) at the center of the screen that was displayed for 500 ms. Following fixation, a display appeared until subjects made a response. The display consisted of one, three, five, or seven items presented in lowercase 72-point MEL system font. Letter strings subtended 1.3 or 1.6 degrees of visual angle horizontally, depending on whether they were four or five letters, respectively. All letter strings subtended 0.5 degrees of visual angle vertically.

In the Word-Present condition, one of the items in the display was a word and the remaining items were nonwords. In the Word-Absent condition, all of the items were nonwords. Items were presented in one of sixteen locations within a 4 x 4 grid matrix. The fixation cross was located at the centre of the matrix and each item was either 2, 4, or 6 degrees of visual angle from fixation.

Subjects responded by depressing one of two computer keys [Z, /], which were counterbalanced across subjects and mapped onto the responses of *present* and *absent*. Responses initiated a 500 ms intertrial interval. All participants performed one block of 32 practice trials before completing the 128 experimental trials.

Results

Only correct responses were included in the analysis of the RT data (91.4 % of the total trials in the experiment). These data were first submitted to a recursive outlier analysis (Van Selst & Jolicœur, 1994), which resulted in the elimination of 1.6 % of the data. Two sets of analyses were conducted on the data. First, the data were analysed using a three-factor mixed design. Second, search slopes were computed separately for each Distractor Type and Target Presence/Absence condition, the results of which are summarized in Figures 1 and 2.

Three-factor mixed design analysis

The RT data were analysed using a 3 x 2 x 4 analysis of variance (ANOVA) examining the between-subjects factor of Distractor Type (Unpronounceable Nonwords vs. Pronounceable Nonwords vs. Pseudohomophones) and the within-subjects factors of

Target Presence/Absence (Word-Present vs. Word-Absent) and Set Size (1 vs. 3 vs. 5 vs. 7). The data are presented in Appendices F, G, and H. All three main effects were significant; for Target Presence/Absence, $F(1,69) = 262$, $MSE = 57637$, $p < .001$, for Set Size, $F(3,207) = 927$, $MSE = 46982$, $p < .001$, and for Distractor Type, $F(2,69) = 39.7$, $MSE = 346757$, $p < .001$. All interactions were also significant; for Target Presence/Absence by Distractor Type, $F(2,69) = 9.88$, $MSE = 57637$, $p < .001$, for Set Size by Distractor Type, $F(6,207) = 24.6$, $MSE = 46982$, $p < .001$, for Target Presence/Absence by Set Size, $F(3,207) = 150$, $MSE = 19222$, $p < .001$, and finally for Target Presence/Absence by Set Size by Distractor Type, $F(6,207) = 2.24$, $MSE = 19222$, $p < .05$.

Search slope analysis

Search slopes were computed for each of the Distractor Types for both Word-Present and Word-Absent conditions, and are depicted in Figures 1 and 2. In addition, data are presented in Appendix I. For both Word-Present and Word-Absent conditions an ANOVA was computed to test if there were differences in search slopes between the distractor conditions. In the Word-Present condition, there was a significant difference between the slopes of the distractor conditions, $F(2,69) = 36.7$, $MSE = 1606$, $p < .001$. Planned comparisons between each of the three Distractor Types were conducted using the omnibus error term, $SEM = 11.57$: $t(23) = 5.93$, $p < .001$ for Unpronounceable nonwords vs. pronounceable nonwords; $t(23) = 8.31$, $p < .001$ for Unpronounceable nonwords vs. pseudohomophones; $t(23) = 2.38$, $p < .05$ for pronounceable nonwords vs. pseudohomophones. In the Word-Absent condition, there was also a significant difference between the slopes of the distractor conditions, $F(2,69) = 20.5$, $MSE = 5813$, *p*

Figure 1. Mean response times as search slopes (in ms), and percentage errors, for Word-Present trials for each distractor type in Experiment 1.

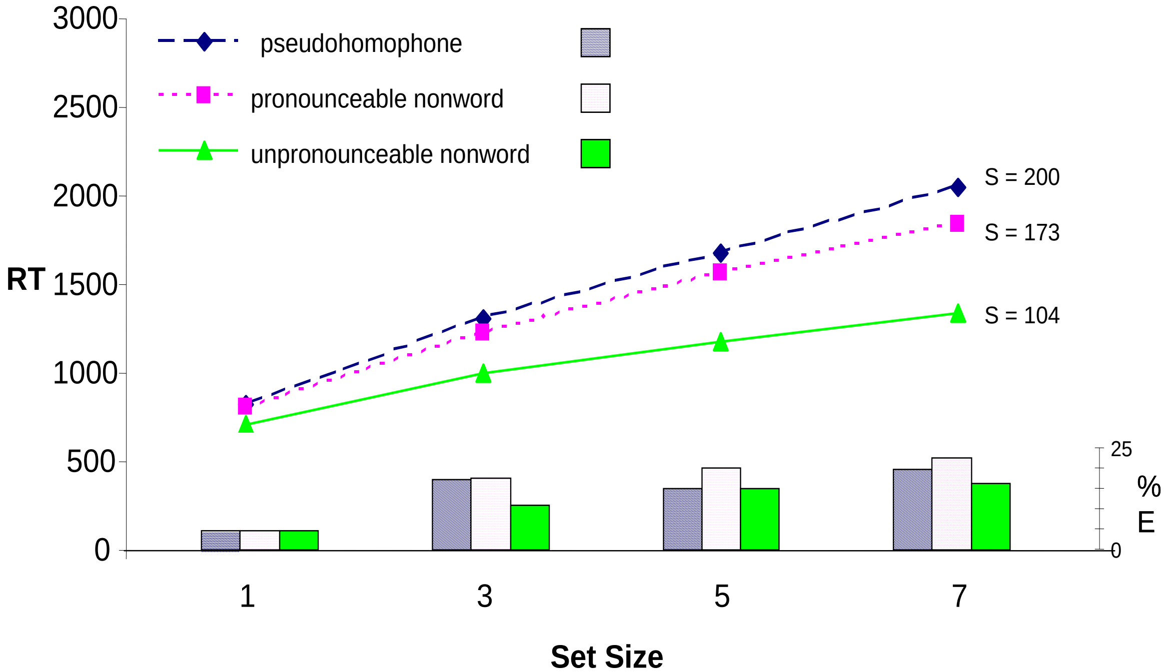
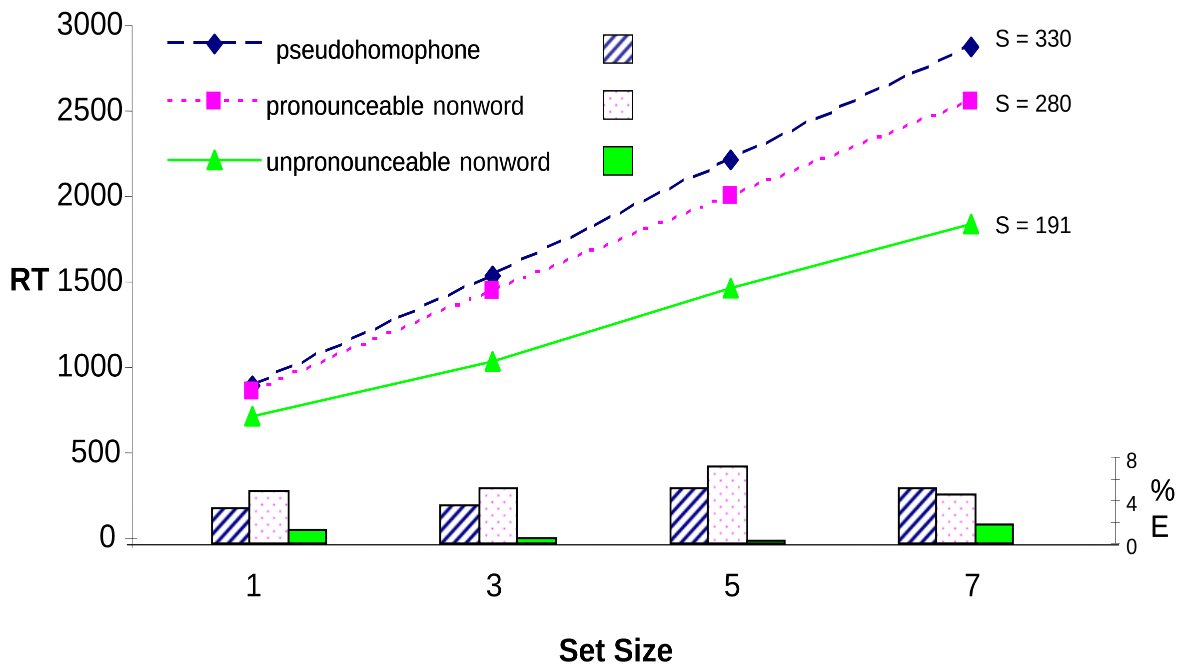


Figure 2. Mean response times as search slopes (in ms), and percentage errors, for Word-Absent trials for each distractor type in Experiment 1.



< .001. Planned comparisons between each of the three Distractor Types using the omnibus error term, *SEM* = 22.01, were as follows; $t(23) = 4.05$, $p < .001$ for Unpronounceable nonwords vs. pronounceable nonwords; $t(23) = 6.33$, $p < .001$ for Unpronounceable nonwords vs. pseuhomophones; $t(23) = 2.28$, $p < .05$ for pronounceable nonwords vs. pseudohomophones.

In sum, search functions were steep and linear. They differed for each of the three Distractor Types such that the Unpronounceable Nonword condition yielded the shallowest search slopes, the Pronounceable Nonword condition yielded the next shallowest slopes, and the Pseudohomophone condition had the steepest search slopes.

Error data. Error data were computed separately for Word-Present and Word-Absent conditions and are included in Figures 1 and 2, respectively and in Appendix I. In the Word-Present condition an ANOVA revealed that there was a significant main effect of Set Size $F(3,207) = 35.9$, $MSE = 80.4$, $p < .001$, such that errors increased as Set Size increased. There was no interaction between Set Size and Distractor Type, $F(6,207) = 1.06$, $MSE = 80.4$, $p > 1$. In the Word-Absent condition error rates did not differ across Set Size, $F(3,207) = 1.39$, $MSE = 15.5$, $p > .1$, nor was their an interaction between Set Size and Distractor Type, $F(6,207) = 1.56$, $MSE = 15.5$, $p > .1$

Discussion

Search slopes were steep for all three types of nonword distractors. As set size increased, RT increased linearly. The results are consistent with a serial search strategy in which participants performed the task by focusing attention upon one item in the display, made a presence/absence discrimination, and then moved attention to the next item in the display if necessary. Furthermore, search slopes became steeper as distractor similarity increased. The shallowest search slopes were obtained when the distractors were Unpronounceable nonwords (e.g. mnxb), the next steepest slopes occurred when the distractors were prounceable nonwords (e.g., nolp), and the steepest slopes occurred when the distractors were psuedohomophones (e.g., phir). Differential search slopes are consistent with the hypothesis that subjects moved spatial attention from one item in the display to another until they either found a word or searched the entire display without encountering a word. As target\distractor differentiation becomes more difficult, the decision as to whether any given item is a word should take longer, and as such, should be reflected in steeper search slopes, which was revealed by the results.

It is worth commenting upon the steep search slopes in the Unpronounceable Nonword condition (e.g., mnxb distractors). Heuristically, one might have speculated that it would be possible to pick out a word quickly from a display that consisted of consonant clusters based upon, if nothing else, target/distractor orthographic dissimilarities. This, however, does not appear to be the case. Rather, it appears that spatial attention is necessary to distinguish words from consonant clusters in the same way that it is necessary to distinguish words from pronounceable nonwords. This result is consistent with a set of cueing experiments conducted by Ferguson, Risko, Stolz, and Besner (submitted), in which participants performed lexical decisions to targets whose locations were either validly or invalidly cued. Type of nonword was manipulated between subjects. The results revealed that not only pronounceable nonwords but consonant clusters, as well, were additive with the spatial manipulation of cuing. Thus, both the cueing experiments described here and Experiment 1 suggest that spatial attention is necessary for orthographic processing, as indexed by differentiating words from consonant strings.

EXPERIMENT 2

The results obtained in Experiment 1 are consistent with the strategy of moving attention from one item in the display to another as the task is performed. Thus, when attention is free to wander throughout the display, the results are characterized by serial search. The next experiment, which will provide a baseline for subsequent implicit tasks, examines what happens when attention is directed to the salient item in the display. Directing attention was accomplished by colouring one of the items red. If a word was present in the display, then the word was coloured red. If a word was not present, then one of the distractors, chosen at random, was coloured red. Accordingly, all of the pertinent information as to whether a word was present in the display was found at the location of a featural singleton. The utility of investigating flat search slopes will become particularly apparent when we employ implicit measures to index word processing.

Method

Participants

Seventy-two University of Waterloo undergraduate students took part in the experiment. All spoke English as their first language and all had normal or corrected-to-normal vision.

Design

The experiment consisted of a 4 (Set Size: 1 vs. 3 vs. 5 vs. 7) x 2 (Target Presence/Absence: Word-Present vs. Word-Absent) x 3 (Distractor Type: Unpronounceable Nonwords vs. Pronounceable Nonwords vs. Pseudohomophone

Nowords) mixed-subjects design. The factors of Set Size and Target Presence/Absence were within-subject and the factor of Distractor Type was between-subject.

Stimulus materials and list construction

The same stimuli that were used in Experiment 1 were used here. Thus, once again, each participant saw only one Distractor Type throughout the entire experiment. Within each Distractor Type condition, all words and nonwords appeared equiprobably in all conditions. Both words and nonwords were rotated through the four conditions formed by the two within-subjects factors of Target Presence/Absence (Word-Present vs. Word-Absent) and Set Size (1, 3 ,5, 7). There were 128 experimental trials in total.

Procedure

The procedure was the same as that for Experiment 1 except for the following. In the Word-Present condition, the word was always presented in red (red 72-point MEL system font). In the Word-Absent condition, one of the distractors was selected at random to be presented in red. The remaining nonword items in the display were presented in white (white 72-point MEL system font). Thus, one and only one item in the display was coloured red. Subjects were instructed to respond to whether the red item in the display was a word or not a word. Subjects responded by depressing one of two computer keys [Z, /], which were counterbalanced across subjects and mapped onto the responses of present and absent.

Results

Only correct responses were included in the analysis of the RT data (95.7 % of the total trials in the experiment). These data were first submitted to a recursive outlier analysis (Van Selst & Jolicœur, 1994), which resulted in the elimination of 1.4 % of the data. As was done for Experiment 1, two sets of analysis were conducted on the data. First, the data were analysed using a three-factor mixed design. Second, search slopes were computed separately for each Distractor Type and Target Presence/Absence condition.

Three-factor mixed design analysis

The RT data were analysed using a 3 x 2 x 4 analysis of variance (ANOVA) examining the between-subjects factor of Distractor Type (Unpronounceable Nonwords vs. Pronounceable Nonwords vs. Pseudohomophones) and the within-subjects factors of Target Presence/Absence (Word-Present vs. Word-Absent) and Set Size (1 vs. 3 vs. 5 vs. 7). The data are presented in Appendices J, K, and L. All three main effects were significant; for Target Presence/Absence, $F(1,69) = 53.4$, $MSE = 7378$, $p < .001$, for Set Size, $F(3,207) = 23.9$, $MSE = 2903$, $p < .001$, and for Distractor Type, $F(2,69) = 16.1$, $MSE = 95571$, $p < .001$ (The significant main effect of Set Size was surprising given our prediction of flat search slopes, however, this effect is qualified by the following. First, a Fisher's LSD post hoc test revealed that only set size 1 differed from the other set sizes, $MSE = 17.1$. In addition, Set Size did not interact with any other factor. Finally, as shown below, slopes were very efficient and did not differ across Distractor Type. We therefore conclude that at Set Sizes of 3, 5, and 7, there is a stimulus filtering cost for distractors, which is not present at Set Size 1). The only interaction that was significant was Target Presence/Absence by Distractor Type, $F(2,69) = 21.3$, $MSE = 7378$, $p < .001$. For all other interactions, $F < 1.26$.

Search slope analysis

Search slopes were computed for each of the Distractor Types for both Word-Present and Word-Absent conditions, and are depicted in Figures 3 and 4. Subject means are presented in Appendix M. For both Word-Present and Word-Absent conditions an ANOVA was computed to test if there were differences in search slopes as a function of Distractor Type. In the Word-Present condition, there was no difference in slopes as a function of distractor condition, $F(2,69) < 1$. In the Word-Absent condition, there was also no significant difference in slopes, although this effect was marginal, $F(2,69) = 2.79$, $MSE = 180.3$, $p > .05$.

Error data. Error data were computed separately for Word-Present and Word-Absent data and are included in Figures 3 and 4 and in Appendix M. In the Word-Present condition an ANOVA revealed that error rates did not differ across Set Size $F(3,207) < 1$ nor was there any interaction between the effects of Set Size and Distractor Type, $F(6,207) = 1.51$, $MSE = 26.6$, $p > 1$. In the Word-Absent condition error rates did differ as a function of Set Size, $F(3,207) = 3.61$, $MSE = 23.8$, $p < .05$. To interpret this result, within-subjects contrasts revealed Set Size to have a significant quadratic relationship, $F(1,69) = 5.66$, $MSE = 23.1$, $p < .05$. We see no theoretical motive for Set Size 5 to have fewer errors than the other set sizes in this Word-Absent condition. This result in all likelihood does not compromise our interpretation of the RT data. There was no interaction between the effects of Set Size and Distractor Type, $F(6,207) < 1$.

Discussion

Search slopes were very shallow for all three types of nonword distractors and there was no difference in any of the slopes as a function of Distractor Type. The results

Figure 3. Mean response times as search slopes (in ms), and percentage errors, for word present trials for each distractor type in Experiment 2.

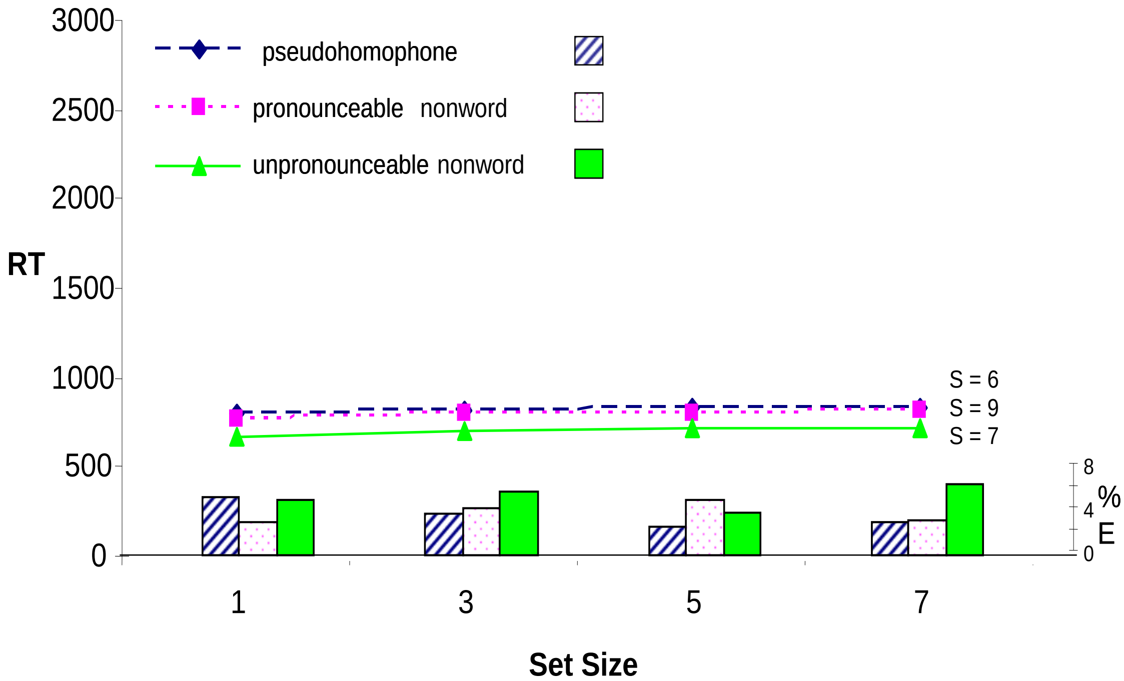
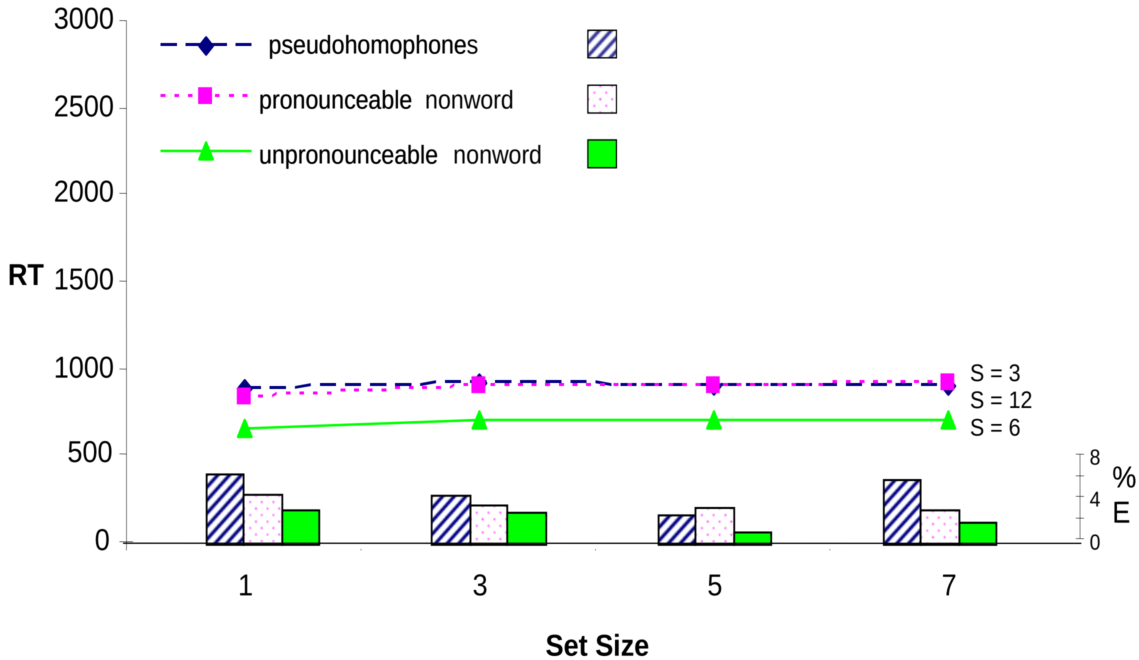


Figure 4. Mean response times as search slopes (in ms), and percentage errors, for word absent trials for each distractor type in Experiment 2.



are consistent with the hypothesis that instructing participants to respond to the red target, directed attention to the salient item. Although the results of Experiment 2 are not surprising, they perform the function of providing a baseline for the implicit search tasks, as will become apparent presently.

Word identification is dependent upon spatial attention in explicit search tasks

In the first experiment, attention was free to wander. Participants moved attention from item to item using a serial search strategy. Accordingly, responding to the presence of a word was relatively slow. In the second experiment, attention was directed to the word if it was present and, accordingly, responding to the presence of a word was relatively fast. Taken together, these explicit search results are consistent with the predictions of early selection. It appears that words are not meaningfully processed until spatial attention is brought to bear upon the letter string. In Experiment 1, if the presence of a word in the display had resulted in response times relatively independent of set size, then that would have constituted evidence for word processing outside of the focus of attention. Given that such a result was not obtained, there is no evidence that words were processed without attention.

Of course, it remains entirely possible that in Experiment 1 the information in the display was processed in parallel but that this processing was not indexed by our explicit search task. In other words, the target word, when present, did undergo processing necessary for lexical activation but participants continued to search from item to item in the display because of a disconnect between this activation and functional awareness of this activation. To examine this possibility we conducted a series of experiments. The purpose of these experiments was to employ implicit measures to address the possibility that words are processed to the level of meaning before spatial attention is brought to bear upon them. We turn now to the experiments, which used priming as the implicit measure to index processing.

Chapter 3: Implicit Visual Search to Index Word Processing

In this set of experiments, participants viewed the same displays that were presented in Experiments 1 and 2, however, the displays were presented for brief durations. Following the display a single target letter string appeared to which subjects performed a lexical decision. When the letter string was a word, half of the time it was the same word that appeared in the display. In this way, identity priming could be used to investigate whether a word in the display undergoes processing.

In this type of an experimental design, attention is allocated as the participant sees fit. Participants are not asked to attend to, or ignore, any one specific item in the display. They are simply shown the briefly-presented display, consisting of one to seven items, and then tested immediately afterwards to see how much, if any, processing of the items has occurred. One advantage of taking the tack of not having specific items to focus upon is that, at least in some ways, it eschews the slippage/leakage problem because there is no target to slip/leak from. Thus, the experiment might be viewed as a test of one's capacity to process items rather than a test of one's selective ability to process a single item. If the items in the display undergo processing, then response latencies in the lexical decision task will be shorter for identity targets than for unrelated targets.

There appear to be three plausible outcomes. First, there may be absolutely no priming. This would be the strongest result for the hypothesis that, unless attention is focused specifically upon the prime word in the display, no processing of that item occurs. Second, there may be a priming effect, independent of set size. This would be the strongest result from the viewpoint of late selection. In this case, the results would suggest that the items in the display were processed in parallel in the explicit task but that subjects, nonetheless, moved attention from item to item to perform the task. Finally, the results may reveal a hybrid of the alternatives listed above. For example, there may be a priming effect, but the priming effect is qualified by set size. In this scenario, priming would be obtained at small set sizes but not at larger set sizes. Interpretation of the latter result may entail consideration of how processing is constrained by capacity limitations (e.g., Lavie, 1995).

EXPERIMENT 3

Method

Participants

Thirty-two University of Waterloo undergraduate students took part in the experiment. All spoke English as their first language and all had normal or corrected-to-normal vision.

Design

The experiment consisted of a 4 (Set Size: 1 vs. 3 vs. 5 vs. 7) x 2 (Target Lexicality: Word vs. Nonword) x 2 (Prime Relation: Related vs. Unrelated) within-subjects design.

Stimulus materials and list construction

The word stimuli consisted of the same 64 words used in Experiments 1 and 2, plus an additional 192 four and five letter words randomly selected from the Celex database. A word was always present in the search display and each word appeared equiprobably across all conditions, across subjects. The only distractor condition used in this experiment was the Pronounceable Nonword condition. The same 448 nonwords that were used in Experiments 1 and 2 were used here. No items were displayed more than once for each participant.

Stimuli were rotated through the 16 conditions formed by the three within-subjects factors of Target Lexicality (Word vs. Nonword), Relation (Related vs. Unrelated) and Set Size (1 vs. 3 vs. 5 vs. 7). There were 128 experimental trials in total.

Procedure

Subjects were tested individually, seated approximately 60 cm from the computer monitor. Subjects read through instructions that were displayed on the monitor, and the experimenter then recapitulated the instructions aloud. Subjects were asked to make a lexical decision to a target letter string that followed a briefly presented display. They were asked to respond as quickly and accurately as possible.

Stimuli were displayed on a standard 15-inch SVGA monitor controlled by Micro Experimental Laboratory (MEL) software (Schneider, 1988, 1990) implemented on a Pentium-IV (1,800 MHz) computer. Response accuracy and latency to the nearest millisecond were measured by MEL software. Letter strings subtended 1.3 or 1.6 degrees of visual angle horizontally, depending on whether they were four or five letters long, respectively. All letter strings subtended 0.5 degrees of visual angle vertically.

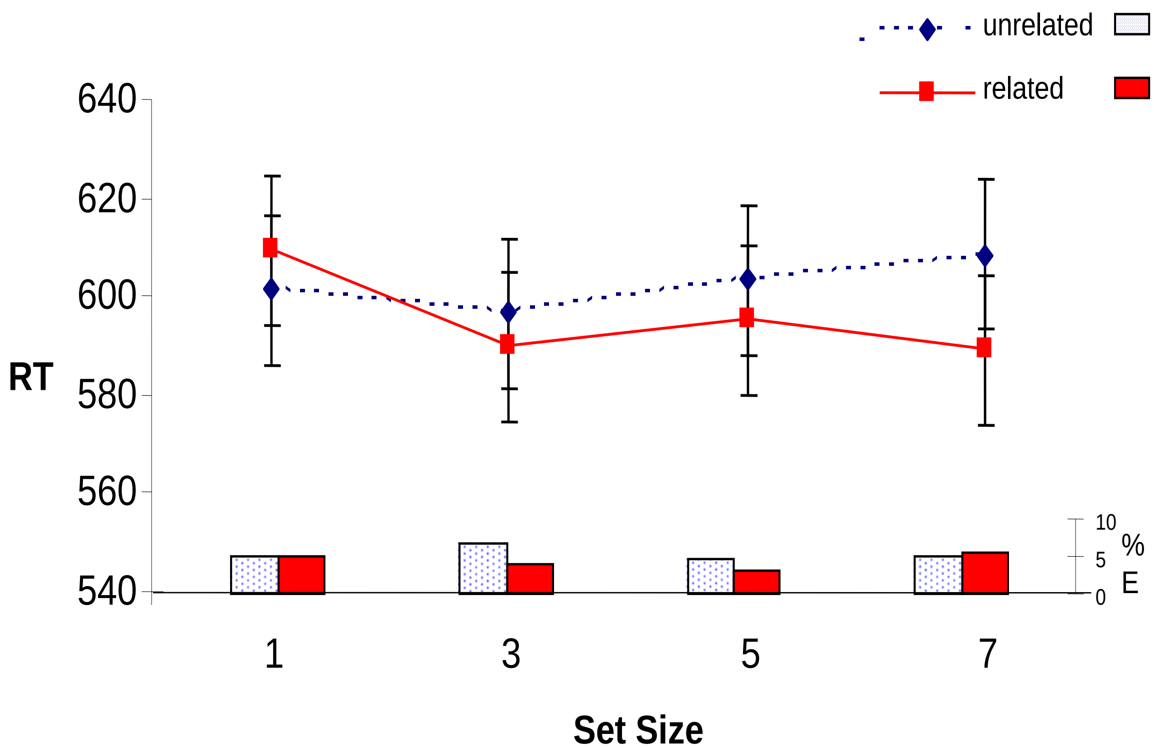
Each trial began with a fixation cross (+) at the center of the screen that was displayed for 500 ms. Following fixation, a display appeared for 100 ms. The display consisted of 1, 3, 5, or 7 letter strings presented in lowercase 72-point MEL system font. Just as in the previous experiments, letter strings were presented in 1 of 16 locations within a 4 x 4 grid matrix. The fixation cross was presented at the centre of the matrix and each item was either 2, 4, or 6 degrees of visual angle from fixation. A word was always present in the display. Following the letter strings a mask appeared for 150 ms at each of the 16 locations. The mask consisted of five characters from the top of the keyboard (e.g., @%&#$). Following the offset of the mask, a target letter string appeared at fixation. The target was equally likely to be a word or a nonword. On half of the trials in which the target was a word, it was the same word that appeared in the display.

Subjects performed a lexical decision task by depressing one of two computer keys [Z, /], which were counterbalanced across subjects and mapped onto the responses of *word* and *nonword*. Responses initiated a 500 ms intertrial interval. All participants performed one block of 32 practice trials before completing the 128 experimental trials.

Results

Only correct responses were included in the analysis of the RT data (94.1 % of the total trials in the experiment). These data were first submitted to a recursive outlier analysis (Van Selst & Jolicœur, 1994), which resulted in the elimination of 3.5 % of the data. Data are presented in Appendix N and in Figure 5, which depicts response times and confidence intervals, as well as percentage errors, for word targets as a function of Relatedness and Set Size. All confidence intervals were calculated in accordance with Loftus and Masson (1994). RT for word targets was assessed using a 2 x 4 ANOVA examining Relatedness (Related vs. Unrelated) and Set Size (1 vs. 3 vs. 5 vs. 7). There was no main effect of Relatedness, $F(1,31) = 1.27$, $MSE = 2180$, $p > .1$, or of Set Size, $F(3,93) = 1.00$, $MSE = 1545$, $p > .1$, nor was their a significant interaction between the effects of the two, $F(3,93) = 1.12$, $MSE = 1771$, $p > .1$. Statistical significance was also tested using the nonparametric measures of the Sign Test and the Wilcoxon Signed Ranks

Figure 5. Mean response times (in ms) with 95% confidence intervals (Loftus and Masson, 1994) and percentage error as a function of relatedness and set size in Experiment 3. The prime display duration was 100ms.



Test. Both tests were collapsed over Set Size. The Sign Test showed there to be a trend towards a relatedness effect with 20 subjects having a shorter response time for related trials than for unrelated trials, and 12 showing the reverse trend. This trend, however, was not statistically significant, $Z = 1.2$, $p = .22$. The Wilcoxon Signed Ranks Test was also not significant, $Z = 1.4$, $p = .15$.

Error data. The mean error rates for each condition are shown at the bottom of Figure 5 and in Appendix N. An ANOVA revealed neither significant main effects for Relatedness nor Set Size, nor was there a significant interaction between the two, all $Fs < 1$.

Mean RT for nonword data was 681 ms in the related condition and 683 in the unrelated condition. The overall mean error rate for nonwords was 6.3%.

Discussion

No priming was observed in this experiment, although, as can be seen from Figure 1 and from the nonparametric results, there was a trend towards a priming effect. Statistically, however, response times in the lexical decision task were no faster when the target letter string was identical to the word presented in the display, relative to when it was unrelated to the word in the display. Furthermore, there was no priming whether the word in the display was presented by itself, with two, four, or six nonword distractors. It appears that we can tentatively conclude that the word in the display did not undergo processing that could support priming. One potential criticism of this experiment is that the duration of the prime display was not long enough for processing to occur. However, there are numerous published studies reporting robust priming effects with briefly presented primes at fixation. Marcel first demonstrated that even when a prime is presented very briefly so that it is not subjectively detected, semantic priming can still be obtained (e.g., Marcel & Patterson, 1978; Marcel, 1983). Since then, several other studies have replicated this result with identity primes at prime durations far less than 100 ms (e.g., Bodner & Masson, 1997; Forster & Davis, 1984). Thus, in the present experiment, it seems that it is not the temporal duration of the prime that is insufficient to produce lexical processing but the spatial location of the prime.

However, to empirically test if priming would be yielded at longer display durations, we conducted a second experiment using a display duration of 200 ms. Increasing the prime display to durations greater than 200 ms would make interpreting the results difficult because of eye movements.

EXPERIMENT 4

Method

Participants

Thirty-two University of Waterloo undergraduate students took part in the experiment. All spoke English as their first language and all had normal or corrected-to-normal vision.

Design

The experiment consisted of a 4 (Set Size: 1 vs. 3 vs. 5 vs. 7) x 2 (Target Lexicality: Word vs. Nonword) x 2 (Prime Relation: Related vs. Unrelated) within-subjects design.

Procedure

The procedure was the same as that for Experiment 3 except that the display duration was increased from 100 ms (in Experiment 3) to 200 ms (in Experiment 4).

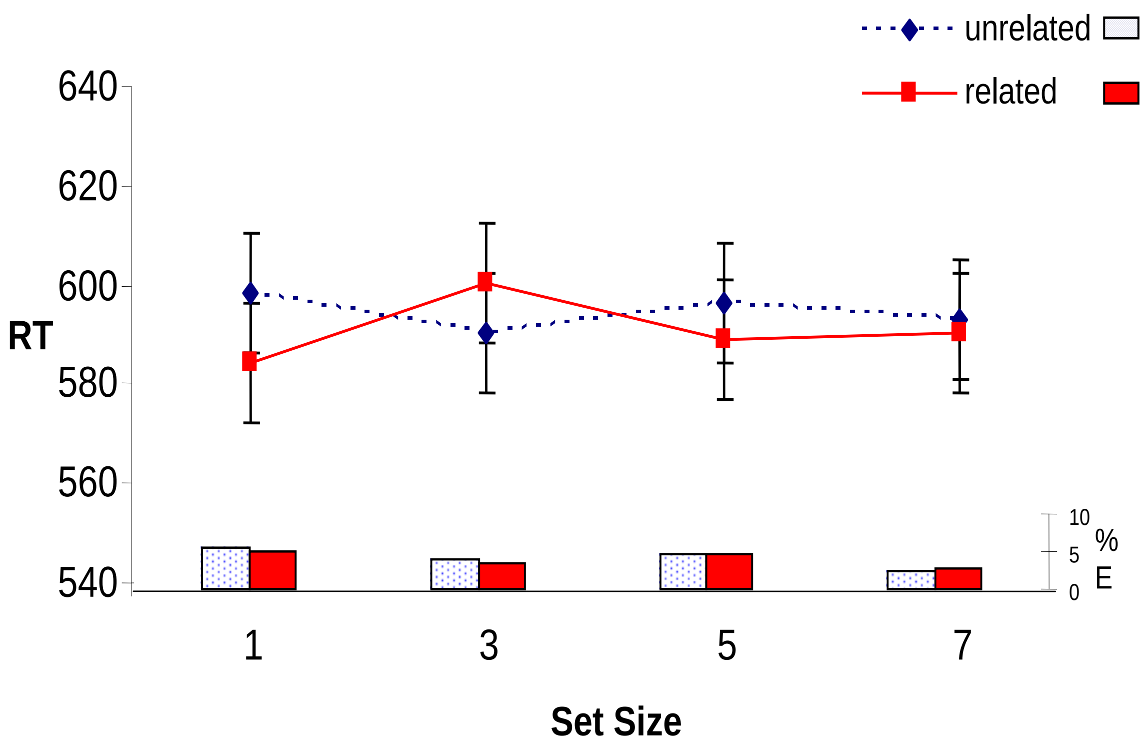
Results

Only correct responses were included in the analysis of the RT data (95.7 % of the total trials in the experiment). These data were first submitted to a recursive outlier analysis (Van Selst & Jolicœur, 1994), which resulted in the elimination of 2.7 % of the data. Data are presented in Appendix O and in Figure 6, which depicts response times and confidence intervals, as well as percentage errors, for the word targets as a function of Relatedness and Set Size. RT for word targets was assessed using a 2 x 4 ANOVA examining Relatedness (Related vs. Unrelated) and Set Size (1 vs. 3 vs. 5 vs. 7). There was no main effect of Relatedness, $F(1,31) < 1$, or Set Size, $F(3,93) < 1$, nor was there a significant interaction between the two, $F(3,93) = 1.49$, $MSE = 1120$, $p > .1$. Once again, the data were collapsed across Set Size and the Sign Test and the Wilcoxon Signed Ranks Test were computed. The Sign Test revealed that 17 subjects showed a faster response time for related trials than for unrelated trials, while 15 showed the reverse trend. This result was not significant, $Z < 1$. The Wilcoxon Signed Ranks Test was also not significant $Z < 1$.

Error data. The mean error rates for each condition are shown at the bottom of Figure 6 and in Appendix O. An ANOVA revealed no main effect for Relatedness $F(1,31) < 1$, nor Set Size $F(3,93) = 2.27$, $MSE = 40.5$, $p > .08$, nor was there a significant interaction between Relatedness and Set Size, $F(3,93) < 1$.

Mean RT for nonword data was 683 ms in the related condition and 677 in the unrelated condition. The overall mean error rate for nonwords was 4.5%.

Figure 6. Mean response times (in ms) with 95% confidence intervals (Loftus and Masson, 1994) and percentage error as a function of relatedness and set size in Experiment 4. The prime display duration was 200ms.



Discussion

The results of this experiment were consistent with the results of Experiment 3 in that no priming was observed. Furthermore, it was inconsequential whether the word in the display was presented by itself, with two, four, or six nonword distractors. There was simply no evidence that the word underwent sufficient processing to support priming.

Narrow focus of spatial attention

To interpret these results it is instructive to consider how and where spatial attention was allocated while the task was performed. If words require spatial attention to be processed, and there was no evidence that the words in the display underwent processing, then where were subjects allocating spatial attention? In other words, why did the word in the display not fall within the focus of spatial attention? One possibility is that subjects were focusing their attention narrowly upon the centre of the screen where the target was always presented. Support for the notion that attention can be narrowly focused upon a single location can be found within a number of studies (e.g., Eriksen & Yeh; 1985, Eriksen & St. James, 1986; Laberge, 1983; Theeuwes, 1991; Yantis & Jonides, 1990). For example, Eriksen et al. proposed a zoom lens account of spatial attention to accommodate the results of a number of spatial cueing studies. They argued that attentional resources can be uniformly distributed over the entire visual field or they can be highly focused upon one small location in space. Within this framework, there is a concomitant increase in processing power as the focus of attention contracts to smaller areas in the visual field. Thus, at a setting in which the entire visual field falls within the allocation of attention, there is little or no detailed processing of any single item. As the attentional focus constricts, there is a reciprocal increase in the amount of processing power that can be apportioned to any specific stimulus. Theeuwes (1991) also employed a spatial cuing paradigm to argue that when attention is narrowly focused upon a location, there is greater processing power. He found within a cuing task that absolute response latencies to identify a target were much smaller when participants could have employed a narrow focus of attention, relative to when they could not. We return later to the possibility that participants are narrowly focusing their attention upon one location.

Colouring the prime to facilitate priming

To act as a control condition, we sought to conduct an experiment in which a robust priming effect would be obtained. Drawing upon the visual search literature and our Experiment 2 results, we hypothesized that if we could make the word in the display visually "pop out" by making it a featural singleton then we would marshal bottom-up resources that would direct spatial attention to the location of the visually unique singleton (e.g., Bergen & Julesz, 1983, Bravo & Nakayama, 1992, Cave & Wolfe, 1990; Duncan & Humphreys, 1989; Hoffman, 1979; Joseph & Optican, 1996; Koch & Ulman, 1985; Nakayama & Joseph, 1988; Niebur, Koch, & Rosin, 1993; Northdurft, 1993; Theeuwes, 1992, 1994, 1996, 2006; Treisman, 1988; Treisman & Gelade, 1980; Wolfe, Cave, & Franzel, 1989). Thus, we coloured the prime word in the display red and conducted another experiment, the purpose of which was to guide attention to the prime and obtain a priming effect with our materials and procedure.

EXPERIMENT 5

Method

Participants

Sixty-four University of Waterloo undergraduate students took part in the experiment. All spoke English as their first language and all had normal or corrected-to-normal vision.

Design

The experiment consisted of a 4 (Set Size: 1 vs. 3 vs. 5 vs. 7) x 2 (Target Lexicality: Word vs. Nonword) x 2 (Prime Relation: Related vs. Unrelated) within-subjects design.

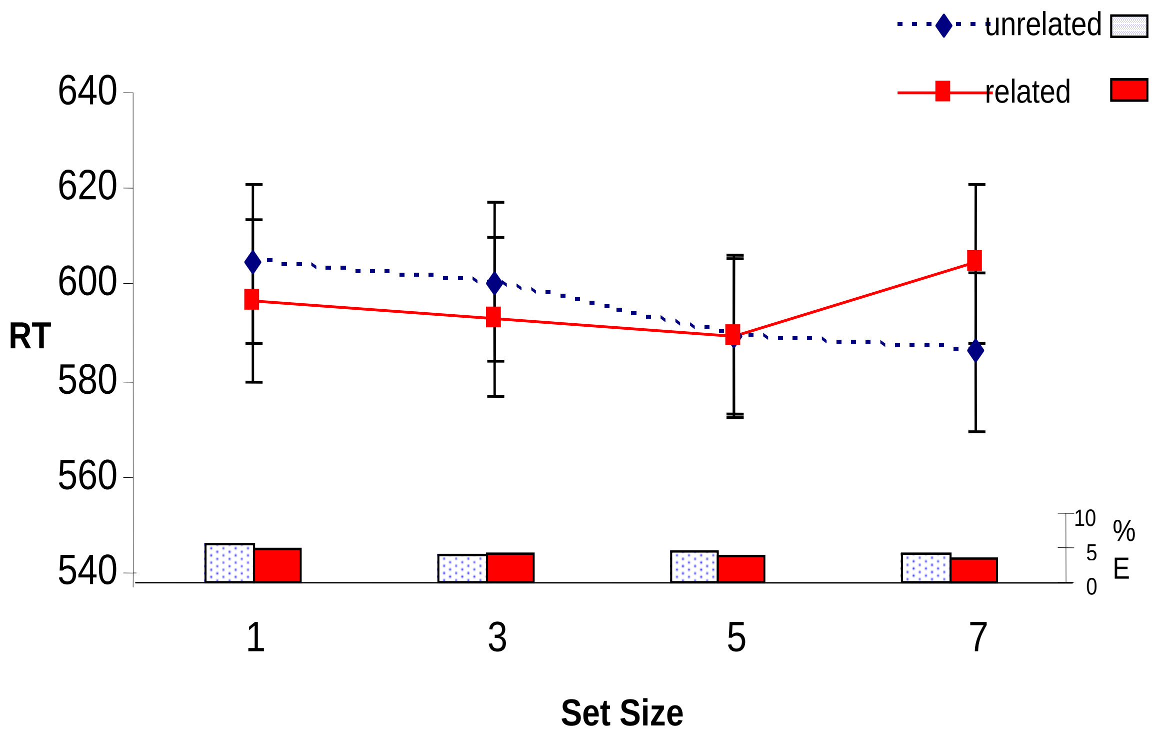
Procedure

The procedure was the same as that for Experiment 3 except that the word in the briefly presented display always appeared in red (red 72-point MEL system font). The remaining nonword items in the display were presented in white (white 72-point MEL system font).

Results

Only correct responses were included in the analysis of the RT data (95.2 % of the total trials in the experiment). These data were first submitted to a recursive outlier analysis (Van Selst & Jolicœur, 1994), which resulted in the elimination of 3.4 % of the data. Data are presented in Appendix P and in Figure 7, which depicts response times and confidence intervals, as well as percentage errors, for the word targets as a function of Relatedness and Set Size. RT for word targets was assessed using a 2 x 4 ANOVA examining Relatedness (Related vs. Unrelated) and Set Size (1 vs. 3 vs. 5 vs. 7). There was no main effect of Relatedness, $F(1,63) < 1$, or Set Size, $F(3,189) = 1.31$, $MSE = 2115$, $p > .1$, nor was there a significant interaction between the two, although this effect approached significance, $F(3,189) = 2.26$, $MSE = 2127$, $p > .08$. The reason that this

Figure 7. Mean response times (in ms) with 95% confidence intervals (Loftus and Masson, 1994) and percentage error as a function of relatedness and set size in Experiment 5. The prime display duration was 100ms and the word in the display was uniquely coloured.



interaction approaches significance appears to be because of the large crossover seen at Set Size 7, in which responses to unrelated targets were considerably faster than responses to related targets. We can think of no reason why responses to unrelated targets would be faster at large Set Sizes. However, to address the possibility that we were missing a Relatedness effect at small Set Sizes we performed post hoc paired sample t-tests for the Set Size of 1, $t(63) = 1.14$, $SEM = 6.94$, $p = .26$, and the Set Size of 3, $t(63) < 1$. As indicated by the results, response times to related trials were not faster, relative to unrelated trials, at small Set Sizes. Nonparametric tests were also conducted. The Sign Test revealed that 36 subjects showed a faster response time for related trials than for unrelated trials, while 28 showed the reverse trend. This result was not significant, $Z < 1$. The Wilcoxon Signed Ranks Test was also not significant $Z < 1$.

Error data. The mean error rates for each condition are shown at the bottom of Figure 7 and in Appendix P. An ANOVA revealed neither significant main effects for Relatedness nor Set Size, nor was there a significant interaction between the two, all *Fs* < 1.

Mean RT for nonword data was 676 ms in the related condition and 677 in the unrelated condition. The overall mean error rate for nonwords was 5.1%.

Discussion

Initially 32 participants were tested in this coloured prime condition, consistent with the number that were tested in the previous priming experiments. However, to our surprise, we still had no evidence of priming so to increase the power in this experiment we tested an additional 32 subjects. Even with 64 subjects no significant priming effect was observed. Once again, it was inconsequential whether the word in the display was presented by itself, with two, four, or six nonword distractors. It does not appear that the uniquely coloured word was processed sufficiently to support repetition priming. Before we comment further upon this result, we report another experiment in which the prime is conspicuously coloured red and the duration of the prime display is increased to 200 ms.

EXPERIMENT 6

Method

Participants

Thirty-two University of Waterloo undergraduate students took part in the experiment. All spoke English as their first language and all had normal or corrected-to-normal vision.

Design

The experiment consisted of a 4 (Set Size: 1 vs. 3 vs. 5 vs. 7) x 2 (Target Lexicality: Word vs. Nonword) x 2 (Prime Relation: Related vs. Unrelated) within-subjects design.

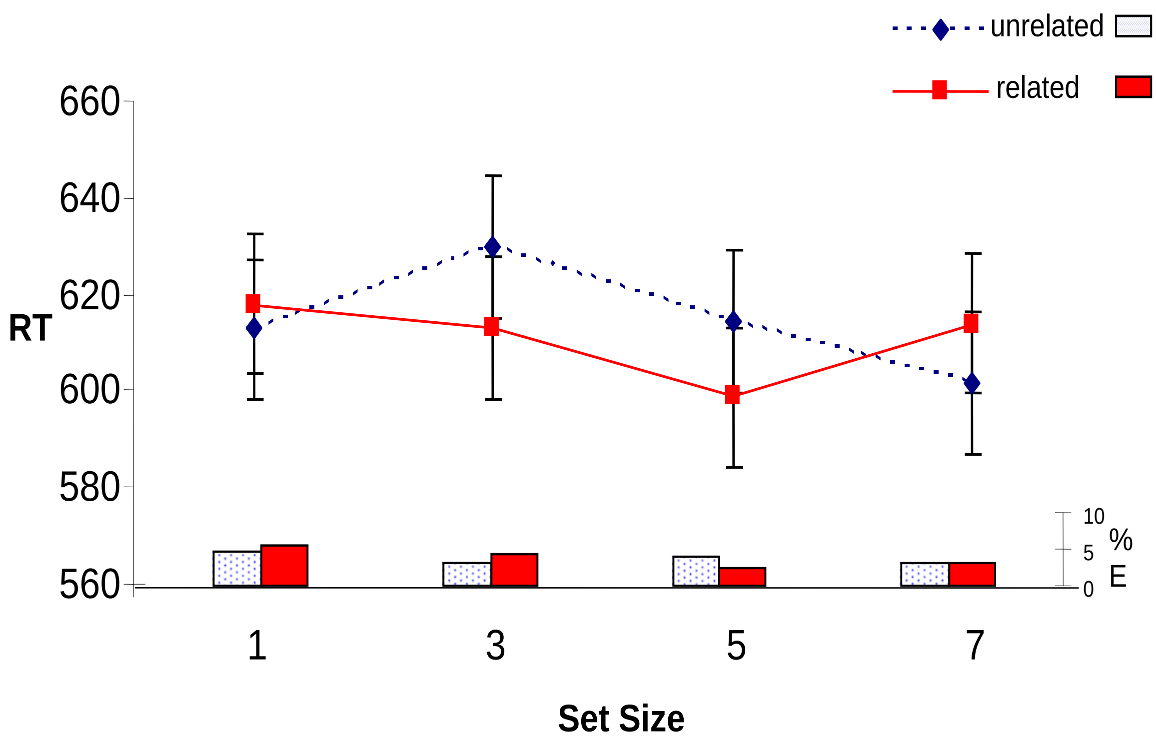
Procedure

The procedure was the same as that for Experiment 5 except that the display was presented for 200 ms.

Results

Only correct responses were included in the analysis of the RT data (94.1 % of the total trials in the experiment). These data were first submitted to a recursive outlier analysis (Van Selst & Jolicœur, 1994), which resulted in the elimination of 2.1 % of the data. Data are presented in Appendix Q and in Figure 8, which depicts response times and confidence intervals, as well as percentage errors, for the word targets as a function

Figure 8. Mean response times (in ms) with 95% confidence intervals (Loftus and Masson, 1994) and percentage error as a function of relatedness and set size in Experiment 6. The prime display duration was 200ms and the word in the display was uniquely coloured.



of Relatedness and Set Size. RT for word targets was assessed using a 2 x 4 ANOVA examining Relatedness (Related vs. Unrelated) and Set Size (1 vs. 3 vs. 5 vs. 7). There was no main effect of Relatedness, $F(1,31) < 1$, or Set Size, $F(3,93) = 1.6$, $MSE = 1916$, $p > .1$, nor was their a significant interaction between the two, $F(3,93) = 2.1$, $MSE = 1641$, $p > .1$. Nonparametric tests were also conducted. The Sign Test revealed that 17 subjects showed a faster response time for related trials than for unrelated trials, while 15 showed the reverse trend. This result was not significant, $Z < 1$. The Wilcoxon Signed Ranks Test was also not significant $Z < 1$.

Error data. The mean error rates for each condition are shown at the bottom of Figure 8 and in Appendix Q. An ANOVA revealed neither significant main effects for Relatedness nor Set Size, nor was there a significant interaction between the two, all $Fs < 1.5$, $p > .2$.

Mean RT for nonword data was 695 ms in both related condition unrelated conditions. The overall mean error rate for nonwords was 8.3%.

Discussion

The results of Experiment 6 were consistent with Experiment 5 in that no priming was observed. Once again, it appears that colouring the prime word in the display fails to attract the attentional resources necessary to process the identity of the colour carrier.

Interpreting the four priming experiments

First, and most relevant to the present study, the results of Experiments 5 and 6, in conjunction with the previous experiments, strongly undermine a late selection account of how words are processed. It appears that when spatial attention is not focused upon the prime word in the display, no lexical processing occurs. Had priming been evident, independent of set size and independent of the colour of the prime word in the display, then that would have constituted strong evidence that items in the display were processed in parallel. Given that such a result was not obtained, there is no evidence for parallel processing. Priming was not even obtained at set sizes of one or when the prime was a featural singleton. The results appear unequivocal. Words are not processed in a display without the allocation of spatial attention.

Colouring the prime does not facilitate priming

It appears that colouring a word in a display does not draw the necessary attentional resources to the colour carrier so that it can be subsequently processed. Ostensibly, this contrasts with Experiment 2, which showed that colouring the word in the display was an effective means to direct attention to the salient item in the display, as evidenced by efficient search slopes. However, one important difference is that in Experiment 2, subjects were instructed to attend to the red item in order to perform the task. In Experiments 5 and 6 there was no such goal-oriented protocol. This suggests that without the support of top-down influences, bottom-up influences, such as colour, may be unable to marshal the attentional resources necessary to meaningful processes the identity of the colour carrier. Previous studies that have examined whether attention is drawn involuntarily to featural singletons in other types of tasks have had conflicting results (e.g., see Jonides & Yantis, 1988; Folk & Annett, 1994; Hillstrom & Yantis, 1994; Todd & Kramer, 1994; Pashler, 1988; Theewes, 1991, 1992, 2006; Joseph & Optican, 1996).

Subjects in Experiments 5 and 6 were informally asked several questions after completing the task. One of the questions was, “Did you notice a red item in the display?" All of the subjects answered yes to this question. It is interesting that despite the fact that subjects did not process the identity of the colour carrier, they were subjectively aware that there was a red item present in the display. This is precisely what Broadbent might have predicted nearly fifty years ago. He argued that only gross features of items may permeate the attentional filter. Thus, whereas the registration of gross characteristics such as colour are processed outside of spatial attention, other information that is semantic in nature, such as the identity of a word, is not processed.

Chapter 4: Implicit Visual Search with a Broadened Attentional Focus

Although the present results strongly question a late selection account of word processing, researchers typically do not feel comfortable hanging their cognitive hats upon null results. For the results to be truly compelling it would be preferable to modify the experiment in such a way as to maintain the integrity of the paradigm but, at the same time, yield a significant result. For example, if we could show participants the same brief prime display, but, just by altering how participants apply their spatial attention, produce a significant priming effect, then that would be a truly compelling argument for the necessity of spatial attention in word processing.

In other words, we want to induce an alternative mental set within participants as they perform the task. The role of mental set has been discussed in psychology journals for a century. Gibson (1941) defined mental set as, “the state of preparedness determined by a person’s context.” It has long been known that behavioural responses to local stimuli are impacted, not just by the stimuli themselves, but by goal-directed or top-down processes. How people perceive stimuli is dependent upon participant goals, instructions, motivations, experiences, expectations, etc. The phenomena of change blindness (e.g., Rensink, 2000; Simons & Levin, 1997) and context effects (e.g., Biederman, Glass, & Stacy, 1973; Friedman, 1979) are well documented examples of how top-down processes affect the way in which stimuli are processed.

Relatively recently, however, researchers have demonstrated that even putatively automatic processes are not exempt from the influences of mental set. Historically, certain stimuli have been thought to draw attention reflexively, independent of conscious intent. One example in the spatial attention literature is the use of abrupt onset cues. The advent of the spatial cueing paradigm (e.g., Posner, 1980; Jonides, 1981) effectively led researchers to believe that one of the properties of abrupt onsets is that they result in involuntary stimulus-driven shifts of attention. In these spatial cuing tasks, subjects responded to a target presented on the left or right of fixation. The target was preceded by a cue, which was presented very briefly at the location of the target (valid cue condition) or at the alternative location (invalid cue condition). Results consistently demonstrated that for valid cues, there was a benefit in response time, but for invalid cues there was a cost. This held true regardless of the percentage of time that the cue was valid or invalid. Thus, these attentional shifts were labeled as exogenous and automatic because they were seemingly outside the attentional control of participants (e.g., Posner, 1980; Jonides, 1981).

Visual search studies also offered evidence consistent with the claim that abrupt onsets lead to automatic shifts of attention. For example, Yantis and Jonides (1984, 1988) presented abrupt onsets in search displays and showed that when the target itself was an abrupt onset, response times were very efficient. This, again, suggested that attention was immediately deployed to the location of the abrupt onset item.

However, Folk, Remington, and Johnston (1992) challenged the view that attention could be captured outside of the control of top-down processes. They argued that even involuntary attentional capture (or as they referred to it, *exogenous attention orientation*) was contingent upon mental set. They pointed to a confound in the existing spatial cuing literature whereby the targets always shared a critical property with the cue. They argued that because participants were *set* to respond to the target, other stimuli, such as cues, sharing critical properties with the target would be attended because of goal-driven behaviour. For example, in a typical spatial cuing task, both the targets and the cues appear as abrupt onsets. If the participant has the mental set to respond to the dynamic luminance change of an upcoming target then the abrupt onset of the cue will capture attention. Folk et al. tested their hypothesis by using stimulus properties of colour and abrupt onsets for both cues and targets. They found that when participants were set to respond to a target based on the defining characteristic of colour, abrupt onset cues did not capture attention, whereas colour cues did capture attention. Conversely, when the participant was set to respond to a target based on the defining characteristic of an abrupt onset, abrupt onset cues captured attention, whereas colour cues did not. This result supported their hypothesis that exogenous attention orientation was contingent upon top-down processes rather than being solely a function of stimulus properties. Subsequent studies have supported this hypothesis (e.g., Folk & Annett, 1994, Folk & Remington, 1998, 2006; Folk, Remington, & Wright, 1994; Yantis & Egeth, 1999).

Other stimulus properties have also been reputed to orient attention reflexively. Some researchers have argued that featural singletons attract attention in a strictly bottom-up manner (e.g., Bergen & Julesz, 1983, Bravo & Nakayama, 1992, Cave & Wolfe, 1990; Duncan & Humphreys, 1989; Hoffman, 1979; Joseph & Optican, 1996; Koch & Ulman, 1985; Nakayama & Joseph, 1988; Niebur, Koch, & Rosin, 1993; Northdurft, 1993; Theeuwes, 1991, 1992, 1994, 2006; Wolfe, Cave, & Franzel, 1989). However, other studies have provided evidence suggesting that this may not be the case (e.g., Folk & Annett, 1994; Folk & Remington, 2006; Hillstrom & Yantis, 1994; Jonides and Yantis, 1988; Todd & Kramer, 1994). Indeed, Experiments 5 and 6 of the present study suggest that colour singletons do not involuntary capture attention. If they did capture attention in a strictly stimulus-driven manner we would expect to see a significant priming effect.

Finally, other cognitive tasks that have been presumed to engage automatic processes have also been shown to be contingent upon mental set. For example, Bauer and Besner (1997) demonstrated the effects of top-down processing in a variant of the Stroop effect. The Stroop effect has long been a bulwark for those arguing that there exists stimulus-driven automatic processes. Bauer and Besner showed that whether or not a Stroop effect was observed depended on the task instructions given to the participants.

In sum, how one processes stimuli is impacted to a large extent by mental set. Thus, it may be possible to change the mental set of participants and subsequently encourage them to process the search displays differently. Specifically, we want to see if we can induce participants to process words that were previously unprocessed.

EXPERIMENT 7

The purpose of the following experiment was to attempt to change how participants allocate their spatial attention when viewing the prime display. The previous null results of Experiments 3 to 6 were particularly interesting given that they persisted even when the prime word in the display was coloured and when the display size was one. As mentioned earlier, one explanation is that attention was focused solely on the centre of the screen throughout the task. This suggests that the letter strings in the display were presented outside of this narrow focus and, accordingly, were not processed. In contrast to the visual search experiments (i.e., Experiments 1 and 2), in all of the priming experiments up to this point, participants were never required to move spatial attention throughout the display to perform the task. The fixation symbol appeared at the beginning of a trial, the display appeared, and then the target word, which required a response, appeared at fixation. Thus, the task relevant information was always at fixation and there was never a need for subjects to allocate spatial attention to any other location.

Therefore, for the next experiment, we sought to prevent participants from focusing attention exclusively upon a single location in space. Instead, subjects were encouraged to expand their spatial attention to include a broader area. This was accomplished by moving the location of the *target* letter string from trial to trial. Importantly, the prime display was presented exactly as it was presented in the previous experiments. By moving the location of the target, subjects could no longer complete the task by focusing attention solely at fixation. Rather, they would need to broaden their application of spatial attention to incorporate all possible locations for the target. Our hypothesis was that this would also broaden the extent to which locations in the prime display would be processed. Therefore, our prediction was that areas of the prime display that were previously unattended would now be attended, and that furthermore, this increase in the suffusion of spatial attention would lead to a significant priming effect.

Method

Participants

Thirty-two University of Waterloo undergraduate students took part in the experiment. All spoke English as their first language and all had normal or corrected-to-normal vision.

Design

The experiment consisted of a 4 (Set Size: 1 vs. 3 vs. 5 vs. 7) x 2 (Target Lexicality: Word vs. Nonword) x 2 (Prime Relation: Related vs. Unrelated) within-subjects design.

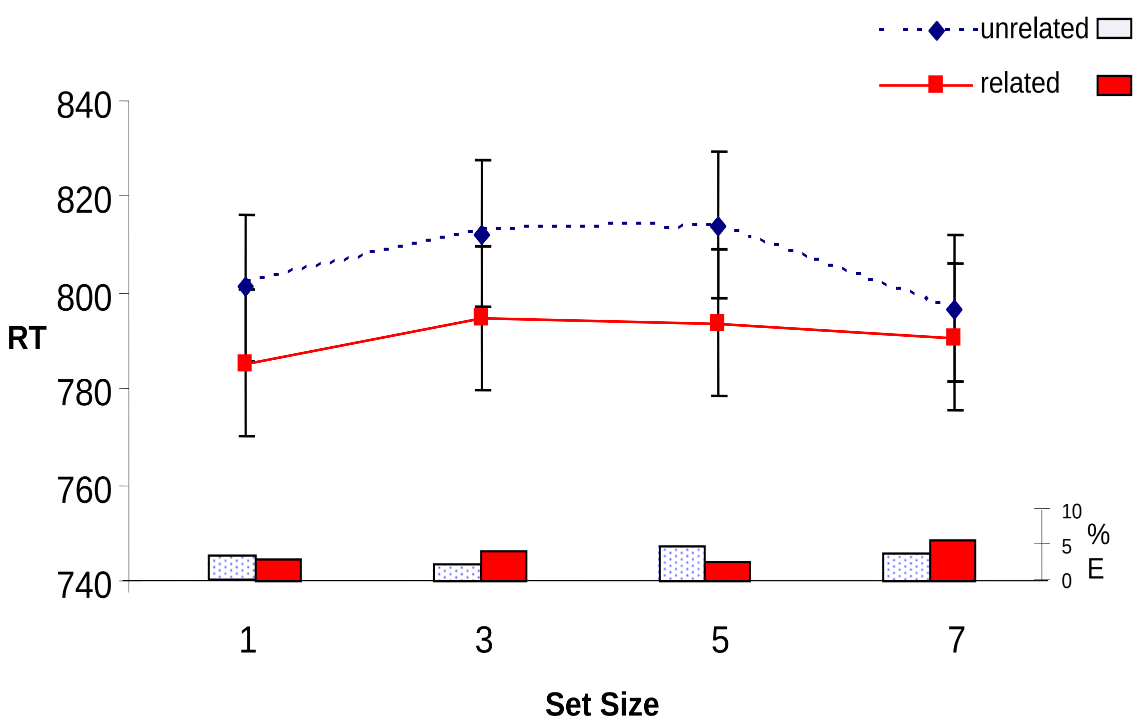
Procedure

The procedure was the same as that for Experiment 6 except for the following. Following the offset of the prime display, the target letter string appeared at one of four locations, rather than at fixation. The four possible locations formed "a square" around fixation, such that each was 3 degrees of visual angle from fixation. The target was equally likely to be presented in any of the four locations.

Results

Only correct responses were included in the analysis of the RT data (95.5 % of the total trials in the experiment). These data were first submitted to a recursive outlier analysis (Van Selst & Jolicœur, 1994), which resulted in the elimination of 2.5 % of the data. Data are presented in Appendix R and in Figure 9, which depicts response times and confidence intervals, as well as percentage errors, for the word targets as a function of Relatedness and Set Size. RT for word targets was assessed using a 2 x 4 ANOVA examining Relatedness (Related vs. Unrelated) and Set Size (1 vs. 3 vs. 5 vs. 7). There was a significant main effect of Relatedness, $F(1, 31) = 4.73$, $MSE = 3055$, $p < .05$. There was no main effect of Set Size, $F(3, 93) = 1.12$, $MSE = 2015$, $p > .1$, nor was their a significant interaction between the two, $F(3, 93) < 1$. Nonparametric tests also yielded significant results. The Sign Test revealed that 22 subjects showed a faster response time for related trials than for unrelated trials, while 10 showed the reverse trend. This result

Figure 9. Mean response times (in ms) with 95% confidence intervals (Loftus and Masson, 1994) and percentage error as a function of relatedness and set size in Experiment 7. The prime display duration was 200ms and the word in the display was uniquely coloured. The target location was spatially uncertain.



was significant, $Z = 2.0$, $p = .05$. The Wilcoxon Signed Ranks Test was also significant $Z = 2.0$, $p < .05$.

Error data. The mean error rates for each condition are shown at the bottom of Figure 9 and in Appendix R. An ANOVA revealed neither significant main effects for Relatedness nor Set Size, nor was there a significant interaction between the two, all $Fs < 1.4$, $p > .2$.

Mean RT for nonword data was 882 ms in the related condition and 885 in the unrelated condition. The overall mean error rate for nonwords was 5.2%.

Discussion

A significant priming effect was observed in Experiment 7. By moving the location of the target from trial to trial, subjects could not complete the task by narrowly focusing attention upon one location in space. Rather, they needed to broaden the focus of their spatial attention so that they could aptly process the target letter string when it appeared in one of the four possible locations. By broadening the aperture of their focus to include possible locations for the upcoming target, areas of the prime display were also processed, which resulted in a significant priming effect.

This result highlights the important role that mental set plays in processing words. It also underscores the fact that whether or not words are processed does not depend exclusively on bottom-up stimulus-driven processes. In the present context one critical aspect of top-down control appears to be how participants allocate attention to spatial locations in the visual display. Before further discussion, a follow-up experiment is reported. The purpose of this experiment is to assess whether priming will persist when the location of the target letter string is uncertain but the prime word is not coloured.

EXPERIMENT 8

It is plausable that the priming effect obtained in Experiment 7 was a result of the conjunction of two factors: the target being moved; and the prime word being coloured. We tested this possibility by not colouring the prime word in the display but still moving the target from trial to trial. If a significant priming effect is again observed, then it seems reasonable to conclude that moving the target facilitates processing of the word in the search display.

Method

Participants

Thirty-two University of Waterloo undergraduate students took part in the experiment. All spoke English as their first language and all had normal or corrected-to-normal vision.

Design

The experiment consisted of a 4 (Set Size: 1 vs. 3 vs. 5 vs. 7) x 2 (Target Lexicality: Word vs. Nonword) x 2 (Prime Relation: Related vs. Unrelated) within-subjects design.

Procedure

The procedure was the same as that for Experiment 7 except that the prime word in the display was presented in the same white font (white 72-point MEL system font) in which the other letter strings were presented.

Results

Only correct responses were included in the analysis of the RT data (94.8 % of the total trials in the experiment). These data were first submitted to a recursive outlier analysis (Van Selst & Jolicœur, 1994), which resulted in the elimination of 2.3 % of the data. Data are presented in Appendix S and in Figure 10, which depicts response times with confidence intervals, and percentage errors, for the word targets as a function of Relatedness and Set Size. RT for word targets was assessed using a 2 x 4 ANOVA examining Relatedness (Related vs. Unrelated) and Set Size (1 vs. 3 vs. 5 vs. 7). There was a significant main effect of Relatedness, $F(1,31) = 5.18$, $MSE = 1909$, $p < .05$. There was no main effect of Set Size, $F(3,93) = 1.09$, $MSE = 2048$, $p > .1$, nor was there a significant interaction between the two, $F(3,93) < 1$. Nonparametric tests were also conducted. The Sign Test revealed that 21 subjects showed a faster response time for related trials than for unrelated trials, while 11 showed the reverse trend. Although there was a trend towards significance (one more subject was required to show a significant priming effect) the test was not significant, $Z = 1.6$, $p > .05$. The Wilcoxon Signed Ranks Test, however, did yield a significant result, $Z = 2.2$, $p < .05$.

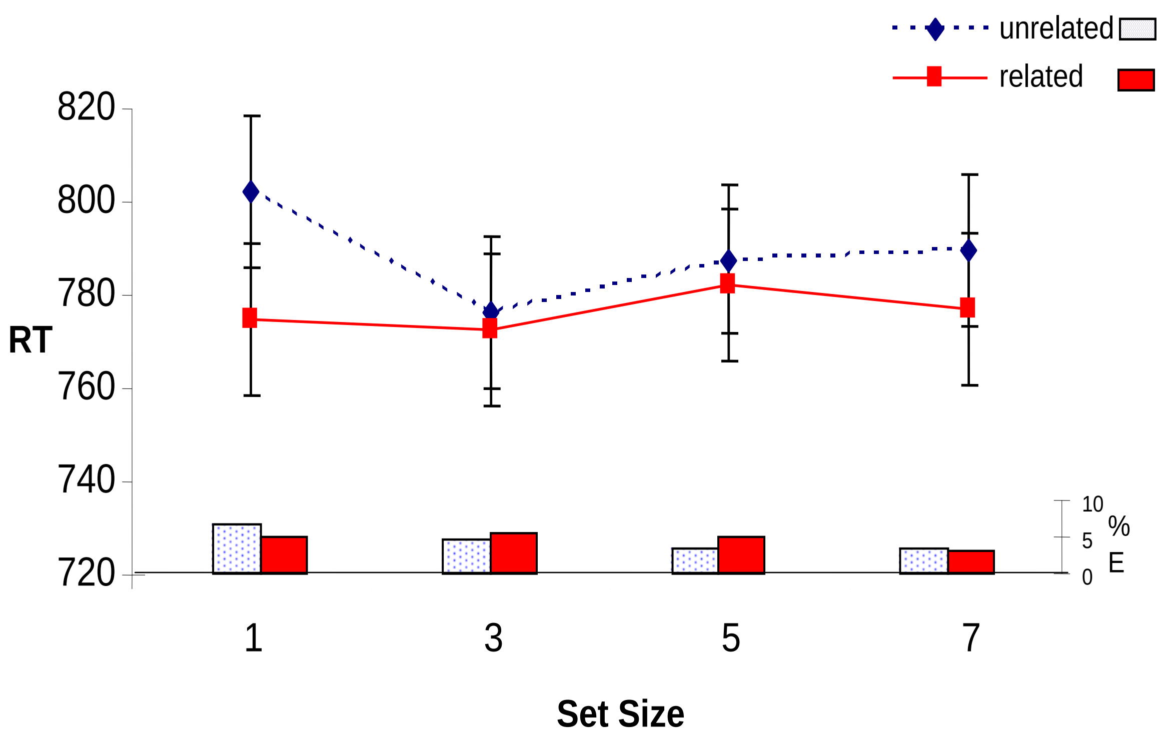
Error data. The mean error rates for each condition are shown at the bottom of Figure 10. An ANOVA revealed neither significant main effects for relatedness nor Set Size, nor was there a significant interaction between the two, all $Fs < 1.5$, $p > .2$.

Mean RT for nonword data was 864 ms in the related condition and 866 in the unrelated condition. The overall mean error rate for nonwords was 5.7%.

Discussion

The results of Experiment 8 were consistent with Experiment 7 in that, overall, the pattern of results is consistent with a significant priming effect. The prime word in the display was presented in the same colour as the other letter strings in the display, therefore, once again, colour does not appear to be a factor in facilitating priming.

Figure 10. Mean response times (in ms) with 95% confidence intervals (Loftus and Masson, 1994) and percentage error as a function of relatedness and set size in Experiment 8. The prime display duration was 200ms and the word in the display was not uniquely coloured. The target location was spatially uncertain.



Regardless of whether the prime word was coloured or not, priming only occurred when the target location was moved. This result underscores the critical role that spatial attention plays in processing words. When spatial attention is applied more diffusely, areas of the prime display, which were previously unprocessed, now undergo processing.

Chapter 5: General Discussion

A series of experiments investigated word recognition within the context of visual search. The goal was to address whether spatial attention must be brought to bear upon a word before it is processed to the level of meaning. Two competing accounts make different predictions about the role of spatial attention in word processing. Late selection accounts assert that spatial attention is not required to identify words because stimulus identification occurs in parallel prior to attentional selection. In contrast, early selection accounts contend that spatial attention must be focused upon a word before it undergoes processing.

Both explicit and implicit measures were used to assess whether spatial attention is a prerequisite for word processing. In the explicit search task, subjects searched a display and indicated whether a word was present or absent among nonword distractors. Search slopes increased linearly as a function of set size for all three types of nonword distractors, consistent with a strategy of serial search. In addition search slopes became steeper as distractor similarity increased, suggesting, once again, that subjects moved attention from item to item as they made present/absent discriminations.

In contrast, when the word in the display was coloured (or a nonword was coloured on a word absent trial), search slopes were very efficient and did not differ across Distractor Type. Colouring the target successfully directed attention to the task relevant item. Taken together, the results from these explicit search tasks support an early selection account of reading.

Another set of experiments was conducted in which explicit recognition was not required to measure lexical processing. This was to address the possibility that in the explicit search task the items were processed in parallel, leading to lexical activation, but that this activation was not indexed using the explicit task. In the implicit task subjects viewed the same search displays that were used in the explicit task, however, the displays were presented briefly and were followed by a single letter string to which subjects performed a lexical decision. When the letter string was a word, half of the time it was the same word that was presented in the display.

In Experiments 3 through 6, no priming was evident. We can therefore only infer that there was no processing of the prime word in the display. In Experiments 7 and 8, when task demands changed so that spatial attention was more diffusely allocated, a significant priming effect was finally observed.

Using a spotlight metaphor to clarify the role of spatial attention

To borrow Posner's (1980) metaphoric spotlight, Experiments 3 through 8 suggest that the attentional beam can be strategically broadened and narrowed. For example, Experiments 3 through 6 were consistent with the idea that participants' attentional beam was narrowly directed upon the centre of the display. The reason that participants allocated their spatial attention in this way was because all of the information necessary to efficiently perform the task was presented at fixation. Thus, task demands allowed for a narrow attentional spotlight. Outside of this spotlight, words were not sufficiently processed to support priming, as evidenced by the fact that there was no difference in response latencies to identity targets, relative to unrelated targets.

However, in Experiments 7 and 8, the attentional spotlight was distributed more diffusely in visual space. The reason for this was because participants were no longer able to perform the task by narrowly focusing an attentional beam at fixation. The target was moved from trial to trial, which encouraged subjects to attend to a greater spatial area. Thus, subjects strategically expanded their attentional spotlights to cover a greater area in visual space. Accordingly, words in the prime display were also within this increased attentional suffusion and underwent processing.

As mentioned, this notion of an expanding and contracting attentional spotlight was proposed by Eriksen (e.g., Eriksen & St. James, 1986; Eriksen & Yeh, 1985), who likened spatial attention to a zoom lens. How apt a description the spotlight metaphor actually is remains to be seen, nonetheless, our results are consistent with an allegorical broadening and narrowing beam.

Using attentional capture to explain the results

The present results could also be interpreted within a framework that need not appeal to a dynamic spotlight that expands and contracts. For example, previous experiments that have employed abrupt onsets as cues have demonstrated that, at least in some cases, attention is captured by the abrupt onset (e.g., Jonides, 1981; Posner, 1980; Theeuwes, 1994; Yantis & Jonides, 1984, 1988). As mentioned, Folk et al. (1992) argued that attentional capture only occurs when targets are abrupt onsets themselves. Yantis and Jonides (1990) and Theeuwes (1991) demonstrated another condition in which the attentional capture of abrupt onsets in eliminated. They showed that when the location of the upcoming target was known for certain peripheral abrupt onsets had no distracting effect. Given this literature, one could couch the present results within an attentional capture account rather than within a spotlight account.

For example, the letter strings in our prime display could be considered to be abrupt onset stimuli themselves. Typically rectangular bars are used as abrupt onset cues, however, it is easy to see that a word or a letter string that is presented as an onset in a display shares the same dynamic luminance characteristic. For the purposes of illustration, consider first the condition where set size is one. In this condition, a single word is presented in the prime display, after which a target is presented. The question is, did the prime word capture attention, and subsequently lead to processing of that prime word? In Experiments 3 to 6, the extant spatial cueing literature would predict that no priming should occur. This is because with spatial certainty of the target location, the distracting prime onsets should not draw attention and thus no processing of the prime word should occur, which is consistent with the present results.

Alternatively, in Experiments 7 and 8, the spatial cuing literature would predict priming. This is because without spatial certainty of the target location, the distracting prime onsets should draw attention and hence lead to processing of the prime word. Note that the target in the experiments was also an abrupt onset, which eschews Folk et al.'s (1992) caveat that attentional capture of abrupt onsets only occurs when the target and the prime share dynamic luminance change characteristics.

Interpreting the results within this attentional capture framework becomes muddied, however, when set sizes other than one are considered. For example, when three, five, or seven onsets are presented in the prime display how does attentional capture occur? Is spatial attention apportioned equivalently between all of the letter strings or is one item in the display preferential selected? If the latter is true, what mechanism facilitates this selection? These types of questions may be explored in the future. One critical point, however, is that whether one interprets the present results within an attentional capture framework or a dynamic spotlight framework, in both cases attention is a requisite for processing words.

How does colouring a word in a display affect processing of that word?

It appears that when top-down influences are recruited to process the identity of a uniquely coloured word in a display, the colour facilitates identification because the word can be located quickly in visual space. Subsequently, spatial attention is allocated to the coloured word, after which processing may commence. However, when a coloured word is presented in a display and top-down influences are not recruited to process its identity because the featural singleton is not relevant to the task, then it appears that no lexical processing of the colour carrier occurs. Bottom-up influences alone appear to be insufficient to marshal the attentional resources necessary for lexical processing. This result is highlighted by Experiments 5 and 6, which showed that colouring the prime word in the display did not facilitate priming.

This result, therefore, addresses a broader issue of whether attention is controlled by top-down goal-oriented behaviour or bottom-up stimulus-driven processes. According to a number of authors (e.g., Broadbent, 1958; Egeth, 1977; Neisser, 1967; Treisman, 1988; Treisman & Gelade, 1980), preattentive processes segment the visual field into perceptual units based upon features such as colour, shape, and size. It is assumed that this preattentive segmentation occurs in parallel and is not constrained by capacity limitations. However, at question is how the limited capacity attention that follows is apportioned to the segmented items. Is the allocation of this second type of attention goal-driven or stimulus-driven? For example, do featural singletons involuntarily attract the limited capacity attention necessary for meaningful processing? The present results suggest not. However, as mentioned above, results from other studies have been mixed (e.g., Jonides & Yantis, 1988; Folk & Annett, 1994; Hillstrom and Yantis, 1994, Todd & Kramer, 1994; Pashler, 1988; Theewes, 1991, 1992, Joseph & Optican, 1996). Whether featural singletons in a display receive processing beyond gross characteristics may well be contingent upon mental set. As mentioned, the role of mental set has been shown to have a much greater influence upon attentional control then was previously thought.

Thus, in the present study, it may have been the case that the identity of the coloured items in the display were not meaningfully processed because the featural characteristic of colour was not relevant to the task. In other words, colour was not salient to target response. This interpretation is consistent with Folk et al.'s (1992) contingent involuntary orienting hypothersis, which ascribes attentional capture to top-down control settings. This account would predict that had colour been relevant to the target, then the red primes in the display would have captured attention and hence, led to processing of the prime word. This, however, is an empirical question that could be addressed in a future study.

How does mental set affect word processing in the present context?

As mentioned above, mental set could influence whether or not a word is processed depending on whether the cognitive system is configured to allow attention to be guided to the word. In the above example, the very specific case of a coloured word undergoing processing may well be contingent on whether control settings are set to attend to the characteristic of colour. However, there is, perhaps, a more general role for mental set in word processing – namely, how attention is allocated within visual space.

We have argued that in Experiments 3 to 6, participants focused their spatial attention narrowly upon one location in the display. The results are consistent with the conclusion that when words are outside of this attentional focus they are not processed. We have also argued that in Experiments 7 and 8 participants broadened their attentional focus to incorporate a greater area of visual space. This broadening of attentional resources led to meaningful processing of stimuli in the display. This capability to vary the focus of attention from a diffuse distribution to a highly focused concentration can be viewed as a faculty of mental set. Top-down control settings may change how attention is directed within visual space as a function of task demands. When the location of the target stimulus is unknown, control settings focus attention in a relatively distributed manner incorporating possible target locations. Accordingly, more of the visual field is meaningfully processed.

In contrast, when the stimulus that requires a response (i.e., the target) is continually presented at one location, control settings direct highly focused attentional resources upon that location. The reason for this narrow focus may be twofold. First, distracting stimuli outside the suffusion of the attentional focus are not meaningfully processed, which expedites the task of responding to the target. Second, as suggested by Eriksen et al. (1985, 1986), when attention is narrowly allocated, there is a concomitant increase in processing power.

In sum, it appears that how attention is allocated is based upon strategic control settings. Whether words undergo processing is contingent upon top-down manipulations of these control settings.

How does mental set arise?

One interesting question concerning the present study is, how does mental set come into being? The literature tends to functionally dichotomized behaviour as arising from either bottom-up or top-down processes. For example, as mentioned previously, abrupt onsets were, at one point, considered to cause involuntary shifts of attention. The language that has been used to describe *involuntary responses* has included the terms *reflexive, bottom-up, stimulus-driven, automatic,* and *exogenous*. These terms are often used interchangeably. Folk et al. (1992) demonstrated that such shifts in attention were not involuntary but rather contingent upon mental set. The language that has been used to describe *voluntary responses* has included the terms *top-down, goal-oriented, nonautomatic, endogenous,* and *strategic*. These terms are also often used interchangeably. In Folk et al.'s study the task instructions and, accordingly, the goals of the observer changed in the experiment, and accordingly, there was a commensurate change in orienting behaviour based on these goals of the observer. For example, when the goal of the participant was to respond to a coloured target, only the coloured cue interfered, whereas when the goal of the participant was to respond to an abrupt onset target, only the abrupt onset cues attracted attention.

An interesting distinction in how mental set was employed in our study was that the goal did not change across Experiments 3 to 8. In all of these experiments the goal of the participant was to respond to whether the target was a word or not. Despite the fact that the goal remained the same across these experiments, the results differed in the last two experiments. Therefore we can infer that something changed (e.g., we have argued that participants applied their attention more diffusely in Experiments 7 and 8). One may argue that the mental set of the participants changed in Experiments 7 and 8 but it is important to note that of the terms above – *top-down, goal-oriented, nonautomatic, endogenous, strategic* – not all are appropriate. This is more than a point of semantics but an issue of how mental set arises and the relation between top-down and bottom-up influences. For example, one could make an argument that the change that occurred between Experiments 3 to 6 and Experiments 7 and 8, was, in fact, stimulus driven! This is because how the stimulus was displayed changed in the latter two experiments, whereas the goals of the participants remained the same. Hence, any of the terms, *involuntary, reflexive, bottom-up, automatic, exogenous* might be aptly applied.

It appears that the change in the manner in which the stimulus was presented led to a change in how the cognitive system was configured. This highlights the intricate relation between bottom-up and top-down processes. From a systemic point of view we are a part of our environment with which we interact. Thus, it appears reasonable that there is a constant blending of top-down and bottom-up processes, one influencing the other in a continual pattern that may blur defining them as distinct. Answering whether or not a response is primarily the result of top-down or bottom-up processes may be tantamount to answering the question about the chicken and the egg. Unfortunately, such an argument is not helpful for understanding how cognitive processes come about and may be more relevant to a discussion on determinism. Nonetheless, it is constructive to bear in mind the potential problems of viewing the cognitive system as distinct from its environment.

Words are not processed independently of attentional resources

Finally, one might question the utility of these experiments given the large body of literature on Stroop dilution (e.g., Kahneman & Chajczyk, 1983). That is, based upon the evidence from experiments using Stroop dilution, it is already known that words are not processed independent of available resources. One difficulty with this assessment is that the present study differs in many ways from studies involving Stroop dilution, though it is true that that they both employ implicit means to examine word processing.

In a typical Stroop dilution experiment a colour patch appears at fixation and a colour-word is presented nearby. Critically, the size of the Stroop effect is reduced when a neutral word is also added to the display. Kahneman and Chajczyk argued that lexical processing is therefore subject to capacity limitations, a very strong implication for early selection. However, others have challenged this interpretation, claiming that neutral flanking items interfere with colour-word distractors prior to lexical processing (e.g., Brown, Ross-Gilbert, & Carr, 1995; Brown, Gore, & Carr, 2002). The argument is that because processing of letterstrings occurs in parallel, activation of the colour-word at the feature-level is attenuated as a result of competition from feature-level activation of the neutral item. Brown et al. (1995) demonstrated that even distractors made from characters from the top of the keyboard reduce the Stroop effect. Thus, they argued that Stroop dilution does not undermine the automaticity of lexical activation per se, but rather shows that the effects of Stroop dilution occur prior and external to word processing mechanisms (but see Roberts & Besner, 2005).

In the present set of experiments, we demonstrated that items in the display are processed sufficiently to support priming in Experiments 7 and 8, but not in Experiments

3 to 6. In both cases, feature-level competition for the prime is identical, indicating that, in the present context, the degree to which words are processed cannot simply be a matter of attenuated processing of the prime's features. Rather, one needs to also consider 1) how spatial attention modulates the processing of words, and 2) how mental set modulates the deployment of attention.

Conclusion

The present study provides strong evidence that without application of spatial attention, words are not processed. In the context of visual search, both explicit and implicit measures were used to undermine a late selection account that stimulus identification occurs in parallel and without attentional resources. Furthermore, the results suggest that people can strategically alter how they allocate attention within visual space. Attention may be narrowly focused upon a single location or more uniformly distributed within the visual field. How attention is deployed is dependent upon the mental set of participants as determined by task demands. Critically, however, for words to be meaningfully processed, they must be located within the suffusion of this dynamic attentional allocation.

Bibliography

Bauer, B., & Besner, D. (1997). Processing in the Stroop task: Mental set as a determinant of performance. *Canadian Journal of Experimental Psychology*, 51, 61-68.

Bergen, J.R., & Julesz, B. (1983). Parallel versus serial processing in rapid pattern detection. *Nature*, 303, 696-698.

Besner, D., Risko, E.F., & Sklair, N. (2005). Spatial attention as a necessary preliminary to early processes in reading, *Canadian Journal of Experimental Psychology*, 59, 99-108.

Besner, D., & Stolz, J.A. (1999). What kind of attention modulates the Stroop effect?, *Psychonomic Bulletin & Review*, 6, 99-104.

Biederman, I., Glass, A.L., & Stacy, E.W. (1973). Searching for objects in real-world scenes. *Journal of Experimental Psychology*, 97, 22-27.

Bodner, G.E., & Masson, M.E.J. (1997). Masked repetition priming of words and nonwords: Evidence for a nonlexical basis for priming. *Journal of Memory and Language*, 37, 268-293.

Bravo, M.J., & Nakayama, K. (1992). The role of attention in different visual tasks. *Perception and Psychophysics*, 51, 465-472.

Broadbent, D.E. (1958). *Perception and communication*. New York: Oxford University Press.

Brown, T.L., Gore, C.L., & Carr, T.H. (2002). Visual attention and word recognition in stroop color-naming: Is word recognition “automatic”? *Journal of Experimental Psychology: General*, 131, 220-240.

Brown, T.L., Roos-Gilbert, L., & Carr, T.H. (1996). Automaticity and word perception: Evidence from Stroop and Stroop dilution effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 21, 1395-1411.

Cave, K., & Wolfe, J. (1990). Modeling the role of parallel processing in visual search. *Cognitive Psychology*, 22, 225-271.

Deutsch, J.A., & Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological Review*, 70, 80-90.

Duncan, J., & Humphreys, G.W. (1989). Visual search and stimulus similarity. *Psychological Review*, 96, 433-458.

Egeth, H. (1977). Attention and preattention. *Psychology of Learning and Motivation*, 11, 277-320.

Eriksen, B.A., & Eriksen, C.W. (1974). Effects of noise letters upon the identification of a target in a nonsearch task. *Perception & Psychophysics*, 14, 155-160.

Eriksen, C.W., & St. James, J.D. (1986). Visual attention within and around the field of focal attention: A zoom lens model. *Perception & Psychophysics*, 40, 225-240.

Eriksen, C.W., & Yeh, Y.Y. (1985). Allocation of attention in the visual field. *Journal of Experimental Psychology: Human Perception and Performance*, 11, 583-597.

Flowers, J.H., & Lohr, D.J. (1985). How does familiarity affect visual search for letter strings? *Perception & Psychophysics*, 37, 557-567.

Folk, C.L., & Annett, S. (1994). Do locally defined feature discontinuities capture attention? *Perception & Psychophysics*, 56, 277-287.

Folk, C.L., & Remington, R.W. (1998). Selectivity in distraction by irrelevant featural singletons: Evidence for two forms of attentional capture. *Journal of Experimental Psychology: Human Perception and Performance*, 24, 847-858.

Folk, C.L., Remington, R.W., & Johnston, J.C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance*, 18, 1030-1044.

Folk, C.L., & Remington, R. (2006). Top-down modulation of preattentive processing: Testing the recovery account of contingent capture, *Visual Cognition*, 14, 445-465.

Folk, C.L., Remington, R.W., & Wright, J.H. (1994). The structure of attentional control: Contingent attentional capture by apparent motion, abrupt onset, and color. *Journal of Experimental Psychology: Human Perception and Performance*, 20, 317-329.

Forster, K.I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 10, 680-698.

Friedman, A. (1979). Framing pictures: The role of knowledge in automatized encoding and memory for gist. *Journal of Experimental Psychology: General*. 108, 316-355.

Gibson, J.J. (1941). A critical review of the concept of set in contemporary experimental psychology. *Psychological Bulletin*, 38, 781-817.

Harris, C.R., Pashler, H.E., & Coburn, N. (2004). Moray revisited: High-priority affective stimuli and visual search. *The Quarterly Journal of Experimental Psychology*, 57, 1-31.

Hillstrom, A.P., & Yantis, S. (1994). Visual motion and attentional capture. *Perception & Psychophysics*, 55, 399-411.

Hoffman, J.E. (1979). A two-stage model of visual search. *Perception & Psychophysics*, 25, 319-327.

Jonides, J., & Yantis, S. (1988). Uniqueness of abrupt visual onset in capturing attention. *Perception & Psychophysics*, 43, 346-354.

Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movement. In J. Long & B. Baddeley (Eds.), *Attention and performance IX* (pp. 187-203). Hillsdale, NJ: Erlbaum.

Joseph, J., & Optician, L. (1996). Involuntary attentional shifts due to orienting differences. *Perception & Psychophysics*, 58, 651-665.

Kahneman, D., & Chajczyk, D. (1983). Tests of the automaticity of reading: Dilution of Stroop effects by color-irrelevant stimuli. *Journal of Experimental Psychology: Human Perception and Performance*, 9, 497-509.

Koch, C., & Ullman, S. (1985). Shifts in selective visual attention: Toward the underlying neural circuitry. *Human Neurobiology*, 4, 219-227.

Laberge, D. (1983). Spatial extent of attention to letters and words. *Journal of Experimental Psychology: Human Perception and Performance*, 9, 371-379.

Lachter, J., Forster, K.I., & Ruthruff, E. (2004). Forty-five years after Broadbent (1958): Still no identification without attention. *Psychological Review*, 111, 880-913.

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, 21, 451-468.

Loftus, G.R., & Masson, M.E.J. (1994). Using confidence intervals in within-subject designs, Psychonomic Bulletin & Review, 1, 476-490.

Mack, A., & Rock, I. (1998). *Inattentional Blindness*. Cambridge, MA: MIT Press.

Marcel, A. (1983). Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognitive Psycology*, 15, 532-550.

Marcel, A.J., & Patterson, C. (1978). Word recognition and production: Reciprocity in clinical and normal studies. In J. Requin (Ed.), *Attention and Performance VII* (pp. 209-226). Hillsdale, NJ: Eribaum.

Nakayama, K., & Joseph, J.S. (1988). Attention, pattern recognition, and popout in visual search. In R. Parasuraman (Ed.), *The attentive brain* (pp. 279-298). Cambridge, MA: MIT Press.

Neisser, U. (1967). *Cognitive Psychology*. New York: Appleton-Century-Crofts.

Niebur, E., Koch, C., & Rosin, C. (1993). An oscillation-based model for the neuronal basis of attention. *Visual Research*, 33, 2789-2802.

Nothdurft, H.C. (1993). Saliency effects across dimensions in visual search. *Vision Research*, 33, 839-844.

Nothdurft, H.C. (2002). Attention shifts to salient targets. *Vision Research*, 42, 1287-1306

Nothdurft, H.C. (2006). Salience and target selection in visual search. *Visual Cognition*, 14, 514-542.

Pashler, H. (1988). Cross-dimensional interaction and texture segregation. Pe*rception & Psychophysics,* 43, 307-318.

Posner, M.I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32, 3-25.

Posner, M.I., Snyder, C.R.R., & Davidson, B.J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology: General*, 109, 160-174.

Rensink, R.A. (2000). Seeing, sensing, and scrutinizing. *Vision Research*, 40, 1469-1487.

Roberts, M.A., & Besner, D. (2005). Stroop dilution revisited: Evidence for domain-specific, limited capacity processing. *Journal of Experimental Psychology, Human Perception and Performance*, 31, 3-13.

Schneider, W. (1988). Micro Experimental Laboratory: An integrated system for IBM-PC compatibles. *Behavior Research Methods, Instrumentation and Computers*, 20, 206-217.

Schneider, W. (1990). *MEL user's guide: Computer techniques for real time experimentation*. Pittsburgh, PA: Psychology Software Tools.

Shaffer, W.O., & LaBerge, D. (1979). Automatic semantic processing of unattended words. *Journal of Verbal Learning and Verbal Behavior*, 18, 413-426.

Simons, D.J., & Levin, D.T. (1997). Change Blindness. *Trends in Cognitive Sciences,* 1, 261-267.

Theeuwes, J. (1990). Perceptual selectivity is task dependent: Evidence from selective search. *Acta Psychologica*, 74, 81-99.

Theeuwes, J. (1991). Cross-dimensional perceptual selectivity. *Perception & Psychphysics*, 50, 184-193.

Theeuwes, J. (1991). Exogenous and endogenous control of attention: The effect of visual onsets and offsets. *Perception & Psychophysics*, 49, 83-90.

Theeuwes, J. (1992). Percptual selectivity for color and form. *Perception & Psychophysics*, 51, 599-606.

Theeuwes, J. (1994). Stimulus-driven capture and attentional set : Selective search for color and visual abrupt onsets. *Journal of Experimental Psychology: Human Perception and Performance*, 20, 799-806.

Theeuwes, J. (1996). Perceptual selectivity for color and form: On the nature of the interference effect. In A.F. Kramer, M. Coles, & G. Logan (Eds.), *Converging operations in the study of visual selective attention* (pp. 297-314). Washington DC: American Psychological Associatoin.

Theeuwes, J. (2006). Visual search for featural singletons: No top-down modulation, only bottom-up priming, *Visual Cognition*, 14, 466-489.

Todd, S., & Kramer, A.F. (1994). Attentional misguidance in visual search. *Perception & Psychophysics*, 56, 198-210.

Treisman, A. (1988). Features and objects: The Fourteenth Bartlett Memorial Lecture. *The Quarterly Journal of Experimental Psychology: A Human Experimental Psychology*, 40, 201-237.

Treisman, A., & Gelade, G. (1980). A feature integration theory of attention. *Cognitive Psychology*, 12, 97-136.

Treisman, A., & Gormican, S. (1988). Feature analysis in early vision: Evidence from search asymmetries, *Psychological Review*, 95, 15-48.

Van Selst, M., & Jolicœur, P. (1994). A solution to the effect of sample size on outlier elimination. *Quarterly Journal of Experimental Psychology*, 47A, 631-650.

Wolfe, J.M. (1994). Guided Search 2.0: A revised model of visual search. *Psychonomic Bulletin & Review*, 1, 202-238.

Wolfe, J.M., Cave, K.R., & Franzel, S.L. (1989). Guided Search: An alternative to the feature integration model for visual search. *Journal of Experimental Psychology: Human Perception and Performance*, 18, 34-49.

Yantis, S., & Egeth, H.E. (1999). On the distinction between visual salience and stimulus-driven attentional capture. *Journal of Experimental Psychology: Human Perception and Performance*, 25, 661-676.

Yantis, S., & Johnston, J.C. (1990). On the locus of visual selection: Evidence from focused attention tasks. *Journal of Experimental Psychology: Human Perception and Performance,* 16, 135-149.

Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance*, 10, 601-621.

Yantis, S., & Jonides, J. (1990). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance,* 16, 121-134.

Appendix A. Word list used in Experiments 1 and 2

after	dime	girl	jeep	maple	pear	skate	twig
back	door	great	jewel	money	place	skip	vest
bonus	dove	greed	kite	moth	power	small	where
book	eagle	hand	large	move	queer	super	which
child	face	hawk	last	night	radar	teeth	woman
clown	final	head	life	part	rake	think	work
cork	first	hood	long	paste	room	tire	world
crow	frog	house	many	peach	same	tower	would

Appendix B. Unpronounceable nonword list used in Experiments 1 and 2.

bcdhh	dfzwy	gydgv	kjhn	njzh	rgkkf	tvpvp	xdyg
bcgfr	dhgd	gyqtf	kjhq	nkjf	rgtdh	twqs	xhgu
bdflg	dhgf	hcfdb	kjnuj	nknx	rgtfb	twzsx	xjpd
bdrv	dhrbf	hdbk	kkhmv	nmdh	rgth	txclj	xjxhb
bfdl	djbh	hdfqq	klgny	nmsnm	rjfhg	txqxq	xscg
bfss	djbhf	hdhtt	klkjl	nmtg	rjfnv	txzsw	xsvt
bfts	dkjbn	hfds	kxgjl	nmvjj	rjhy	tytz	xtrjk
bhclc	dkjn	hfgts	ldjjn	nnch	rkrr	vbbv	xvhvf
bjgf	dlpdk	hfrfd	ldjyt	nngy	rmjbl	vbfy	xvjnf
bjhb	dlzd	hfrg	ldrw	nsjbc	rnmnr	vbjjf	xvtf
bncj	dmjd	hftg	lfdg	pclf	rqwpn	vbqd	xwugj
bndf	dpclk	hftrj	lfht	pclk	rryb	vbscv	xxwkp
bndg	dqkq	hftry	lfjhf	pdfm	rvhd	vbxt	xycty
bngf	drhgd	hgbfd	lfjj	pfjnf	rvyd	vcnv	xzsdp
bnxj	dzgs	hghrb	lgkk	pfkk	rwzqr	vcxmn	xzsqh
bprb	fbnj	hgtpz	ljkjf	pfvd	rxfs	vdttr	ydfg
bqfd	fdvn	hgtrt	lkmnv	pglgf	rxvh	vfgfw	yfgq
bqhw	ffrg	hhgs	lkpnm	pjgcm	rytd	vfjhq	ygyv
bqywh	fgbb	hhqzx	lkshf	pjqb	ryytr	vflpf	yhnjk
brfcc	fgfc	hhwhw	lkxq	pkhj	sbjs	vfng	ymmnh
bscf	fghfh	hjhb	lmhd	pklms	sbysr	vfpl	ymvh
bsfd	fgrtx	hjpz	lnztb	pknj	sdfjv	vgfbw	yqgh
bshg	fgxb	hnfjj	lpxmx	pljkn	sdhnv	vgtq	yqgyw
bvbvq	fhgyt	hpjhl	lpzxq	plkrb	sdtb	vjbtj	yqpy
bvdcg	fhjr	hplp	lqkzm	plkvf	sfcxx	vjfg	yrbvg
bvgqp	fjbjf	hplv	lrcl	plkxc	sfqh	vnmhm	yrty
cbjf	fjhth	jbfj	ltqwh	plld	sjhuw	vpyw	ysgy
cdss	fjkhf	jcbnh	lwcl	plpfv	sjvp	vrdfc	ythgk
cdswk	fjyc	jdbv	lwkwm	plvnj	snvt	wbkw	ytjlm
cfhd	fkfnj	jdfc	mckk	pmxzc	sqwq	wdcs	ytqws
cgdt	fnbj	jdhjh	mcnb	pnbfv	sscf	wnjwy	ytrnl
cgff	fndl	jdjb	mcyy	pnpph	sskm	wnkj	ytrv
cgvbf	fnnjf	jdqwl	mfdr	ppfk	ststr	wnxf	ytwcz
chcl	fplq	jdwzx	mfnvt	pqcx	svcg	wplk	yufhb
chgc	fqgf	jgjh	mgjh	qcfxp	svcq	wpplg	yvpvp
chgy	gbfg	jhbq	mgkh	qcvcf	svddx	wqmzr	yvzs
chyd	gdkxb	jhcvb	mhmjm	qcxxw	svdl	wqnnz	zbsg

Appendix B (continued).

cjbd	gfbvm	jhdcy	mhqq	qcxzg	svfv	wqsgd	zcdt
cjghy	gfkf	jhnz	mksdf	qdswj	sxky	wqsjn	zcgzc
cjgyd	gfrsx	jhtbv	mkyt	qfdx	sxzl	wqszn	zdff
cjhgd	ghggr	jjfg	mlgf	qfgf	sytjl	wqwn	zggz
cjhhy	ghzg	jjgn	mlnpt	qggwb	szysf	wqwnb	zjhu
cnkj	gkjgf	jmcnt	mprbd	qghg	tdgb	wqytw	zkjnh
cnnvb	glngp	jnbg	mqtwp	qgjh	tfdj	wrct	zpzr
cpck	gmplp	jnqj	mvcz	qjgqt	tfhh	wssq	zrtk
cpcl	gncp	jpsp	mvnp	qkqj	tgnh	wvcp	zsgs
cpcll	gqdws	jspxm	mwmj	qkzxh	thbdv	wvhj	zstg
cppfl	gqfw	kblmj	mzcbv	qlbv	tjhj	wvwy	zstr
cwcj	gsdv	kcjbh	nbcgd	qncq	tncbg	wxszt	zsxl
dchy	gvjbu	kdbbf	nbgkf	qnmqm	tpzxk	wxzsq	zvxcv
dcmt	gvjvc	kdbj	nbhcf	qpllz	tqwv	wyrv	zvyf
dcxp	gvmnk	kdgg	nbplw	qppqx	tsjf	wzxs	zwfxf
dczz	gvpy	kdvf	ncbvj	qpqkl	ttbf	xbjj	zxwy
dfhbg	gvrt	kfjn	ncvb	rbfv	ttmjk	xbnj	zyhmg
dfjhg	gwqg	kgfk	nhtrj	rfdsv	ttpt	xbysf	zzffs
dfzwb	gxsql	kgjk	njbq	rfdvr	ttybw	xczsf	zzxqd

Appendix C. Pronounceable nonword list used in Experiments 1 to 8

ainth	daff	fleach	heged	krem	onde	scov	tharz
arld	daid	flieg	herck	kret	orld	seags	therc
babb	daist	flind	herf	krirs	ounth	senth	theth
baime	dalce	flis	hesc	krong	palb	sesp	thonx
barpe	danz	flisp	hewb	kryt	pamph	setch	throg
baum	dauk	flon	holn	kunx	parbe	sheg	toide
beale	dawd	flork	horts	kwenk	pauks	shiss	tovs
beath	deged	fluce	hule	kwoo	peim	shrup	traw
beles	deiv	flun	imbs	kwutt	pemps	shuln	trem
berl	demb	fowd	immed	kylp	peph	shyc	trert
besc	derd	frang	jabes	labe	peutt	sirst	trib
bleaf	dern	fras	jacte	lafe	pewn	skeck	troke
blefe	dirp	freip	jand	lawc	phac	skeep	tunk
bleg	donc	frew	jarc	lerg	phals	skogg	tuth
blerk	donts	froin	jark	leths	phrup	skovs	tweg
blesk	dran	frooz	jeush	leul	phuft	slaul	twie
bligg	drant	frop	jewch	lewb	piett	sloab	tworp
blit	drase	frult	jife	lolk	plail	slont	tync
blom	drea	fuche	jimps	lolph	plaw	slox	vapse
boax	dreck	fuln	jipe	lomth	pleg	slybs	vilm
boit	dreln	furpe	jolm	lulve	pluff	smemb	vilse
bolc	droab	fusk	juivs	lunn	plync	smimf	visc
brast	droac	fymn	julgn	maff	poid	smish	voke
bront	drope	gakt	jush	mave	poitt	smow	voove
brulk	droxe	garr	kaiff	mawk	poot	snav	voste
bryf	dryne	gaubs	kalds	mepte	porf	snilt	voun
buif	duign	gect	kang	merps	prawl	snoy	vuct
bymn	dulds	geem	karcs	meth	preeb	snymp	warch
caig	dursh	ghict	kawg	meug	preuc	sopts	weff
caln	duxts	gholk	keeld	mewk	pudd	sost	woitt
ceefe	dwits	gilb	keer	mirve	pupth	spage	wotes
chice	dworz	giph	kefe	moiz	quaib	spess	wouse
chikt	dwuif	glauf	kefts	mome	quave	spick	wulb
choul	dwuis	glin	kemn	mund	quek	spust	yalt
chuth	eagg	glisc	kenge	murf	quens	stalt	yarm
cibe	eans	glon	kewge	nands	railt	stebe	yarte
ciff	ekts	gnach	kighl	nars	rarp	stib	yasc

Appendix C (continued).

cilm	eled	gnux	kilck	nart	rebed	strux	yeap
cive	escs	goan	kilv	narv	rerns	sulch	yebb
clald	ethed	gorms	klaph	neech	rharf	sush	yeel
clett	faufs	gowle	klare	neft	rhull	susk	yict
clis	fave	grat	klilm	neln	rhums	swef	yirst
cluft	feamn	grirf	klisc	neub	rhyds	sweg	yirv
cooc	febb	grosk	kluf	nild	rirmn	swog	yoam
cowce	feck	gube	klus	ninte	romf	swunc	yode
cresk	fekes	gufed	kluss	nirm	ronce	syce	yofe
crolt	fenth	gusck	knaf	nirs	rond	tade	yold
crus	ferg	guve	knig	nolc	rooc	tapht	yumph
crusk	ferke	gwafe	knorv	noob	rulde	tapts	yurk
cuke	feuf	gwar	knov	norg	rurd	tarb	zarv
cuse	feuge	gwat	kodge	nowsh	rurgn	tarst	zean
cuzz	fewth	gwate	konce	nuds	sarc	tase	zinx
cwoxt	filk	gwyt	koov	obbs	sarp	teafe	zolb
cwurp	flads	gyte	koun	oged	saugs	tems	zonx
cygue	flakt	halch	krarg	oggs	scilf	tewk	zowse
cyld	flane	hass	kred	ohse	scook	thafe	zurp

Appendix D. Pseudohomophone nonword list used in Experiments 1 and 2.

adij	denz	irge	kuph	phaik	rhume	soad	vurst
aikk	depe	jeepe	kured	phang	righd	soard	vuze
aips	deth	jemm	kusp	phate	righm	soile	vyne
amed	dett	jinn	kweer	phays	rize	soked	waic
arck	doam	jirm	kwik	phead	roatt	soop	wais
awks	doar	jurc	kwirc	phech	roaze	sope	wead
bace	doce	juse	kwoat	phee	roode	spawt	weat
bact	doct	kaige	kwyte	phir	roon	spead	weav
baild	doun	kaik	laite	phit	roote	spiez	weic
baul	dred	kaim	leece	phite	rored	spigh	weik
beaze	droun	kaiv	leeve	phlee	roze	spild	weill
bepe	erged	kamp	lefe	phloe	ruil	spoar	wele
beid	erth	kann	lere	phlu	ruim	stait	wenn
bighk	fain	kanoo	leup	phood	rutes	starz	werce
birnt	fale	karvs	leuze	phool	ryde	steid	werm
birst	fawks	kase	ligh	phorc	sainn	sterz	weve
blaim	fead	kask	lircs	phorm	sais	stik	whade
blede	feer	kasm	loors	phund	saled	stund	whage
bleek	feitt	kats	looze	pirl	sawse	styl	whain
blone	fele	kawz	lowde	pleaz	sawze	sugn	wheid
bludd	fiet	kert	luce	pleze	scie	sunck	wherd
boal	fite	keut	lume	plopt	scit	surch	wherk
boced	fleat	kews	lyve	plux	sckab	surv	whigh
boms	fliez	kirb	maque	poak	sckof	swet	whorp
bownd	fligh	kirl	meil	poal	sckul	swob	wiep
boze	flik	klame	mene	poarz	scoar	swomp	wigh
braik	fourc	klamp	mics	poes	seap	swon	wighp
breaf	foze	klif	miek	pourc	sease	swopt	wils
brouz	fued	kloes	mighk	praze	seene	syed	wipte
burne	furde	knek	mighl	pruve	shef	syne	wird
caick	furm	knere	milck	psix	shels	taik	wite
caiv	gapce	knok	moade	psoo	shign	taip	wizz
cead	gere	knoos	moal	psor	shinn	tair	woch
ceap	ghaze	knooz	moast	psuc	shue	taque	worf
ceez	ghoaz	koad	mocte	purks	shute	taul	worfe
ceke	ghurl	koagn	moov	pyct	sinc	tawc	wort
chace	ghush	koald	mosc	quaik	sinse	teaze	wosh

Appendix D (continued).

chawc	givs	koate	muzed	raiv	sity	tenze	wrag
cheke	gload	koed	naim	raiz	skail	tewb	wrage
chiem	gnape	koled	nawde	raket	skar	tikt	wraid
chooz	gnoaz	komed	nawze	reack	skare	tize	wrant
cied	gnue	koold	neade	reaff	skind	toal	wrare
cilc	gnyte	kord	negg	reele	skore	torne	wreaf
citts	gole	kore	neide	reep	skrub	toze	wrex
cleac	golph	kork	nek	rewte	slak	trics	wrich
cloc	groce	kost	nict	rhat	slamb	tuch	wrisc
cloct	grupe	kourl	noiz	rheil	slepe	tuks	wroab
cluiz	gyft	kourt	nowgn	rheks	slir	tutch	wroc
coard	hawls	krash	nuis	rhewd	slirp	typte	wruim
coff	heer	krece	nyfed	rhide	slode	tyze	wryp
cond	hert	kreek	nyne	rhile	slue	urnd	wyne
cwack	herze	kries	oande	rhip	smier	voag	wyzz
cwere	hoam	kroad	oarl	rhite	snaic	voat	yoars
cynge	hokes	krybb	ouls	rhole	sneik	vude	yooth
daitt	hoov	kude	paiz	rhope	snoze	vurbs	zoan
dele	hooz	kued	peale	rhuil	soack	vurce	zuim

Appendix E. Word list used in Experiments 3 to 8

about	book	dove	girl	know	night	rose	tire
acid	both	down	give	large	noble	round	toast
adore	bring	draw	glass	last	nudge	rule	today
after	build	dream	glide	late	occur	sack	towel
alert	cable	drink	gloom	leach	olive	sail	tower
allow	call	drive	good	learn	only	salad	tray
also	camel	drum	great	leave	other	same	trunk
amaze	cane	each	greed	lend	oven	save	tune
among	case	eagle	green	life	pact	scout	turn
ankle	catch	early	grid	limb	part	scrub	twig
argue	cause	edit	grill	line	paste	scum	under
atom	chair	empty	group	loaf	peach	sect	usher
baby	charm	equip	gust	lodge	pear	sense	very
back	child	even	hair	long	pine	shall	vest
bacon	chime	every	hand	make	place	short	vivid
badge	chin	fable	harp	many	plant	show	wage
bake	city	face	harsh	maple	pluck	skate	want
ball	clam	fall	have	mayor	poem	skip	wart
bank	clear	feast	hawk	melt	point	small	whale
bash	clown	feel	head	menu	poker	smile	what
beak	club	final	here	merge	pork	sound	where
bean	coil	find	honey	might	power	stand	which
bear	come	first	hood	mole	prowl	still	will
beard	cork	flag	horn	money	quart	super	wink
beet	corn	flake	house	moth	queer	take	woman
berry	crow	flame	human	mound	quite	teeth	work
black	dark	floor	jeep	mourn	rack	thaw	world
blaze	data	food	jewel	mouth	radar	there	would
blood	deaf	form	juice	move	raise	these	write
blue	dime	frog	just	much	rake	they	year
board	dirt	from	keep	must	relay	think	yell
bonus	door	gang	kite	never	room	thorn	zone

Appendix F. Participant means for Experiment 1 in the Unpronounceable Nonword Distractor condition as a function of Target Presence/Absence and Set Size for both Response Time (RT) and Percentage Error (%Error)

Word Present							
RT				%Error			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
647	1119	1240	1221	0.0	6.3	12.5	25.0
801	1047	1323	1718	0.0	12.5	18.8	18.8
806	1017	1229	1453	0.0	12.5	6.3	6.3
816	1310	1454	1535	6.3	0.0	0.0	6.3
852	1240	1474	1533	6.3	12.5	43.8	31.3
592	860	988	1120	12.5	25.0	25.0	37.5
641	867	878	1160	18.8	25.0	31.3	25.0
654	940	928	1074	6.3	25.0	37.5	37.5
635	812	1165	1335	6.3	0.0	12.5	6.3
807	1095	1499	1434	6.3	0.0	0.0	0.0
646	851	974	1150	0.0	25.0	0.0	6.3
753	1068	1056	1357	6.3	0.0	18.8	25.0
625	928	1208	1357	6.3	6.3	0.0	12.5
713	1006	1032	1188	6.3	37.5	6.3	25.0
698	1016	1276	1361	0.0	6.3	0.0	0.0
642	934	1067	1307	6.3	0.0	6.3	18.8
695	1024	1273	1371	0.0	0.0	25.0	18.8
795	1094	1315	1381	0.0	0.0	6.3	0.0
622	907	1002	1267	0.0	6.3	0.0	0.0
672	881	1024	1324	6.3	25.0	12.5	25.0
713	1010	1375	1440	6.3	6.3	18.8	6.3
765	970	1068	1344	0.0	12.5	37.5	25.0
732	1023	1084	1487	0.0	6.3	6.3	0.0
696	923	1184	1321	6.3	6.3	25.0	25.0

Appendix F (continued).

Word Absent							
RT				%Error			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
684	1260	1534	1887	0.0	0.0	0.0	0.0
845	1043	1703	2082	0.0	0.0	0.0	0.0
829	1168	1520	2062	0.0	0.0	0.0	0.0
742	1336	1857	2389	0.0	0.0	0.0	0.0
857	1005	1268	1614	6.3	0.0	0.0	6.3
579	872	1106	1294	0.0	0.0	0.0	0.0
639	843	1146	1366	6.3	0.0	0.0	18.8
682	919	1280	1642	6.3	0.0	0.0	12.5
664	926	1355	1861	0.0	0.0	0.0	0.0
816	1323	2146	2605	0.0	0.0	0.0	0.0
627	1008	1427	1724	0.0	0.0	0.0	0.0
760	878	1379	1684	0.0	6.3	0.0	6.3
659	1122	1724	2142	0.0	0.0	0.0	0.0
627	846	1175	1543	0.0	0.0	0.0	0.0
686	1044	1465	1974	0.0	0.0	0.0	0.0
669	910	1305	1692	0.0	0.0	0.0	0.0
744	1005	1478	1960	6.3	0.0	0.0	0.0
772	1204	1533	2011	0.0	0.0	0.0	0.0
583	1096	1515	2028	0.0	0.0	0.0	0.0
697	844	1140	1455	6.3	0.0	0.0	0.0
727	1076	1735	2248	0.0	0.0	0.0	0.0
703	1026	1514	1633	0.0	6.3	6.3	0.0
712	1028	1404	1755	0.0	0.0	0.0	0.0
693	984	1245	1505	0.0	0.0	0.0	0.0

Appendix G. Participant means for Experiment 1 in the Pronounceable Nonword Distractor condition as a function of Target Presence/Absence and Set Size for both Response Time (RT) and Percentage Error (%Error)

Word Present							
RT				%Error			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
716	1287	1271	1458	0.0	6.3	31.3	31.3
865	1328	1695	2131	0.0	6.3	6.3	12.5
756	1444	1627	2017	6.3	6.3	18.8	25.0
813	1147	1742	2053	12.5	25.0	18.8	25.0
862	1257	2013	1788	0.0	6.3	31.3	12.5
724	971	1449	1517	25.0	31.3	25.0	18.8
706	1236	1538	1482	0.0	25.0	0.0	25.0
842	1296	1724	1410	6.3	12.5	25.0	12.5
699	1072	1525	1960	0.0	12.5	43.8	18.8
996	1291	1526	2273	0.0	0.0	12.5	6.3
845	1106	1387	1510	18.8	6.3	25.0	18.8
745	1193	1529	2020	6.3	37.5	18.8	43.8
878	1366	1699	2443	0.0	25.0	18.8	37.5
713	1015	1264	1355	0.0	31.3	25.0	12.5
805	1223	1354	1803	6.3	12.5	12.5	31.3
754	1211	1453	1884	6.3	12.5	12.5	18.8
880	1448	1964	2040	6.3	0.0	6.3	0.0
660	931	994	1127	6.3	37.5	25.0	37.5
738	1049	1001	1737	0.0	18.8	25.0	12.5
942	1482	2006	2240	0.0	31.3	18.8	31.3
937	1684	2135	2400	0.0	12.5	31.3	31.3
807	1123	1392	1740	0.0	18.8	18.8	12.5
797	1213	1663	1835	0.0	6.3	6.3	12.5
868	1154	1620	2032	12.5	31.3	12.5	37.5

Appendix G (continued).

Word Absent							
RT				%Error			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
835	1288	1537	1826	6.3	6.3	6.3	18.8
944	1643	1989	2733	0.0	0.0	6.3	0.0
799	1599	2292	2894	0.0	0.0	0.0	0.0
765	1197	1743	2495	0.0	0.0	6.3	0.0
894	1474	2197	2859	0.0	0.0	6.3	6.3
717	1261	1775	2229	6.3	0.0	6.3	0.0
796	1244	2123	2562	6.3	6.3	6.3	6.3
821	1432	1897	2450	0.0	0.0	6.3	0.0
758	1377	1880	2357	0.0	6.3	6.3	0.0
916	1721	2153	2812	0.0	6.3	0.0	6.3
891	1417	1532	2143	6.3	0.0	6.3	0.0
972	1457	2076	2345	18.8	6.3	18.8	12.5
817	1672	2243	3054	0.0	12.5	0.0	0.0
671	1238	1566	1875	12.5	0.0	0.0	0.0
825	1260	2078	2517	6.3	0.0	6.3	0.0
869	1289	2185	2559	6.3	18.8	18.8	6.3
1090	2033	2853	3843	0.0	6.3	12.5	12.5
652	978	1290	1769	18.8	18.8	18.8	12.5
815	1298	1741	2525	6.3	12.5	6.3	6.3
974	1658	2357	2704	0.0	6.3	6.3	6.3
1098	1950	2056	2540	18.8	18.8	25.0	12.5
907	1553	2281	2872	0.0	0.0	0.0	6.3
865	1544	2180	2937	0.0	0.0	6.3	0.0
950	1337	1781	2255	6.3	0.0	0.0	0.0

Appendix H. Participant means for Experiment 1 in the Pseudohomophone Distractor condition as a function of Target Presence/Absence and Set Size for both Response Time (RT) and Percentage Error (%Error)

Word Present							
RT				%Error			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
800	1363	1791	2143	0.0	6.3	18.8	12.5
955	1497	1843	2340	0.0	12.5	6.3	6.3
760	1154	1173	1564	0.0	0.0	12.5	12.5
1061	1291	1713	1905	0.0	18.8	25.0	37.5
844	1164	1228	1576	12.5	31.3	18.8	31.3
856	1368	1489	2121	0.0	25.0	18.8	37.5
803	1258	1940	2445	18.8	6.3	0.0	6.3
842	1266	1508	2012	0.0	12.5	0.0	12.5
817	1311	1544	1906	6.3	0.0	18.8	12.5
1008	1486	2310	2484	0.0	37.5	18.8	6.3
796	1223	1511	2201	6.3	18.8	6.3	6.3
705	1156	1416	2060	6.3	0.0	6.3	18.8
821	1485	2322	2335	6.3	12.5	0.0	0.0
704	956	1389	1578	12.5	18.8	6.3	31.3
766	1453	1913	1930	6.3	6.3	25.0	0.0
706	1289	1401	1803	0.0	18.8	31.3	37.5
920	1599	2204	2334	0.0	0.0	0.0	0.0
797	1147	1429	2171	6.3	25.0	25.0	18.8
675	1183	1206	1531	6.3	43.8	18.8	31.3
818	1381	1969	2230	0.0	18.8	12.5	31.3
815	1324	1425	1834	6.3	43.8	56.3	50.0
794	1324	1768	1958	6.3	18.8	18.8	18.8
913	1294	2056	2272	6.3	25.0	6.3	18.8
945	1536	1790	2250	0.0	0.0	0.0	25.0

Appendix H (continued).

Word Absent							
RT				%Error			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
1034	1699	2513	2987	6.3	12.5	12.5	6.3
890	1703	2289	3415	0.0	0.0	0.0	0.0
885	1262	1646	2227	0.0	0.0	0.0	6.3
1197	1492	2221	2451	6.3	12.5	12.5	12.5
833	1403	1737	2697	6.3	6.3	6.3	18.8
822	1538	1972	2569	6.3	0.0	0.0	0.0
909	1783	2471	3792	12.5	6.3	25.0	6.3
943	1590	1954	2514	0.0	0.0	0.0	0.0
986	1520	2220	2842	0.0	0.0	0.0	0.0
969	1644	2359	2977	0.0	12.5	0.0	0.0
799	1573	2432	3203	0.0	6.3	0.0	18.8
766	1318	2106	2559	0.0	0.0	0.0	6.3
776	1816	3042	3844	6.3	0.0	0.0	6.3
709	1273	1724	2103	0.0	0.0	12.5	6.3
845	1831	2295	2958	6.3	0.0	6.3	0.0
849	1139	1419	2207	0.0	6.3	6.3	0.0
1132	2002	3745	4753	0.0	6.3	6.3	12.5
885	1366	1848	2432	0.0	0.0	6.3	6.3
790	1154	1833	2036	12.5	0.0	6.3	6.3
788	1452	2326	3114	0.0	6.3	0.0	6.3
836	1472	1885	2386	0.0	0.0	12.5	6.3
924	1673	2512	3040	12.5	6.3	12.5	0.0
998	1575	2164	2983	6.3	0.0	0.0	0.0
1049	1662	2335	3000	0.0	6.3	0.0	0.0

Appendix I. Participant Search Slope Response Time (RT) means for Experiment 1 as a function of Target Presence/Absence and Set Size

Experiment 1 Search Slopes					
Word Present			Word Absent		
Unpronounceable Nonword	Pronounceable Nonword	Pseudohomphone Nonword	Unpronounceable Nonword	Pronounceable Nonword	Pseudohomphone Nonword
92	111	223	194	161	334
151	208	225	219	286	408
108	198	122	203	349	221
115	216	148	273	287	225
114	177	113	127	331	296
86	143	196	119	253	284
78	132	280	124	309	467
62	106	188	162	268	254
123	212	175	201	265	313
114	203	263	310	306	337
82	114	225	185	193	404
90	208	216	164	237	308
124	251	269	252	364	522
73	109	153	154	197	232
113	156	198	214	295	340
106	182	170	173	298	218
114	200	242	206	454	630
99	73	220	202	183	256
102	147	130	238	279	221
105	221	241	129	295	393
127	242	158	261	222	253
92	153	197	164	331	360
116	178	242	175	343	327
107	198	208	135	218	326

Appendix J. Participant means for Experiment 2 in the Unpronounceable Nonword Distractor condition as a function of Target Presence/Absence and Set Size for both Response Time (RT) and Percentage Error (%Error)

Word Present							
RT				%Error			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
790	828	786	813	0.0	0.0	6.3	12.5
637	698	740	760	0.0	0.0	6.3	6.3
660	714	730	723	12.5	0.0	6.3	0.0
559	557	600	606	6.3	6.3	0.0	6.3
608	91	689	641	12.5	6.3	0.0	6.3
609	616	596	607	6.3	12.5	6.3	0.0
630	653	688	680	0.0	6.3	0.0	0.0
650	691	693	709	6.3	18.8	0.0	6.3
638	686	695	690	0.0	12.5	6.3	0.0
895	783	798	792	0.0	0.0	0.0	6.3
552	604	605	645	6.3	6.3	12.5	31.3
551	567	589	619	12.5	12.5	6.3	25.0
673	664	680	667	6.3	0.0	6.3	6.3
672	958	843	775	6.3	6.3	6.3	6.3
649	688	720	711	12.5	12.5	6.3	0.0
985	1070	1141	1118	6.3	0.0	0.0	0.0
647	700	713	735	6.3	6.3	6.3	18.8
836	801	794	744	0.0	0.0	0.0	0.0
607	649	663	696	12.5	6.3	0.0	12.5
633	639	633	650	0.0	6.3	0.0	6.3
543	574	598	616	0.0	18.8	6.3	0.0
721	798	758	737	0.0	0.0	6.3	0.0
620	574	668	660	12.5	6.3	6.3	6.3
721	731	718	771	0.0	0.0	6.3	6.3

Appendix J (continued).

Word Absent							
RT				%Error			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
747	749	767	770	0.0	0.0	6.3	0.0
629	693	620	651	0.0	0.0	0.0	6.3
639	690	747	727	0.0	6.3	0.0	6.3
513	541	541	553	0.0	0.0	0.0	0.0
650	663	724	699	6.3	6.3	6.3	6.3
526	557	617	561	6.3	0.0	6.3	0.0
588	643	675	671	0.0	0.0	6.3	0.0
699	721	641	680	0.0	0.0	0.0	0.0
630	668	662	635	0.0	12.5	0.0	0.0
816	819	844	794	31.3	0.0	0.0	0.0
544	575	612	609	6.3	6.3	6.3	12.5
518	640	570	622	0.0	12.5	0.0	6.3
663	751	712	689	0.0	0.0	0.0	0.0
653	881	777	714	18.8	6.3	0.0	0.0
617	640	665	633	6.3	6.3	0.0	6.3
1020	1123	1058	1161	0.0	6.3	0.0	0.0
678	767	764	712	0.0	0.0	0.0	0.0
720	773	851	778	6.3	0.0	0.0	0.0
629	692	668	682	0.0	0.0	0.0	6.3
653	727	703	657	6.3	6.3	0.0	0.0
518	545	576	590	0.0	0.0	0.0	0.0
708	719	775	721	0.0	0.0	0.0	0.0
598	620	625	622	0.0	6.3	0.0	0.0
676	709	680	695	0.0	6.3	0.0	6.3

Appendix K. Participant means for Experiment 2 in the Pronounceable Nonword Distractor condition as a function of Target Presence/Absence and Set Size for both Response Time (RT) and Percentage Error (%Error)

Word Present							
RT				%Error			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
764	850	810	858	6.3	18.8	12.5	6.3
818	788	791	824	0.0	0.0	0.0	0.0
662	699	685	657	0.0	6.3	0.0	18.8
761	794	829	884	0.0	0.0	0.0	6.3
761	891	874	829	6.3	6.3	18.8	0.0
881	843	859	870	0.0	6.3	6.3	6.3
767	807	802	866	12.5	0.0	0.0	0.0
683	762	754	815	12.5	0.0	0.0	0.0
732	836	836	849	0.0	0.0	0.0	6.3
890	757	769	841	0.0	6.3	12.5	0.0
836	921	867	814	0.0	0.0	0.0	0.0
751	945	909	865	0.0	0.0	6.3	0.0
737	777	794	829	0.0	0.0	6.3	0.0
799	862	900	934	0.0	12.5	0.0	0.0
714	704	772	806	6.3	0.0	6.3	6.3
704	754	748	772	12.5	6.3	0.0	6.3
797	823	816	772	0.0	0.0	0.0	0.0
723	814	754	851	0.0	18.8	0.0	0.0
682	703	755	739	6.3	0.0	0.0	0.0
808	839	832	835	0.0	0.0	6.3	0.0
685	683	714	718	0.0	6.3	18.8	0.0
629	645	675	675	12.5	12.5	18.8	6.3
733	809	788	852	0.0	0.0	6.3	12.5
904	892	937	916	0.0	6.3	6.3	6.3

Appendix K (continued).

Word Absent							
RT				%Error			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
934	862	956	910	12.5	6.3	0.0	0.0
809	801	874	845	0.0	0.0	0.0	6.3
732	689	703	691	0.0	0.0	0.0	0.0
845	972	1072	949	0.0	6.3	6.3	0.0
843	973	863	941	6.3	6.3	0.0	6.3
886	906	1054	827	6.3	0.0	0.0	0.0
852	857	865	861	6.3	0.0	6.3	0.0
695	781	760	745	0.0	0.0	0.0	6.3
925	955	861	897	0.0	6.3	0.0	0.0
842	890	980	938	18.8	6.3	6.3	6.3
967	923	948	997	0.0	0.0	6.3	0.0
821	1430	993	1560	0.0	31.3	6.3	25.0
803	848	807	834	0.0	0.0	6.3	0.0
960	828	1087	979	6.3	0.0	6.3	0.0
716	790	848	849	0.0	0.0	0.0	0.0
822	811	864	883	6.3	6.3	6.3	6.3
827	937	938	885	0.0	0.0	0.0	0.0
852	888	948	995	12.5	0.0	0.0	6.3
794	885	878	829	0.0	0.0	0.0	0.0
962	1002	877	975	6.3	12.5	12.5	12.5
726	716	808	717	18.8	0.0	0.0	6.3
718	807	745	752	12.5	18.8	25.0	6.3
763	838	827	834	12.5	0.0	6.3	0.0
1010	1064	970	1255	0.0	0.0	0.0	0.0

Appendix L. Participant means for Experiment 2 in the Pseudohomophone Distractor condition as a function of Target Presence/Absence and Set Size for both Response Time (RT) and Percentage Error (%Error)

Word Present							
RT				%Error			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
723	726	685	678	12.5	0.0	12.5	6.3
725	857	791	851	0.0	0.0	0.0	6.3
671	690	740	709	12.5	0.0	12.5	0.0
786	783	818	826	0.0	0.0	0.0	0.0
875	846	902	949	6.3	0.0	0.0	0.0
863	892	899	891	6.3	6.3	0.0	0.0
702	782	789	759	0.0	6.3	0.0	0.0
650	784	778	781	6.3	18.8	0.0	12.5
802	751	772	787	0.0	0.0	0.0	6.3
726	797	744	786	6.3	0.0	0.0	0.0
751	730	741	768	25.0	12.5	12.5	6.3
761	750	788	765	0.0	6.3	0.0	0.0
957	1064	967	961	6.3	0.0	6.3	6.3
718	727	769	783	6.3	6.3	12.5	12.5
856	854	863	883	6.3	0.0	0.0	0.0
854	854	814	827	0.0	0.0	0.0	0.0
727	707	760	781	0.0	0.0	0.0	0.0
707	767	726	781	0.0	12.5	0.0	0.0
1126	1149	1175	1135	0.0	0.0	0.0	0.0
833	971	993	985	6.3	6.3	0.0	6.3
681	706	757	691	12.5	6.3	0.0	0.0
815	772	801	836	0.0	0.0	0.0	0.0
869	907	886	934	0.0	0.0	6.3	0.0
798	871	851	766	18.8	12.5	0.0	12.5

Appendix L (continued).

Word Absent							
RT				%Error			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
724	773	754	755	0.0	0.0	0.0	18.8
1012	942	940	1030	12.5	6.3	0.0	6.3
819	809	823	780	0.0	6.3	0.0	6.3
898	813	873	913	6.3	6.3	12.5	6.3
1007	1074	1145	1077	0.0	0.0	6.3	6.3
1111	1041	1102	1095	12.5	18.8	6.3	6.3
772	851	746	781	12.5	6.3	6.3	6.3
727	807	746	794	6.3	0.0	6.3	12.5
879	782	818	838	0.0	0.0	0.0	0.0
867	945	760	780	12.5	12.5	0.0	12.5
703	735	713	749	12.5	6.3	0.0	18.8
779	745	829	780	0.0	0.0	0.0	0.0
1079	954	976	1036	18.8	6.3	12.5	12.5
751	770	755	752	0.0	6.3	0.0	0.0
867	911	880	976	6.3	0.0	0.0	0.0
820	967	878	799	6.3	6.3	0.0	0.0
726	771	818	797	0.0	6.3	0.0	6.3
804	852	860	891	31.3	12.5	18.8	18.8
1406	1528	1444	1277	0.0	0.0	0.0	0.0
1074	1171	1160	1131	0.0	0.0	0.0	0.0
684	763	772	774	6.3	6.3	0.0	0.0
871	885	920	917	0.0	6.3	0.0	0.0
959	1161	1010	972	18.8	0.0	6.3	12.5
749	779	906	879	12.5	12.5	0.0	12.5

Appendix M. Participant Search Slope Response Time (RT) means for Experiment 1 as a function of Target Presence/Absence and Set Size

Experiment 1 Search Slopes					
Word Present			Word Absent		
Unpronounceable Nonword	Pronounceable Nonword	Pseudohomphone Nonword	Unpronounceable Nonword	Pronounceable Nonword	Pseudohomphone Nonword
1	12	-9	4	1	4
21	1	16	0	9	3
10	-1	8	16	-5	-5
9	20	8	6	21	5
5	9	14	10	9	14
-1	-1	4	8	-2	1
9	15	9	14	2	-4
9	19	19	-7	6	7
8	18	-1	0	-9	-4
-15	-7	6	-2	19	-22
14	-6	3	12	6	6
11	15	3	12	89	4
0	15	-4	2	3	-5
10	22	12	4	16	-1
11	17	4	4	23	15
23	10	-6	18	12	-8
14	-4	11	5	9	13
-14	16	9	13	25	13
14	11	3	7	5	-24
2	4	24	-1	-4	8
12	7	4	12	3	14
0	8	5	5	2	9
11	17	9	4	10	-6
7	4	-6	2	32	26

Appendix N. Participant means for Experiment 3 as a function of Relatedness and Set Size for Response Times and (Percentage Errors)

Experiment 3							
Related				Unrelated			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
825 (0.0)	807 (0.0)	882 (0.0)	847 (12.5)	818 (0.0)	876 (0.0)	828 (0.0)	1015 (0.0)
488 (0.0)	495 (12.5)	468 (12.5)	475 (0.0)	503 (0.0)	515 (0.0)	457 (12.5)	461 (0.0)
658 (0.0)	590 (12.5)	662 (0.0)	617 (0.0)	677 (0.0)	580 (12.5)	737 (12.5)	651 (0.0)
432 (0.0)	460 (0.0)	448 (0.0)	462 (12.5)	511 (12.5)	434 (25.0)	474 (0.0)	502 (12.5)
472 (12.5)	438 (0.0)	497 (0.0)	431 (0.0)	467 (0.0)	459 (0.0)	487 (0.0)	543 (12.5)
585 (12.5)	589 (0.0)	661 (0.0)	573 (0.0)	776 (12.5)	622 (0.0)	624 (12.5)	636 (12.5)
628 (0.0)	594 (0.0)	546 (12.5)	583 (0.0)	587 (0.0)	602 (0.0)	577 (0.0)	652 (0.0)
483 (0.0)	513 (0.0)	549 (0.0)	484 (0.0)	479 (0.0)	510 (0.0)	582 (0.0)	502 (0.0)
598 (0.0)	639 (0.0)	595 (0.0)	627 (12.5)	540 (12.5)	599 (0.0)	592 (12.5)	663 (12.5)
649 (0.0)	651 (0.0)	685 (0.0)	658 (0.0)	772 (12.5)	723 (25.0)	682 (0.0)	699 (0.0)
567 (0.0)	551 (0.0)	607 (12.5)	597 (0.0)	644 (0.0)	658 (25.0)	593 (0.0)	542 (12.5)
541 (0.0)	588 (0.0)	561 (0.0)	544 (0.0)	597 (12.5)	587 (12.5)	607 (0.0)	597 (0.0)
595 (0.0)	638 (0.0)	559 (0.0)	544 (0.0)	626 (12.5)	584 (25.0)	561 (0.0)	574 (0.0)
554 (0.0)	549 (0.0)	548 (0.0)	531 (0.0)	553 (0.0)	530 (0.0)	546 (0.0)	550 (0.0)
508 (0.0)	552 (0.0)	590 (0.0)	535 (0.0)	580 (0.0)	538 (0.0)	597 (0.0)	620 (0.0)
549 (0.0)	514 (0.0)	485 (0.0)	575 (0.0)	525 (0.0)	562 (0.0)	531 (25.0)	478 (0.0)
487 (0.0)	489 (0.0)	458 (0.0)	436 (25.0)	479 (12.5)	472 (0.0)	492 (0.0)	488 (12.5)
864 (0.0)	684 (0.0)	761 (0.0)	685 (0.0)	774 (0.0)	735 (0.0)	750 (0.0)	834 (0.0)
643 (12.5)	682 (0.0)	582 (0.0)	664 (0.0)	620 (0.0)	591 (0.0)	591 (12.5)	541 (0.0)
716 (0.0)	716 (0.0)	724 (12.5)	717 (0.0)	716 (0.0)	720 (0.0)	630 (0.0)	655 (0.0)
916 (12.5)	717 (0.0)	694 (0.0)	804 (0.0)	713 (0.0)	686 (12.5)	699 (12.5)	697 (0.0)
642 (0.0)	569 (0.0)	589 (0.0)	547 (0.0)	577 (0.0)	619 (0.0)	581 (0.0)	660 (12.5)
575 (12.5)	588 (0.0)	543 (25.0)	590 (37.5)	499 (0.0)	507 (0.0)	588 (12.5)	541 (0.0)
729 (37.5)	601 (0.0)	669 (0.0)	600 (12.5)	614 (0.0)	563 (0.0)	714 (12.5)	671 (0.0)
638 (25.0)	687 (0.0)	600 (12.5)	628 (0.0)	620 (12.5)	659 (0.0)	634 (0.0)	633 (25.0)
570 (0.0)	668 (0.0)	548 (12.5)	591 (0.0)	595 (0.0)	567 (12.5)	626 (0.0)	636 (0.0)
731 (0.0)	624 (12.5)	674 (0.0)	683 (0.0)	624 (12.5)	707 (12.5)	735 (0.0)	733 (25.0)
539 (0.0)	517 (37.5)	600 (0.0)	547 (0.0)	538 (12.5)	537 (25.0)	561 (12.5)	554 (0.0)
615 (0.0)	604 (25.0)	611 (0.0)	590 (25.0)	616 (0.0)	657 (0.0)	602 (0.0)	563 (0.0)
722 (12.5)	634 (0.0)	632 (0.0)	682 (12.5)	596 (12.5)	692 (0.0)	620 (0.0)	586 (12.5)
441 (12.5)	385 (25.0)	451 (0.0)	464 (25.0)	431 (25.0)	398 (25.0)	416 (12.5)	442 (12.5)
536 (12.5)	547 (0.0)	570 (0.0)	548 (0.0)	581 (0.0)	607 (0.0)	599 (0.0)	555 (0.0)

Appendix O. Participant means for Experiment 4 as a function of Relatedness and Set Size for Response Times and (Percentage Errors)

Experiment 4							
Related				Unrelated			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
508 (0.0)	641 (0.0)	570 (0.0)	726 (0.0)	635 (0.0)	598 (0.0)	606 (12.5)	659 (0.0)
639 (0.0)	645 (0.0)	705 (25.0)	626 (0.0)	798 (12.5)	704 (12.5)	756 (12.5)	680 (0.0)
659 (0.0)	640 (0.0)	661 (0.0)	656 (0.0)	641 (12.5)	689 (12.5)	654 (0.0)	639 (0.0)
624 (0.0)	728 (12.5)	722 (0.0)	628 (0.0)	737 (0.0)	724 (0.0)	806 (0.0)	745 (0.0)
566 (0.0)	543 (0.0)	551 (12.5)	542 (12.5)	573 (0.0)	546 (12.5)	567 (0.0)	569 (0.0)
658 (0.0)	608 (0.0)	614 (0.0)	582 (0.0)	723 (0.0)	562 (0.0)	644 (0.0)	687 (0.0)
673 (12.5)	627 (0.0)	569 (12.5)	604 (12.5)	687 (0.0)	694 (12.5)	652 (12.5)	767 (12.5)
643 (0.0)	642 (0.0)	654 (12.5)	691 (0.0)	661 (25.0)	700 (0.0)	682 (12.5)	742 (0.0)
496 (0.0)	596 (12.5)	542 (12.5)	483 (12.5)	518 (12.5)	495 (0.0)	625 (25.0)	526 (12.5)
528 (12.5)	726 (0.0)	510 (0.0)	589 (0.0)	637 (12.5)	658 (12.5)	548 (12.5)	490 (0.0)
613 (0.0)	628 (0.0)	617 (0.0)	575 (12.5)	635 (0.0)	704 (0.0)	594 (12.5)	603 (0.0)
504 (0.0)	481 (0.0)	572 (0.0)	490 (0.0)	563 (0.0)	521 (12.5)	495 (0.0)	493 (0.0)
515 (0.0)	534 (0.0)	456 (0.0)	534 (0.0)	505 (12.5)	590 (0.0)	495 (0.0)	493 (0.0)
626 (0.0)	572 (0.0)	573 (0.0)	591 (0.0)	536 (12.5)	634 (0.0)	599 (0.0)	633 (0.0)
532 (0.0)	489 (12.5)	475 (0.0)	480 (0.0)	516 (12.5)	489 (0.0)	479 (25.0)	487 (0.0)
528 (25.0)	535 (0.0)	465 (0.0)	492 (0.0)	536 (0.0)	576 (12.5)	593 (12.5)	575 (25.0)
590 (0.0)	649 (0.0)	651 (0.0)	682 (12.5)	622 (0.0)	612 (0.0)	617 (0.0)	625 (0.0)
537 (12.5)	535 (12.5)	501 (0.0)	528 (0.0)	559 (0.0)	530 (0.0)	537 (0.0)	506 (0.0)
551 (12.5)	527 (12.5)	586 (12.5)	538 (0.0)	498 (12.5)	491 (12.5)	545 (0.0)	484 (0.0)
575 (12.5)	559 (0.0)	554 (0.0)	607 (0.0)	509 (0.0)	537 (0.0)	543 (0.0)	592 (0.0)
580 (12.5)	578 (12.5)	545 (12.5)	596 (0.0)	558 (12.5)	509 (0.0)	509 (0.0)	548 (12.5)
503 (0.0)	566 (0.0)	541 (0.0)	593 (0.0)	570 (0.0)	502 (0.0)	548 (0.0)	548 (0.0)
614 (0.0)	608 (12.5)	558 (0.0)	596 (0.0)	534 (0.0)	608 (0.0)	538 (0.0)	578 (0.0)
549 (0.0)	664 (0.0)	599 (0.0)	584 (12.5)	527 (12.5)	547 (0.0)	503 (0.0)	566 (0.0)
590 (0.0)	571 (0.0)	594 (25.0)	593 (12.5)	546 (0.0)	539 (0.0)	576 (12.5)	623 (12.5)
625 (0.0)	717 (0.0)	744 (12.5)	749 (0.0)	649 (0.0)	670 (0.0)	672 (0.0)	667 (0.0)
587 (0.0)	522 (0.0)	563 (0.0)	487 (0.0)	582 (0.0)	525 (0.0)	613 (0.0)	518 (0.0)
480 (12.5)	482 (12.5)	526 (0.0)	498 (0.0)	467 (0.0)	452 (0.0)	490 (0.0)	477 (0.0)
541 (25.0)	520 (12.5)	550 (0.0)	534 (0.0)	541 (12.5)	519 (25.0)	494 (0.0)	543 (0.0)
917 (12.5)	938 (0.0)	930 (0.0)	824 (0.0)	891 (0.0)	856 (0.0)	938 (0.0)	763 (0.0)
483 (0.0)	498 (0.0)	473 (0.0)	490 (0.0)	536 (12.5)	461 (0.0)	468 (0.0)	486 (0.0)
660 (12.5)	643 (0.0)	683 (12.5)	707 (0.0)	664 (0.0)	660 (0.0)	707 (0.0)	659 (0.0)

Appendix P. Participant means for Experiment 5 as a function of Relatedness and Set Size for Response Times and (Percentage Errors)

Experiment 5							
Related				Unrelated			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
580 (0.0)	575 (12.5)	582 (0.0)	561 (0.0)	614 (0.0)	571 (0.0)	561 (0.0)	570 (0.0)
482 (0.0)	519 (12.5)	518 (12.5)	500 (12.5)	543 (0.0)	530 (0.0)	562 (12.5)	501 (12.5)
576 (0.0)	631 (0.0)	642 (0.0)	657 (12.5)	721 (0.0)	650 (0.0)	684 (12.5)	590 (0.0)
443 (12.5)	505 (12.5)	482 (12.5)	484 (12.5)	494 (25.0)	516 (0.0)	509 (0.0)	468 (37.5)
602 (0.0)	588 (0.0)	626 (0.0)	599 (0.0)	615 (0.0)	659 (0.0)	636 (0.0)	613 (0.0)
536 (0.0)	569 (0.0)	599 (0.0)	496 (0.0)	598 (0.0)	545 (0.0)	632 (0.0)	575 (0.0)
613 (0.0)	664 (0.0)	579 (0.0)	583 (0.0)	712 (12.5)	576 (12.5)	623 (0.0)	683 (0.0)
684 (0.0)	597 (0.0)	714 (0.0)	720 (12.5)	741 (0.0)	615 (0.0)	692 (0.0)	604 (12.5)
627 (0.0)	600 (0.0)	516 (0.0)	534 (0.0)	692 (12.5)	579 (0.0)	600 (12.5)	600 (0.0)
629 (0.0)	673 (12.5)	593 (0.0)	634 (12.5)	635 (0.0)	656 (0.0)	673 (0.0)	550 (0.0)
437 (12.5)	454 (12.5)	459 (0.0)	402 (0.0)	466 (25.0)	449 (0.0)	418 (25.0)	462 (25.0)
585 (0.0)	585 (12.5)	565 (0.0)	603 (0.0)	583 (12.5)	511 (0.0)	557 (0.0)	549 (0.0)
578 (0.0)	519 (25.0)	555 (12.5)	537 (0.0)	599 (25.0)	546 (37.5)	574 (12.5)	578 (0.0)
649 (0.0)	616 (0.0)	585 (12.5)	598 (0.0)	641 (0.0)	580 (0.0)	706 (0.0)	613 (0.0)
642 (0.0)	623 (0.0)	611 (0.0)	599 (0.0)	608 (12.5)	684 (0.0)	621 (0.0)	730 (0.0)
641 (25.0)	588 (0.0)	574 (0.0)	616 (12.5)	642 (0.0)	669 (12.5)	593 (0.0)	589 (12.5)
508 (12.5)	545 (0.0)	607 (0.0)	526 (0.0)	568 (0.0)	546 (12.5)	537 (0.0)	542 (0.0)
622 (0.0)	564 (0.0)	610 (0.0)	585 (0.0)	601 (0.0)	616 (0.0)	637 (0.0)	529 (0.0)
451 (0.0)	419 (12.5)	436 (0.0)	452 (0.0)	463 (12.5)	424 (0.0)	456 (0.0)	425 (0.0)
500 (0.0)	563 (0.0)	490 (0.0)	496 (25.0)	534 (0.0)	525 (0.0)	509 (0.0)	573 (0.0)
822 (0.0)	585 (0.0)	731 (0.0)	685 (0.0)	725 (0.0)	695 (0.0)	706 (12.5)	627 (0.0)
703 (0.0)	649 (12.5)	711 (0.0)	713 (0.0)	752 (0.0)	751 (0.0)	683 (12.5)	663 (0.0)
660 (12.5)	674 (12.5)	695 (0.0)	606 (0.0)	662 (0.0)	610 (12.5)	671 (0.0)	740 (0.0)
550 (0.0)	605 (0.0)	533 (0.0)	621 (12.5)	546 (0.0)	636 (0.0)	604 (0.0)	626 (0.0)
693 (0.0)	690 (0.0)	748 (0.0)	604 (12.5)	605 (37.5)	729 (12.5)	703 (12.5)	621 (12.5)
517 (0.0)	554 (0.0)	517 (0.0)	574 (12.5)	644 (0.0)	641 (12.5)	584 (0.0)	530 (0.0)
616 (0.0)	579 (0.0)	554 (0.0)	572 (0.0)	566 (0.0)	621 (12.5)	632 (0.0)	547 (0.0)
504 (0.0)	626 (0.0)	521 (12.5)	534 (0.0)	523 (0.0)	554 (0.0)	493 (0.0)	585 (0.0)
465 (12.5)	499 (0.0)	479 (0.0)	482 (0.0)	452 (25.0)	483 (0.0)	471 (0.0)	453 (0.0)
499 (0.0)	552 (12.5)	521 (0.0)	492 (0.0)	586 (12.5)	546 (0.0)	545 (0.0)	627 (12.5)
632 (0.0)	640 (0.0)	589 (0.0)	595 (12.5)	635 (25.0)	658 (0.0)	621 (0.0)	653 (0.0)
560 (12.5)	526 (0.0)	569 (0.0)	609 (0.0)	600 (0.0)	647 (12.5)	599 (12.5)	611 (12.5)

Appendix P (continued)

Experiment 5							
Related				Unrelated			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
567 (12.5)	605 (0.0)	551 (0.0)	625 (0.0)	557 (0.0)	601 (12.5)	572 (0.0)	540 (0.0)
616 (12.5)	639 (12.5)	590 (0.0)	608 (12.5)	578 (0.0)	586 (12.5)	597 (12.5)	680 (0.0)
565 (0.0)	595 (0.0)	658 (12.5)	589 (0.0)	601 (0.0)	641 (0.0)	534 (12.5)	594 (0.0)
626 (0.0)	567 (0.0)	606 (12.5)	723 (0.0)	666 (0.0)	619 (0.0)	670 (0.0)	560 (0.0)
535 (12.5)	589 (12.5)	458 (12.5)	497 (0.0)	524 (0.0)	561 (0.0)	578 (12.5)	568 (12.5)
580 (0.0)	560 (0.0)	528 (0.0)	581 (0.0)	546 (12.5)	695 (0.0)	517 (12.5)	533 (25.0)
594 (0.0)	619 (0.0)	585 (12.5)	637 (0.0)	624 (0.0)	547 (12.5)	588 (0.0)	582 (0.0)
662 (12.5)	546 (12.5)	600 (12.5)	695 (12.5)	611 (0.0)	599 (12.5)	596 (0.0)	575 (0.0)
835 (0.0)	731 (0.0)	753 (0.0)	850 (12.5)	810 (0.0)	803 (0.0)	687 (12.5)	771 (0.0)
541 (0.0)	577 (0.0)	663 (0.0)	604 (0.0)	562 (0.0)	538 (0.0)	552 (0.0)	501 (25.0)
632 (0.0)	626 (0.0)	601 (0.0)	631 (0.0)	535 (0.0)	554 (0.0)	548 (0.0)	586 (0.0)
545 (25.0)	496 (12.5)	555 (12.5)	597 (0.0)	609 (37.5)	556 (12.5)	556 (37.5)	528 (0.0)
552 (0.0)	545 (12.5)	543 (0.0)	527 (0.0)	521 (0.0)	513 (0.0)	504 (0.0)	499 (0.0)
549 (37.5)	643 (12.5)	542 (0.0)	535 (0.0)	530 (12.5)	540 (0.0)	510 (0.0)	550 (0.0)
685 (12.5)	635 (0.0)	616 (12.5)	753 (12.5)	696 (12.5)	618 (0.0)	586 (0.0)	623 (0.0)
491 (12.5)	503 (0.0)	480 (0.0)	484 (0.0)	475 (0.0)	451 (0.0)	415 (12.5)	444 (0.0)
458 (0.0)	456 (0.0)	509 (0.0)	515 (0.0)	519 (0.0)	492 (0.0)	495 (0.0)	490 (0.0)
494 (0.0)	524 (12.5)	473 (0.0)	503 (0.0)	504 (0.0)	466 (0.0)	477 (0.0)	552 (0.0)
654 (0.0)	598 (12.5)	744 (0.0)	733 (0.0)	717 (0.0)	682 (12.5)	692 (0.0)	690 (0.0)
715 (0.0)	678 (0.0)	676 (0.0)	757 (12.5)	722 (0.0)	741 (0.0)	588 (12.5)	567 (0.0)
570 (25.0)	552 (0.0)	582 (0.0)	584 (0.0)	615 (0.0)	559 (12.5)	548 (0.0)	562 (25.0)
510 (0.0)	547 (0.0)	523 (0.0)	547 (0.0)	586 (0.0)	460 (0.0)	503 (0.0)	517 (0.0)
502 (0.0)	537 (0.0)	493 (0.0)	490 (0.0)	484 (0.0)	462 (0.0)	562 (12.5)	463 (0.0)
887 (0.0)	763 (0.0)	841 (12.5)	1155 (12.5)	813 (0.0)	788 (0.0)	723 (0.0)	836 (0.0)
554 (0.0)	749 (0.0)	666 (12.5)	673 (0.0)	592 (0.0)	624 (0.0)	732 (0.0)	681 (12.5)
662 (0.0)	589 (0.0)	537 (37.5)	618 (0.0)	567 (12.5)	592 (12.5)	566 (0.0)	538 (0.0)
691 (0.0)	768 (0.0)	659 (0.0)	644 (0.0)	665 (12.5)	710 (0.0)	657 (25.0)	750 (12.5)
505 (0.0)	581 (0.0)	549 (0.0)	527 (0.0)	549 (12.5)	493 (0.0)	491 (0.0)	535 (0.0)
879 (0.0)	851 (0.0)	853 (12.5)	874 (0.0)	749 (0.0)	1174 (0.0)	825 (0.0)	826 (0.0)
675 (25.0)	615 (0.0)	575 (0.0)	665 (0.0)	594 (0.0)	591 (0.0)	542 (0.0)	623 (0.0)
544 (25.0)	505 (0.0)	535 (0.0)	535 (0.0)	581 (0.0)	549 (12.5)	540 (0.0)	546 (0.0)
701 (0.0)	593 (12.5)	654 (12.5)	671 (0.0)	618 (0.0)	607 (0.0)	680 (0.0)	582 (12.5)

Appendix Q. Participant means for Experiment 6 as a function of Relatedness and Set Size for Response Times and (Percentage Errors)

Experiment 6							
Related				Unrelated			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
730 (0.0)	758 (0.0)	718 (0.0)	678 (0.0)	785 (0.0)	790 (0.0)	746 (0.0)	642 (0.0)
529 (0.0)	572 (0.0)	579 (0.0)	534 (0.0)	562 (0.0)	540 (0.0)	609 (0.0)	578 (0.0)
725 (0.0)	657 (0.0)	622 (0.0)	748 (0.0)	682 (12.5)	615 (0.0)	724 (12.5)	670 (0.0)
566 (0.0)	622 (12.5)	621 (0.0)	593 (0.0)	653 (0.0)	565 (0.0)	613 (0.0)	549 (12.5)
564 (12.5)	595 (0.0)	582 (0.0)	572 (0.0)	602 (0.0)	568 (0.0)	561 (25.0)	576 (0.0)
739 (0.0)	713 (0.0)	706 (0.0)	731 (0.0)	725 (0.0)	809 (0.0)	776 (12.5)	743 (0.0)
458 (0.0)	456 (0.0)	469 (0.0)	426 (0.0)	503 (25.0)	478 (0.0)	447 (0.0)	403 (12.5)
615 (0.0)	583 (12.5)	561 (12.5)	554 (0.0)	541 (12.5)	589 (12.5)	580 (0.0)	589 (0.0)
579 (0.0)	600 (0.0)	632 (0.0)	572 (0.0)	597 (0.0)	709 (0.0)	599 (0.0)	649 (0.0)
666 (0.0)	624 (0.0)	643 (0.0)	649 (0.0)	659 (0.0)	665 (0.0)	689 (0.0)	603 (0.0)
699 (0.0)	733 (0.0)	652 (0.0)	655 (0.0)	730 (0.0)	735 (12.5)	683 (12.5)	663 (0.0)
623 (25.0)	637 (0.0)	558 (12.5)	602 (12.5)	569 (12.5)	591 (12.5)	532 (0.0)	568 (25.0)
530 (0.0)	528 (0.0)	466 (0.0)	503 (0.0)	548 (25.0)	620 (0.0)	511 (0.0)	547 (0.0)
763 (0.0)	746 (0.0)	751 (12.5)	735 (0.0)	751 (0.0)	761 (0.0)	719 (0.0)	707 (12.5)
639 (0.0)	637 (0.0)	589 (0.0)	538 (12.5)	643 (25.0)	516 (12.5)	582 (0.0)	554 (0.0)
812 (0.0)	659 (0.0)	699 (0.0)	793 (0.0)	632 (0.0)	712 (0.0)	813 (0.0)	623 (12.5)
620 (0.0)	593 (0.0)	552 (0.0)	645 (0.0)	572 (0.0)	597 (0.0)	591 (0.0)	564 (0.0)
456 (12.5)	425 (12.5)	488 (12.5)	519 (25.0)	479 (0.0)	464 (0.0)	491 (12.5)	436 (0.0)
556 (0.0)	591 (0.0)	568 (0.0)	663 (0.0)	550 (0.0)	607 (0.0)	573 (0.0)	535 (0.0)
721 (0.0)	786 (0.0)	778 (0.0)	721 (0.0)	707 (0.0)	763 (0.0)	795 (0.0)	826 (0.0)
565 (25.0)	510 (0.0)	539 (0.0)	572 (0.0)	602 (0.0)	549 (0.0)	507 (0.0)	584 (0.0)
541 (0.0)	541 (12.5)	514 (12.5)	530 (12.5)	546 (0.0)	551 (0.0)	487 (0.0)	549 (12.5)
735 (0.0)	655 (0.0)	681 (0.0)	737 (0.0)	598 (0.0)	765 (12.5)	747 (0.0)	689 (0.0)
491 (12.5)	657 (25.0)	500 (0.0)	533 (12.5)	543 (12.5)	627 (0.0)	586 (25.0)	567 (0.0)
711 (12.5)	645 (0.0)	590 (0.0)	673 (0.0)	688 (0.0)	574 (12.5)	632 (0.0)	604 (0.0)
697 (0.0)	620 (0.0)	739 (0.0)	772 (12.5)	593 (0.0)	613 (0.0)	626 (0.0)	719 (0.0)
560 (0.0)	597 (0.0)	581 (0.0)	640 (0.0)	577 (0.0)	608 (0.0)	626 (25.0)	531 (0.0)
571 (12.5)	534 (12.5)	578 (0.0)	549 (0.0)	605 (0.0)	606 (0.0)	518 (0.0)	532 (12.5)
726 (25.0)	762 (0.0)	617 (0.0)	634 (12.5)	712 (0.0)	843 (0.0)	656 (0.0)	741 (0.0)
506 (12.5)	469 (25.0)	565 (0.0)	543 (0.0)	582 (12.5)	584 (12.5)	557 (0.0)	556 (0.0)
545 (12.5)	572 (12.5)	531 (12.5)	494 (0.0)	578 (12.5)	558 (12.5)	564 (0.0)	617 (0.0)
537 (12.5)	544 (12.5)	490 (0.0)	541 (0.0)	498 (0.0)	579 (0.0)	521 (0.0)	539 (0.0)

Appendix R. Participant means for Experiment 7 as a function of Relatedness and Set Size for Response Times and (Percentage Errors)

Experiment 7							
Related				Unrelated			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
780 (0.0)	763 (0.0)	796 (0.0)	673 (25.0)	740 (0.0)	842 (0.0)	794 (12.5)	751 (0.0)
751 (0.0)	743 (0.0)	717 (0.0)	734 (12.5)	773 (0.0)	792 (0.0)	816 (0.0)	802 (12.5)
781 (0.0)	847 (0.0)	840 (0.0)	851 (0.0)	831 (0.0)	864 (0.0)	822 (0.0)	886 (0.0)
696 (0.0)	642 (0.0)	618 (0.0)	716 (12.5)	713 (0.0)	744 (0.0)	812 (12.5)	709 (0.0)
735 (0.0)	713 (0.0)	654 (0.0)	708 (12.5)	710 (25.0)	670 (12.5)	718 (25.0)	740 (0.0)
778 (0.0)	745 (0.0)	709 (12.5)	762 (0.0)	817 (0.0)	859 (0.0)	837 (12.5)	814 (12.5)
769 (0.0)	690 (25.0)	739 (0.0)	809 (0.0)	747 (0.0)	810 (0.0)	782 (0.0)	781 (12.5)
684 (0.0)	702 (12.5)	721 (0.0)	731 (0.0)	776 (0.0)	807 (0.0)	813 (12.5)	732 (12.5)
789 (0.0)	843 (0.0)	897 (0.0)	768 (0.0)	857 (0.0)	878 (0.0)	764 (12.5)	730 (12.5)
786 (0.0)	821 (25.0)	883 (0.0)	881 (0.0)	839 (12.5)	920 (0.0)	848 (12.5)	848 (0.0)
1005 (0.0)	943 (0.0)	834 (0.0)	962 (0.0)	864 (0.0)	923 (25.0)	955 (0.0)	903 (0.0)
839 (0.0)	855 (0.0)	885 (0.0)	908 (0.0)	838 (0.0)	853 (12.5)	909 (0.0)	971 (0.0)
744 (0.0)	737 (0.0)	786 (12.5)	641 (0.0)	734 (25.0)	921 (0.0)	735 (12.5)	720 (0.0)
823 (0.0)	790 (0.0)	798 (0.0)	812 (0.0)	808 (0.0)	859 (12.5)	803 (0.0)	889 (0.0)
707 (25.0)	779 (0.0)	739 (0.0)	732 (0.0)	826 (0.0)	770 (0.0)	755 (0.0)	742 (0.0)
805 (0.0)	814 (0.0)	851 (0.0)	891 (0.0)	901 (0.0)	853 (0.0)	949 (0.0)	950 (0.0)
839 (0.0)	1002 (12.5)	931 (0.0)	930 (0.0)	855 (25.0)	882 (0.0)	988 (25.0)	813 (0.0)
678 (0.0)	788 (0.0)	715 (0.0)	730 (12.5)	754 (0.0)	735 (0.0)	761 (0.0)	776 (0.0)
796 (0.0)	729 (12.5)	818 (0.0)	878 (0.0)	819 (0.0)	812 (0.0)	795 (0.0)	843 (25.0)
871 (12.5)	814 (0.0)	829 (0.0)	749 (12.5)	797 (0.0)	766 (12.5)	901 (0.0)	785 (0.0)
780 (0.0)	796 (0.0)	764 (0.0)	737 (12.5)	791 (0.0)	754 (0.0)	747 (0.0)	734 (0.0)
725 (0.0)	731 (0.0)	784 (0.0)	724 (0.0)	764 (0.0)	731 (0.0)	737 (12.5)	747 (12.5)
721 (12.5)	787 (0.0)	767 (0.0)	712 (25.0)	752 (0.0)	776 (0.0)	766 (0.0)	739 (0.0)
800 (12.5)	898 (12.5)	859 (0.0)	875 (25.0)	736 (0.0)	768 (0.0)	808 (0.0)	813 (0.0)
636 (0.0)	616 (12.5)	634 (12.5)	614 (25.0)	689 (0.0)	628 (0.0)	650 (0.0)	668 (12.5)
944 (12.5)	868 (0.0)	946 (12.5)	860 (12.5)	868 (12.5)	897 (0.0)	863 (0.0)	867 (12.5)
910 (12.5)	926 (12.5)	797 (12.5)	915 (0.0)	831 (0.0)	882 (0.0)	849 (0.0)	765 (0.0)
743 (0.0)	893 (0.0)	878 (12.5)	827 (0.0)	871 (0.0)	854 (0.0)	865 (0.0)	816 (0.0)
872 (0.0)	886 (0.0)	780 (0.0)	771 (0.0)	770 (0.0)	827 (0.0)	783 (0.0)	771 (0.0)
780 (0.0)	748 (12.5)	829 (0.0)	782 (0.0)	826 (0.0)	733 (0.0)	787 (0.0)	747 (0.0)
848 (12.5)	776 (0.0)	847 (12.5)	878 (0.0)	920 (12.5)	780 (0.0)	867 (0.0)	854 (0.0)
756 (0.0)	789 (0.0)	785 (0.0)	772 (0.0)	851 (0.0)	842 (0.0)	804 (12.5)	821 (0.0)

Appendix S. Participant means for Experiment 8 as a function of Relatedness and Set Size for Response Times and (Percentage Errors)

Experiment 8							
Related				Unrelated			
setsize1	setsize3	setsize5	setsize7	setsize1	setsize3	setsize5	setsize7
688 (0.0)	751 (12.5)	717 (0.0)	704 (0.0)	930 (12.5)	755 (12.5)	819 (0.0)	882 (0.0)
996 (0.0)	995 (0.0)	986 (0.0)	944 (0.0)	990 (12.5)	981 (0.0)	1056 (0.0)	1054 (0.0)
854 (0.0)	727 (0.0)	940 (0.0)	850 (0.0)	811 (12.5)	827 (0.0)	815 (0.0)	839 (0.0)
814 (0.0)	788 (0.0)	778 (0.0)	771 (0.0)	830 (12.5)	730 (12.5)	757 (12.5)	799 (0.0)
796 (0.0)	778 (0.0)	782 (0.0)	786 (0.0)	750 (12.5)	817 (0.0)	797 (12.5)	760 (12.5)
820 (0.0)	785 (12.5)	752 (12.5)	772 (0.0)	879 (0.0)	740 (12.5)	787 (0.0)	749 (12.5)
875 (12.5)	830 (0.0)	860 (0.0)	965 (0.0)	972 (12.5)	890 (0.0)	822 (12.5)	913 (12.5)
688 (0.0)	618 (12.5)	735 (0.0)	688 (0.0)	702 (0.0)	667 (0.0)	676 (0.0)	729 (0.0)
747 (0.0)	879 (12.5)	837 (12.5)	740 (0.0)	809 (12.5)	778 (0.0)	827 (25.0)	907 (12.5)
692 (12.5)	753 (0.0)	696 (0.0)	680 (12.5)	690 (0.0)	731 (0.0)	648 (12.5)	699 (0.0)
819 (0.0)	842 (12.5)	744 (12.5)	760 (0.0)	816 (0.0)	850 (25.0)	773 (0.0)	787 (0.0)
680 (0.0)	749 (0.0)	809 (25.0)	739 (0.0)	713 (0.0)	813 (0.0)	699 (0.0)	818 (0.0)
732 (12.5)	667 (0.0)	679 (0.0)	714 (0.0)	792 (37.5)	719 (12.5)	772 (0.0)	688 (12.5)
803 (12.5)	763 (12.5)	766 (25.0)	852 (0.0)	798 (12.5)	781 (0.0)	875 (0.0)	830 (12.5)
715 (0.0)	715 (0.0)	758 (0.0)	701 (0.0)	774 (12.5)	736 (0.0)	698 (0.0)	731 (0.0)
859 (0.0)	792 (0.0)	731 (0.0)	798 (0.0)	726 (0.0)	779 (12.5)	775 (0.0)	756 (0.0)
753 (12.5)	775 (0.0)	712 (12.5)	741 (0.0)	795 (0.0)	729 (0.0)	744 (0.0)	690 (0.0)
772 (0.0)	805 (0.0)	769 (0.0)	823 (0.0)	832 (0.0)	800 (12.5)	827 (0.0)	742 (12.5)
888 (12.5)	755 (12.5)	779 (0.0)	742 (0.0)	832 (0.0)	798 (0.0)	751 (0.0)	746 (0.0)
734 (0.0)	728 (0.0)	743 (0.0)	772 (0.0)	773 (0.0)	705 (12.5)	815 (25.0)	805 (12.5)
728 (0.0)	744 (12.5)	851 (0.0)	786 (0.0)	816 (12.5)	747 (0.0)	647 (12.5)	783 (0.0)
679 (0.0)	771 (0.0)	879 (12.5)	777 (12.5)	722 (0.0)	866 (0.0)	808 (0.0)	756 (0.0)
757 (12.5)	706 (25.0)	761 (0.0)	744 (12.5)	782 (25.0)	736 (0.0)	788 (0.0)	781 (0.0)
699 (0.0)	621 (0.0)	666 (0.0)	727 (12.5)	671 (0.0)	703 (0.0)	729 (0.0)	706 (0.0)
730 (0.0)	882 (0.0)	846 (0.0)	854 (12.5)	823 (0.0)	839 (0.0)	901 (0.0)	884 (0.0)
728 (25.0)	749 (0.0)	696 (12.5)	712 (12.5)	792 (0.0)	698 (0.0)	689 (0.0)	752 (0.0)
954 (12.5)	862 (12.5)	835 (0.0)	882 (0.0)	1007 (0.0)	879 (12.5)	960 (0.0)	818 (0.0)
806 (0.0)	876 (12.5)	821 (25.0)	802 (0.0)	815 (0.0)	760 (0.0)	830 (0.0)	807 (0.0)
776 (0.0)	782 (0.0)	719 (0.0)	739 (0.0)	811 (0.0)	762 (0.0)	844 (0.0)	799 (0.0)
795 (12.5)	719 (12.5)	819 (0.0)	769 (0.0)	767 (0.0)	724 (12.5)	761 (0.0)	789 (12.5)
772 (0.0)	808 (12.5)	864 (0.0)	802 (25.0)	797 (12.5)	804 (0.0)	786 (0.0)	778 (0.0)
647 (25.0)	707 (0.0)	701 (12.5)	725 (0.0)	679 (12.5)	704 (12.5)	733 (0.0)	699 (0.0)