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The impact of perceptual grouping on repetition blindness

Andrea Jackson
University of Windsor

The impact of perceptual grouping on repetition blindness

By

Andrea M. Jackson

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The Impact of Perceptual Grouping on Repetition Blindness

by

Andrea Jackson

APPROVED BY:

____
K. Arnell, External Examiner
Brock University

____
M. Guarini
Department of Philosophy

____
C. Abeare
Department of Psychology

____
J. Singleton-Jackson
Department of Psychology

____
L. Buchanan, Advisor
Department of Psychology

13 June 2016

Declaration of Co-Authorship / Previous Publication

I. Co-Authorship Declaration

I hereby declare that this thesis incorporates material that is result of joint research, as follows: Parts I – II of this document include research that was jointly published by this author and her supervisor Dr. Lori Buchanan and partly based off this author's Master's thesis (Parts I – IA). In all cases, the key ideas, primary contributions, experimental designs, data analysis and interpretation, were performed by the author with the co-author serving in an advisory role.

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II. Declaration of Previous Publication

This thesis includes one original paper that has been previously published/submitted for publication in a peer reviewed journal, as follows:

Thesis Chapter	Publication title/full citation	Publication status
Part I - II	Jackson & Buchanan (2016). Survival of the grouped or three's a crowd? Repetition blindness in groups of letters and words. *Memory & Cognition*, *44*, 278-291. doi: 103758/sl3421-015-0556-9	Published. The final publication is available at Springer via http://dx.doi.org/103758/sl3421-015-0556-9

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Abstract

Repetition blindness is the failure to detect repetitions in a display of items that are presented visually and rapidly (Kanwisher, 1987). In contrast, perceptual grouping of nonlinguistic items has been found to prevent RB (Goldfarb & Treisman, 2011). Parts I – II review a series of experiments described in full in a paper by Jackson and Buchanan (2016) where the effect of perceptual grouping on linguistic items in an RB paradigm is explored. Participants viewed rapid serial visual presentation (RSVP) and brief simultaneous visual presentation (BSVP) streams populated with letters or words and provided a judgment of frequency. Two highly discrepant patterns of performance across participants were observed; one that evidenced repetition blindness for groups of three identical linguistic stimuli and one that demonstrated improved accuracy for those groups. Part III describes a series of novel experiments where participants viewed the BSVP displays used in Parts IA – II as well as BSVP displays where groups were made more salient through use of well-established grouping principles (e.g., proximity, similarity). A variable pattern of performance was observed, whereby grouping based on letter case demonstrated the strongest effect in the form of increased accuracy as compared to the non-grouped display. Grouping based on proximity and color similarity demonstrated somewhat increased accuracy, and grouping that contained a time component demonstrated no improvement in accuracy as compared to the non-grouped display.

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List of Abbreviations

BSVP…….. Brief simultaneous serial presentation

JOF……… Judgment of frequency

RB……….. Repetition blindness

RSVP……. Rapid serial visual presentation

RT………... Reaction Time

SG……….....Survival of the grouped

The impact of perceptual grouping on repetition blindness

Part I: Repetition blindness and spontaneous grouping[1]

Repetition blindness (RB) is a reliable and robust phenomenon that operates at the junction of perception, semantics, and memory. It is the failure to detect a repeated occurrence of a visual stimulus when items are presented rapidly (Kanwisher, 1987). For example, in a presentation consisting of four letters (ABAC), participants will only report one occurrence of the letter A. The speed of presentation needed to achieve this effect is about 100-150ms per item and can be attained either through use of rapid serial visual presentation (RSVP; single items presented sequentially) or brief simultaneous visual presentation (BSVP; all items presented at once) (N. Kanwisher, 1991; Luo & Caramazza, 1996).

Repetition blindness is assumed to occur at the level of encoding (Epstein & Kanwisher, 1999; Kanwisher, Kim, & Wickens, 1996; Luo & Caramazza, 1996; Neill, Neely, Hutchison, Kahan, & VerWys, 2002), prior to the convergence of auditory and visual inputs (Kanwisher & Potter, 1989), but see Armstrong and Mewhort (1995) for an alternative, memory-based account. This level of processing, though early, is still fairly abstract as RB acts on general stimulus identity rather than strict visual form. For example, it occurs even when items differ in case (e.g., “sofa” and “SOFA”) (Bavelier & Potter, 1992; Kanwisher, 1987; Schendan, Kanwisher, & Kutas, 1997) or in orientation (Coltheart, Mondy, & Coltheart, 2005; Corballis & Armstrong, 2007) and is attenuated

[1] Part I is the product of joint research published by Jackson and Buchanan (2016) and based off of Jackson’s Master’s thesis.

by personal saliency (Arnell, Shapiro, & Sorensen, 1999). Moreover, exact stimulus identity does not seem to be a requirement: repetition blindness has been found for a number of merely similar items, including those that share phonology (e.g., Bavelier, 1994; Bavelier & Potter, 1992), orthography (e.g., Harris & Morris, 2000, 2001, 2004; Morris & Harris, 2002), or conceptual/semantic identity (e.g., Bavelier, 1994).

Multiple explanations of repetition blindness exist, but the most well-received is Kanwisher's (1987) token individuation hypothesis in which the "blindness" is not for the items themselves, but for the distinction between items; the repeated items are not encoded as two discrete events. In this view, item perception involves the activation of a "type", or representation in long-term memory, and the creation of a "token", or memory for that particular instance of the type. Under conditions that produce RB, an item's type is repeatedly activated, but the creation of multiple tokens ultimately fails (Kanwisher, 1987).

Bavelier and Potter (Bavelier & Potter, 1992) extended this theory by positing that tokens are established via first the creation of said token and then the stabilization of that token in memory. Tokens for both presentations of the RB items may initially be created, but one is subsequently lost if not properly stabilized via registering information about the type (e.g., phonology, orthography) in memory. In another amendment to the theory, the existence of RB for novel objects has challenged the necessity of pre-existing types (Arnell & Jolicoeur, 1997).

The token individuation hypothesis (Kanwisher, 1987) provides an eloquent and thoughtful explanation of RB when considering two presentations of an item in an otherwise heterogeneous RSVP or BSVP display, as is the standard in the many RB studies. However, these heterogeneous displays typically have at least one non-identical item inserted between repeated items. What if that was not the case? In Kanwisher's (1987) view, RB should occur for successive identical items as the theory itself does not speak to the necessity of intervening items. Data consistent with this comes from Mozer (1989), who found that participants frequently underestimated counts of repeated letters. Specifically, Mozer (1989) investigated what Frick (1989) originally termed the homogeneity effect using frequency estimations of homogeneous versus heterogeneous letter strings. Mozer (1989) suggested that consistent underestimation of homogenous displays is the spatial analogue to the temporal effects Kanwisher (1987) theorizes produce RB.

Goldfarb and Treisman (2011) report results that differ from Mozer (1989) using simultaneous (BSVP) displays of colored symbols. Trials were composed of either a repetition with an intervening item (e.g., ABAB) or a repetition that was grouped (e.g., AABB). Quite expectedly, they observed RB for the repetition with the intervening item, but surprisingly found enhanced accuracy for the grouped condition. Coining this effect "the survival of the grouped," (hereafter referred to as SG) they suggested that their findings are consistent with extant theories of RB. Specifically, they propose that the group of items is seen as a single, multifaceted item (akin to a face being composed of eyes, nose, mouth, etc.) as opposed to individual units. As such, this group would require only a single episodic token (or object file, an analogous concept) (Goldfarb & Treisman, 2011).

Further evidence for a SG effect and support for Goldfarb and Treisman's (2011) suggestion that multiple items can become a meaningful single unit comes from Abrams, Dyer and MacKay (1996). In their experiment sentences were presented in RSVP in either syntactically correct parsings (e.g., “They wanted/to play sports/but sports/were not allowed”) or syntactically incorrect parsings (e.g., “They wanted to/play sports but/sports were not/allowed”). A repetition deficit for only the syntactically incorrect condition was hypothesized to be due to the ease of processing associated with syntactically correct grouping.

Goldfarb and Treisman (2011) suggested that the effect of grouping would not be as salient in RSVP as in BSVP, but prior research suggests that tokens can extend across time as well as space (Kahneman, Treisman, & Gibbs, 1992). For example, in apparent motion, two carefully timed and spatially separated items appear to be a single, moving object – or a single episodic token (Kahneman et al., 1992). The creation of object files, as described by Kahneman and colleagues (1983; 1992), is guided by the unity and continuity of an item. Accordingly, it could be argued that traditional RB displays are distinctly disconnected given the presence of an intervening item, but an uninterrupted display of three identical items would be likely to be perceived as a continuous, single unit.

Taken together, the evidence indicates that a pre-existing suggestion of a group or larger unit via an intrinsic grouping property (e.g., syntactically correct phrase, same colored forms), affords protection from repetition blindness (Abrams et al., 1996; Goldfarb & Treisman, 2011). This is consistent with the idea that the unit on which RB operates is the unit that is attended by the participant (Kanwisher & Potter, 1990). The phenomenon of apparent motion (Wertheimer, 1912) also supports the possibility of preserved perception of a group in a unified and continuous sequential display

(Kahneman et al., 1992), but Mozer's (1989) underestimations of simultaneous displays of homogenous letters appears to carry with it no such suggestion of a larger unit.

What remains unclear is if this homogeneity effect is restricted to Mozer's (1989) original conditions (homogenous items presented simultaneously) or if it can be found in traditional RB experimental conditions, which include heterogeneous RSVP displays. Specifically, would a group of identical items appear more "group like," or would the grouping be more salient, if it was presented in the context of other items with which it could be contrasted (e.g., AABB) as compared to a string of identical items (e.g., AAAA)? If the homogeneity effect is found in traditional RB experimental conditions with linguistic stimuli, it would suggest that such SG effects are limited to non-linguistic stimuli or syntactically grouped linguistic stimuli.

The experiments summarized below in Part IA aimed to determine whether Mozer's (1989) homogeneity effect can be found in traditional RB conditions (letters and words, RSVP and BSVP displays) or whether under such conditions SG would be found. The experiments used RSVP and BSVP displays of single letters or four letter words. The experiment described in Part II was designed to clarify and replicate results found in the initial experiments as well as further specific hypotheses about strategy.

The role of participant strategy was explored in Part IA using a judgment of frequency (JOF) response coupled with reaction times (RTs). According to Brown, Buchanan and Cabeza (2000), when JOFs are produced through a familiarity-based strategy (i.e., a "gut feeling"), RTs are relatively unchanged across conditions. Alternatively, when participants actively tally specific instances of a target item, RT increases with the number of items presented. Although such an increase in RT was seen in Wong and Chen (Wong & Chen, 2009) where participants performed a repetition blindness task in an RSVP format, the same effect has not been examined with grouped presentations.

In sum, Part IA summarizes Experiments 1-4 of my Master's thesis. Parts II and III describe experiments that form the empirical part of this dissertation. The experiments and logic from my Master's thesis set the stage for Parts II and III and will be described in detail below.

Part IA: Summary of Master's Thesis and Jackson & Buchanan (2016)[2]

The following experiments, described in detail in my Master's thesis and Jackson and Buchanan (2016), were designed to answer two questions. Under standard RB conditions using linguistic stimuli, 1) is a homogeneity or SG effect more likely? and 2) what strategy do viewers use to perform this task?

Two experiments were designed to determine whether SG or RB would result with RSVP displays of single letters and four-letter words. Participants were instructed to view the RSVP displays and then indicate how many times they saw a pre-identified target letter or word in the display. The target appeared in a given trial either once, twice, three times, or not at all. The pace of the presentation for each participant was set individually to achieve a 75% accuracy rate for unrepeated items in the experimental task. This cutoff was chosen based on prior literature (Kanwisher et al., 1996). Accuracy and RT data were collected.

[2] Part IA is the product of joint research published by Jackson and Buchanan (2016) and based off of Jackson's Master's thesis.

For both letters and words, decreased accuracy was observed at both two and three presentations of the target as compared to a single presentation. This suggests RB, rather than SG, can be found for linguistic stimuli presented in RSVP. Weak evidence for a possible item enumeration strategy was observed in both experiments as well, demonstrated by increased RTs at three target presentations as compared to one and two target presentations.

Two other experiments were designed as BSVP complements of the RSVP tasks, in which participants viewed simultaneous displays of letters or words. Similar to the RSVP experiments, RB was broadly observed across trials with more than one target presentation. However, unlike the RSVP experiments, the distribution of scores at three target presentations appeared to be bimodal with some participants performing particularly well (i.e., SG) and some participants performing poorly (i.e., RB). It was hypothesized that these distinct patterns of performances corresponded to different strategies used by participants. More specifically, it was predicted that those who performed well at three target presentations (hereafter referred to as high accuracy performers) were likely using a familiarity-based strategy and those who performed poorly (hereafter referred to as low accuracy performers) were likely using an enumeration-based strategy. Post-hoc analyses comparing RTs of high and low accuracy performers at three target presentations confirmed this supposition – high accuracy performers produced faster RTs.

The presence of high and low accuracy performers and distinct approaches to JOF in BSVP displays indicates that this form of presentation facilitates an SG effect in some participants. This processing advantage may be the product of a familiarity-based strategy or, alternatively, these participants may have used a modified item enumeration strategy whereby the targets are perceived as a single item, consistent with Goldfarb and Treisman's (2011) interpretation.

Part II: Jackson & Buchanan (2016), Experiment 1 of Dissertation[3]

Experiment 1, also described in Jackson and Buchanan (2016) was designed to address limitations present in my Master's thesis. Specifically, discovery and statistical analysis of the high and low accuracy performers were executed post hoc and were therefore largely exploratory. There was also a lack of randomization across experiments, which precluded cross-experiment comparisons. Additionally, an explicit question about strategy, which would have provided converging support, was not asked. Finally, the procedure to determine exposure duration did not consistently yield comparable accuracy rates in their corresponding experiments (i.e., accuracy was generally higher in the formal experiments as compared to the procedure designed to determine exposure duration). Given the high accuracy performers were found in multiple experiments to have higher accuracy across all target presentations, the possibility exists that the results of this group were largely driven by individuals who were performing at ceiling.

Accordingly, Experiment 1 directly tested the existence of groups of high and low accuracy performers; randomized participants across experiments; asked an explicit question regarding strategy; and addressed ceiling level performance by reducing exposure duration across participants. It was hypothesized that 1) high and low accuracy performers would be found even with the reduced exposure durations, 2) high accuracy

[3] Part II is the product of joint research, included as Experiment 5 of 5, published by Jackson and Buchanan (2016).

performers would have shorter, flatter RTs across target presentations as compared to low accuracy performers, and 3) high and low accuracy performers could be differentiated based on strategy use, with high accuracy performers using non-sequential strategies (perceiving display as a whole) and low accuracy performers using sequential strategies (rapid reading).

Method

Participants

Participants were 80 (75 used in analyses) University of Windsor undergraduate psychology students (70 female, mean age = 21, age range = 18-35). Number of participants exceeded the recommended sample size of 60 suggested by some of the smaller effect sizes (Cohen's d = .35) found in my Master's thesis and a power analysis using an alpha level of .05 and G*Power software (Faul, Lang, & Buchner, 2007). Participants were required to have normal or corrected-to-normal vision as well as English as a first language and received partial course credit.

Stimulus Materials and Design

Stimulus materials included the four experiments used in my Master's thesis compiled into a 2 x 2 x 3 mixed design with one between subjects variable (format) with two levels (RSVP or BSVP) and two within subjects variables. Within subjects variables included stimuli (words or letters) and targets (one, two, or three presentations).

For the experiments that used letters, all capital letters were used except the visually similar I and L, and U and V. For the experiments that used words, four-letter words with a low orthographic neighborhoods (between three and four) were used (Durda & Buchanan, 2006; See Appendix A). Words with low orthographic neighborhoods have been found to be better recalled in RB tasks and reduce the likelihood of orthographic similarity between unrepeated items (Coltheart & Langdon, 2003; Morris & Still, 2008). Although individual words varied by orthographic frequency, the average frequency of each condition did not. Words containing the letter M or W were excluded as they often resulted in the word size exceeding the two degrees of visual angle from the center of displays used in the BSVP version of the task.

For all tasks, items were presented in turquoise, Times New Roman, size 12 font on a black screen. Each trial was preceded and followed by stimulus masks composed of a row of four asterisks. For the RSVP experiments, items were presented centrally and sequentially. For the BSVP experiments, the display as a whole was centrally located with items presented simultaneously in the four quadrants of a square that was contained within 4X4 degrees of visual angle.

One hundred experimental trials were presented in each task. A trial included an initial presentation of the target item, a mask of four asterisks, the RSVP or BSVP display, a mask of four asterisks, and then a prompt (“How many?”) for the participants to indicate how many targets were in the display via a button press. Participants initiated each trial with a button press. There were 20 trials that included four unrepeated items, including one target (e.g., A-B-C-D); 20 trials with two unrepeated items and two targets with an intervening item (e.g., A-B-C-B); 20 trials with one unrepeated item and three uninterrupted presentations of the target (e.g.,: A-A-A-D); 20 trials composed of only three unrepeated items (example: A-B-C); and 20 trials composed of only two unrepeated items (example: A-B). These last two filler trial types were included to reduce guessing based on the assumption that all trials contained four letters. Intervening items in the

BSVP displays were created by placing the repeated targets on a diagonal so that targets were not horizontally or vertically adjacent. Trial types were randomized.

Participants were randomly assigned to either the RSVP or BSVP condition and viewed either the letter condition before the word condition or vice versa in a randomized, counterbalanced design. Exposure duration was set for all participants by determining the modal value for each condition (format and stimuli) from my Master's thesis and subtracting 14ms. This value was chosen based on the refresh rate of the computer monitor. For example, the modal exposure duration for the BSVP words experiment was 114ms. A set (vs. individually calibrated) exposure duration was chosen due to the difficulty encountered in my Master's thesis in mapping performance on a full report task, which was necessary to determine performance on unrepeated trials, to a task that required a JOF.

Using the above described formula, the exposure duration for the BSVP words condition in the current experiment was 100ms. For one condition, RSVP letters, the calculated exposure duration yielded unacceptably low (below the cut-off of 35%) accuracy in pilot testing. Therefore the modal value from the corresponding experiment, rather than the modal value minus 14ms was used. Exposure durations for each condition were as follows: RSVP letters: 58ms, BSVP letters: 58ms, RSVP words: 86ms, BSVP words: 100ms.

Apparatus and Procedure

Participants performed this task individually in normal room illumination. The task was executed on a PC using the Windows XP operating system and DirectRT software (Jarvis, 2012). Responses were made on a DirectRT compatible button bar labeled for the number of target items seen (zero through four) along with a button designated to initiate each trial. Each button press was mapped to corresponding numbers in the output file.

Participants first viewed the following instructions:

> "In this task, you will see a rapidly presented list of letters. There may be as few as two or as many four letters in each trial. At the start of each trial a single letter will be presented, this is the target letter. After all the letters have been presented, you will be prompted to indicate how many times you saw the target letter. As soon as you have a single numerical response in mind, respond with the corresponding number on the keypad. The first 10 trials will be for practice. Please press the OK button when you are ready to start the task."

Participants then completed ten practice trials. The researcher remained in the room for the first three practice trials to ensure understanding of task demands. Clarification was provided if necessary. The experimental trials began immediately after the 10 practice trials. After all the trials in a given condition were presented participants answered a multiple choice question about their primary strategy. Options were drawn from pilot data where participants were asked an open-ended question about strategy and included 1) I read each item as quickly as possible, 2) I viewed the items as part of a larger whole, 3) I went with my gut, 4) I mostly guessed, and 5) other. Following this they completed the second condition in the same manner.

Results

Separate analyses were conducted on the accuracy (mean percent correct) and RT data. Omnibus ANOVAs were initially used to elucidate overall trends in the data and to determine whether data could be collapsed across conditions in subsequent analyses. Cases were removed if a participant's accuracy on the unrepeated conditions for the standard or enhanced display was below 35%. This figure was based on previous literature suggesting that at this point, RB is no longer found for words (Harris & Morris, 2004). Accordingly, five participants in this experiment performed below the accuracy cut-off and therefore their data were not included in the analyses. Four of these participants had completed the RSVP version of the task with the other performing the BSVP version.

The overall ANOVA for accuracy by participants found main effects for number of targets, $F(1.95,138.51) = 132.83$, $p < .001$, $\eta^2 = .65$[4] and format, $F(1,71) = 26.34$, $p < .001$, $\eta^2 = .27$. No main effects of stimuli or order were found, but multiple interactions were observed involving both stimuli and order. Accordingly, type of stimuli was analyzed separately with condition as a between subjects variable and order was entered as a covariate in subsequent analyses.

Assignment to high and low accuracy groups was based on a pattern of performance observed in previous experiments. Specifically, inclusion into the high accuracy group was based on meeting one of two criteria, 1) accuracy at three presentations greater than accuracy at two presentations or 2) accuracy approximately equivalent across conditions (accuracy at one and three presentations within 5%). These criteria were meant to capture those who did not exhibit RB at three presentations, but may or may not have exhibited RB at two presentations. Accordingly, 21 participants

[4] Huhn-Feldt correction applied for violation of assumption of homogeneity of variances.

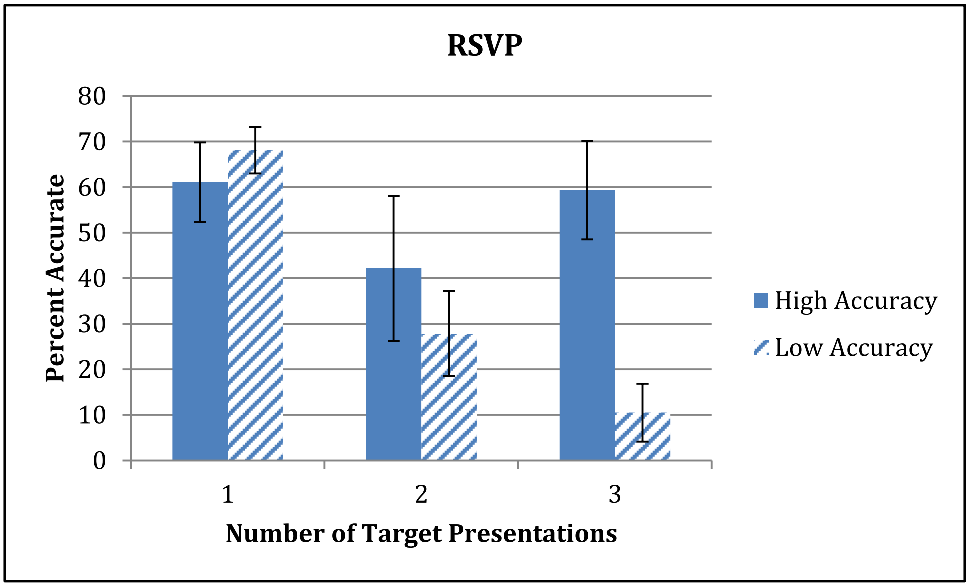
were classified as high accuracy performers when the stimuli were letters (54 low accuracy performers) and 25 participants were classified as high accuracy performers when the stimuli were words (50 low accuracy performers). Interestingly, group membership was not entirely consistent between stimuli. Specifically, although the participants were more likely to remain classified in the same group for both letters and words $\chi 2$ (1) = 7.44, p = .008, only 71% of participants remained in the same group across stimuli.

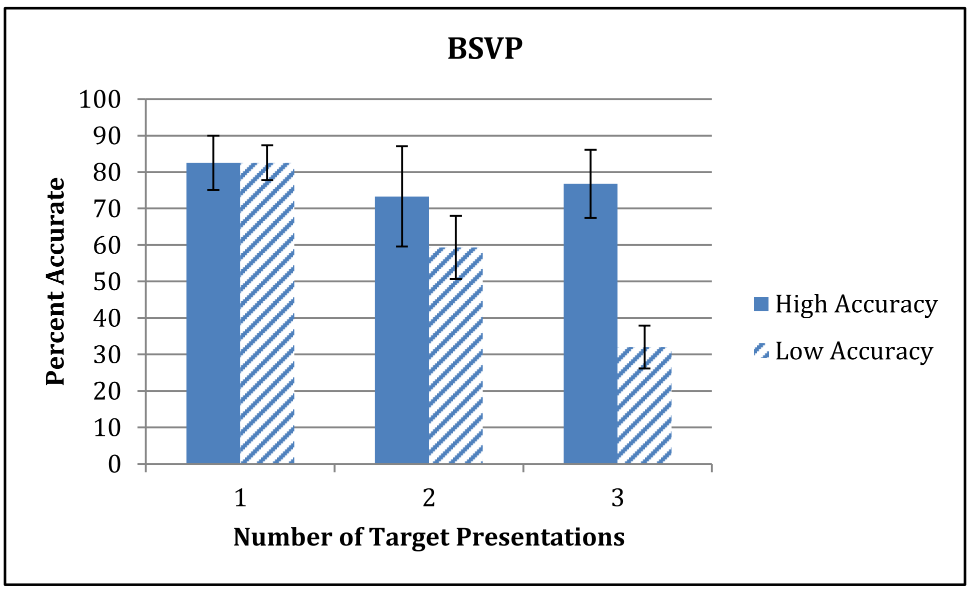
The ANOVA for accuracy for letters by group membership and format yielded main effects of group membership, $F(1,70) = 27.34$, $p < .001$, $\eta^2 = .28$, with those classified as high accuracy performers unsurprisingly yielding higher accuracy overall; format, $F(1,70) = 37.56$, $p < .001$, $\eta^2 = .35$, with overall higher accuracy in BSVP conditions; and targets, $F(2,140) = 7.23$, $p = .001$, $\eta^2 = .09$, with accuracy decreasing as number of targets increase. A group membership by targets interaction was found, $F(2,140) = 52.59$, $p < .001$, $\eta^2 = .43$. Follow-up independent samples t-tests revealed that those in the high accuracy group were found to have higher accuracy only at two, $t(73) = 2.09$, $p = .040$, and three, $t(73) = 9.77$, $p < .001$, target presentations. A format by targets interaction was also found, $F(2,140) = 4.15$, $p = .018$, $\eta^2 = .056$, suggesting a more linear, but shallow, decline in accuracy as targets increased in the BSVP condition (one target > two targets > three targets) as compared to the RSVP condition, which evidenced a sharp decline in accuracy from one to two target presentations, but no additional decline in accuracy from two to three target presentations. Descriptive statistics are presented in Figure 1.1.

In regard to strategy use for letters, the most commonly reported strategy was perceiving letters as shapes (n = 32), followed by rapid reading (n = 19), and perceiving the display as a whole (n = 17). Use of rapid reading vs. perceiving the display as a whole was not found to be associated with group membership. Those who viewed the displays as a whole were likewise not found to have higher accuracy at three presentations of the target as compared to those who read rapidly.

Figure 1.1

Mean Accuracy for Letters by Format, Group and Targets





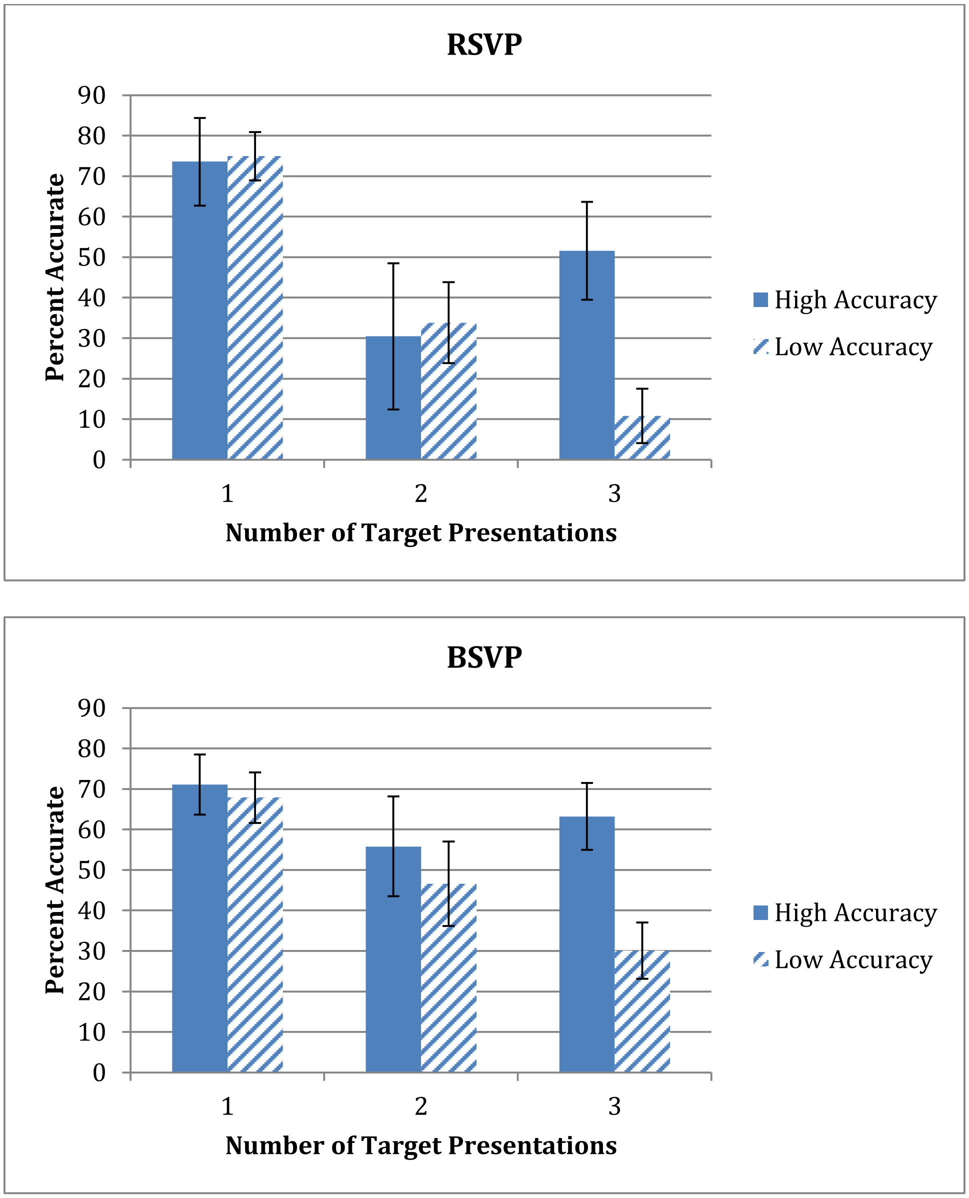
The ANOVA for accuracy for words by group membership yielded nearly identical results as the analysis of letters. Again, main effects were found for group, $F(1,70) = 12.51$, $p = .001$, $\eta^2 = .15$, with those classified as high accuracy performers again yielding higher accuracy overall; format, $F(1,70) = 6.60$, $p = .012$, $\eta^2 = .09$, with greater accuracy for BSVP as compared to RSVP; and number of targets, $F(1.88, 131.52) = 7.47$, $p = .001$, $\eta^2 = .10$[5], whereby accuracy was greater at one target presentation as compared to two, $t(74) = 8.97$, $p < .001$ and three target presentations, $t(74) = 10.89$, $p < .001$. Identical interactions were also found. There was a group membership by targets interaction, $F(1.88, 131.52) = 24.31$, $p < .001$, $\eta^2 = .26$[6]. Follow-up t-tests revealed that high and low accuracy performers only differed in accuracy at three target presentations, $t(73) = 8.51$, $p <$ 001. A format by targets interaction was also observed $F(1.88, 131.52) = 9.75$, $p < .001$, $\eta^2 = .12$[7], with a greater drop in accuracy at two, $t(73) = 3.06$, $p = .003$ and three, $t(73) = 4.28$, $p < .001$ target presentations in the RSVP as compared to the BSVP condition. Descriptive statistics are presented in Figure 1.2.

Strategy for words also mirrored that of letters. Specifically, the most frequently used strategies included rapid reading (n = 24), perceiving the display as a whole (n = 25), and focusing only on the shapes of the words (n = 20). Group membership was again not associated with use of rapid reading or perception of the whole. However, use of the latter strategy did yield higher accuracy at three target presentations as compared with rapid reading, $t(47) = 2.03$, $p = .05$.

[5, 6, 7] Greenhouse-Geisser correction applied for violation of assumption of homogeneity of variances.

Figure 1.2

Mean Accuracy for Words by Format, Group and Targets



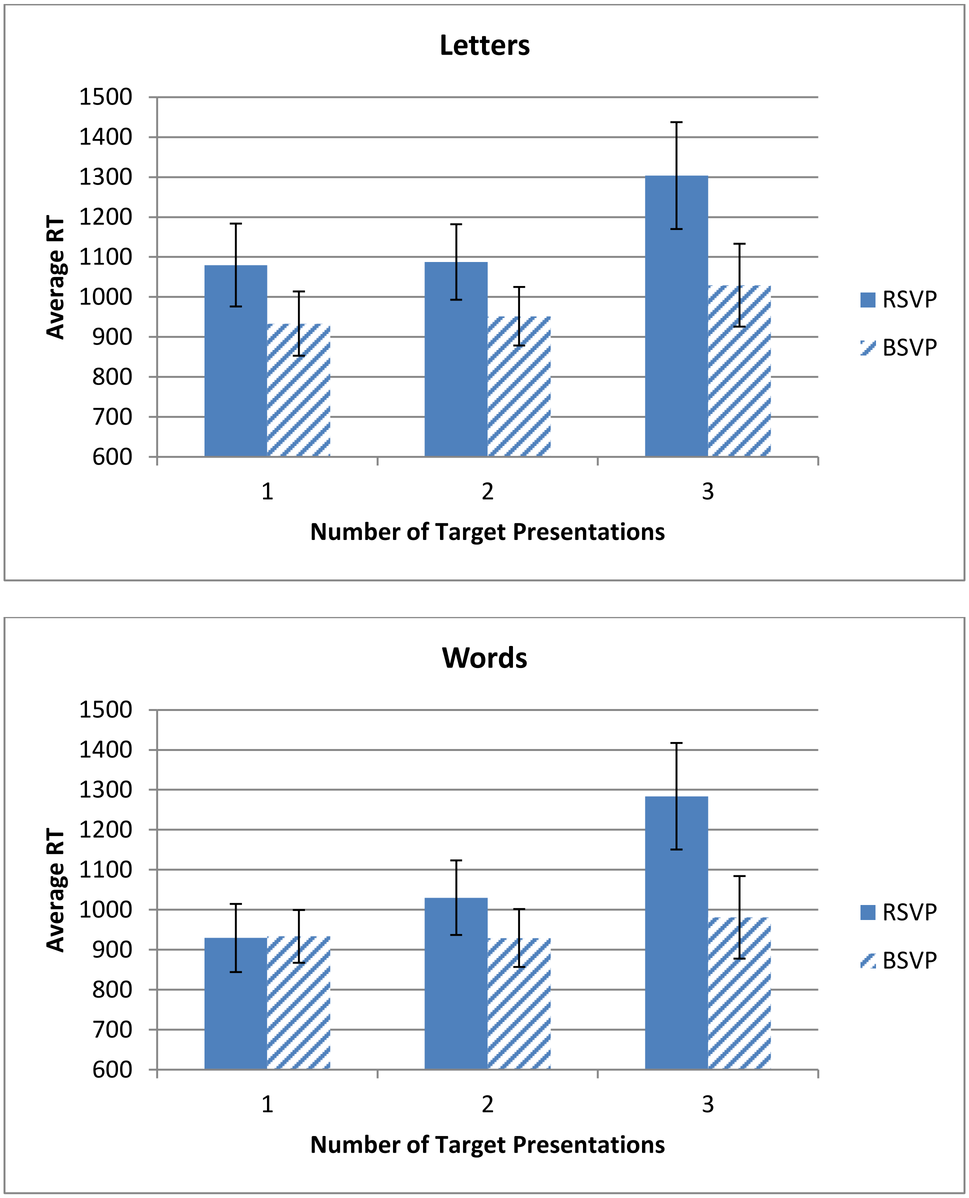
Ninety-one outlier trials were removed from the RT analysis, a total of 1.8% of data. Individual trials were removed if they exceeded 2.5 standard deviations of the condition's mean score for reaction time. One additional participant was also removed from analysis based on an analysis of outliers. The overall ANOVA for RT found main effects of format, $F(1,50) = 9.62$, $p = .003$, $\eta^2 = .16$, with BSVP faster than RSVP; order, $F(1,50) = 5.86$, $p = .019$, $\eta^2 = .11$, with those who viewed letters first exhibiting faster RTs overall; stimuli, $F(1,50) = 5.70$, $p = .02$, $\eta^2 = .10$, with faster RTs for words as compared to letters; and number of targets, $F(1.54,77.15) = 27.57$, $p < .001$, $\eta^2 = .36$[8], with RTs increasing as number of targets increase. Several interactions were also observed. Specifically, a stimuli by order interaction, $F(1,50) =38.76$, $p < .001$, $\eta^2 = .48$, revealed that RTs for letters were the same regardless of order, but that those who viewed letters first were faster when viewing words (887.83ms) as compared to those who viewed words first (1141.58ms). A format by number of targets interaction was also observed, $F(1.54,77.15) = 9.67$, $p = .001$, $\eta^2 = .16$[9], with a steeper increase in reaction time across targets seen for RSVP as compared to BSVP. Descriptive statistics are presented in Figure 1.3.

The ANOVA for RT for letters by group membership yielded no effect of group membership. Likewise, the ANOVA for RT for words by group membership yielded no effect of group membership. See Appendix C for additional reporting of results.

[8, 9] Greenhouse-Geisser correction applied for violation of assumption of homogeneity of variances.

Figure 1.3

Mean RT for Letters and Words by Format and Targets



Discussion

Results of Experiment 1 revealed that high and low accuracy performers were still distinguishable when overall accuracy was reduced via shortened exposure duration. Both high and low accuracy performers demonstrated equivalent accuracy at one target presentation, suggesting that the advantage shown by high accuracy performers was not simply due to this group being better at detecting targets overall. Moreover, when just the word condition is examined, the groups only differed in accuracy at three target presentations, where SG is hypothesized to occur. Interestingly, in the letter condition, the high accuracy performers demonstrated increased accuracy at both two and three target presentations as compared to the low accuracy performers. This suggests that letters and words may not always be processed similarly, with SG for letters occurring at two presentations.

In sum, with regard to strategy use as evidenced by RT, the previous performance patterns were not found. Instead both groups showed a uniform gradual increase in RT with increased number of target presentations. This may be because those with the fast, flat reaction times were actually those who were performing at ceiling in previous experiments. Given the reduced modal exposure duration in the current experiment, the issue of ceiling level performance was reduced.

Explicit questioning of strategy use also revealed no differences between groups, with those viewing the displays as a whole no more likely to be a member of the high or low accuracy performers. However, those who employed this strategy did tend to have higher accuracy at three target presentations overall. These findings suggest that explicit strategy may contribute to enhanced accuracy at three target presentations, but is not a determining factor in group membership.

Conclusion: Repetition blindness and spontaneous grouping

Taken together, data from my Master’s thesis and Experiment 1, described above, reveal an overall pattern of repetition blindness across repeated and grouped conditions for letters and words displayed either sequentially or simultaneously. In other words, when linguistic stimuli are presented in traditional RB experimental conditions, the majority of responses to grouped items closely resemble Mozer's (1989) homogeneity effect, with underestimation of repeated, identical items – or RB. This lack of grouping advantage may reflect a reader's propensity to group letters into words and words into phrases rather than to group linguistic stimuli by identity. Such an assertion is further supported by Abram and colleagues (1996) finding that RB can be prevented by presenting phrases in syntactically appropriate groups, suggesting that participants perceived the phrase as a unit containing a group of words.

A pattern of decreasing accuracy as number of target presentations increased appeared to be more pronounced in RSVP than BSVP, with BSVP tasks often yielding a shallower decline in accuracy for repeated and grouped trials. Reduced RB with BSVP over RSVP has often been observed in the literature and explained by automatic coding of location, which helps to distinguish identical items thus reducing RB (Epstein & Kanwisher, 1999; N. Kanwisher, 1991; Luo & Caramazza, 1996). Alternatively, Goldfarb and Treisman (2011) hypothesized that grouping is more salient in BSVP as compared to RSVP, suggesting that reduced RB when items are presented simultaneously may be due to SG.

In regard to predominate patterns across RT data, increasing RTs as number of target presentations increased was consistently observed across tasks using an RSVP format. This result is consistent with previous investigation into RB RTs by Wong and Chen (2009), who also found increased RTs as target presentations increased. The RT data for BSVP tasks often yielded no differences based on number of target presentations, but these analyses were underpowered. In the final experiment, RTs were found to increase as number of target presentations increased, but like the accuracy data, the slope of this increase was flatter in BSVP as compared to RSVP. Additionally, participants responded more quickly to BSVP displays overall as compared to RSVP displays.

These RT patterns suggest that the majority of participants likely used an enumeration-based strategy, whereby instances of the target were mentally tallied before the response was given. This is further supported by the responses of those participants asked explicitly about strategy use. In terms of stated strategy use, the majority of participants noted either reading rapidly or scanning rapidly for the general shapes of the letters and words. In contrast, fewer participants reported viewing the display as a whole or using a “gut” response. When analyzed by format, however, use of rapid reading or scanning is predominately found for RSVP as compared to BSVP formats. Specifically, BSVP tasks tended to yield more individuals who endorsed viewing the display as a whole and exhibited either no differences in RTs by number of target presentations or a much shallower increase in RTs by number of target presentations.

Although the data overall demonstrate a general lack of a SG and the presence of an enumeration-based strategy, a compelling number of participants displayed a markedly different pattern of responding. Specifically, these participants generated a pattern of accuracy that more closely resembled Goldfarb and Treisman’s (2011) results, with increased accuracy (SG) when viewing the grouped trials. This alternate pattern of performance first became evident in the BSVP tasks, where Goldfarb and Treisman (2011) hypothesized SG would be most salient. Experiment 1 confirmed the existence of the two patterns of performance while removing the possibility that those with increased accuracy for the grouped displays were just more accurate at detecting targets overall.

Although RTs for the high accuracy performers were initially observed to be faster and flatter than their less accurate counterparts, suggesting a difference in strategy, reducing ceiling level performance by decreasing exposure durations seemed to eliminate this difference. This suggestion of uniform strategy use may actually reflect strategy use at the time of recall, rather than encoding, as originally described by Brown and colleagues (2000). In other words, the two groups may initially perceive the stimuli differently, but use the same strategy to recall this perception when responding. However, explicit strategy use failed to differentiate between groups, despite the fact that those who viewed the displays as a whole did have increased accuracy as compared to those who simply read the displays as quickly as they could.

Given this, the individual differences in patterns of performances are more likely due to individual differences in responsiveness to the saliency of the grouped configuration than explicit selection of a specific strategy or conscious effort to group items. In fact, use of overt report has been found to be insufficient in measuring whether perceptual grouping has taken place (Lamy, Segal, & Ruderman, 2006). Interestingly, individual differences in responsiveness to perceptual grouping have been found to vary systematically with the reading ability in children. Specifically, the saliency of perceptual grouping has been demonstrated to increase as reading ability decreases (Williams & Bologna, 1985). Williams and Bologna (1985) suggest that this effect is due to poor readers being less proficient at selectively attending to items within a unit or group than good readers. Accordingly, it is possible that the high accuracy group may experience stronger grouping effects overall as well as demonstrate difficulty attending to individual items within a group.

Kahneman and colleagues (1992) suggested that the creation of a token could be driven either by bottom-up (i.e., stimulus) factors, as is likely the case in these experiments, or allocation of attention. Similarly, it has been repeatedly demonstrated that the unit affected by RB is the unit that is attended (Epstein & Kanwisher, 1999; Kanwisher, Driver, & Machado, 1995; Kanwisher & Potter, 1990). As such, it would be expected that those viewing the display as a whole would produce SG. The fact that this was not the case suggests that, despite viewing the display as a whole, participants still processed the items as individual units in order to comply with task demands. In other words, using the example of a face as the multifaceted item, participants viewed the face, but still tallied up how many eyes were present, leaving them vulnerable to RB.

Alternatively, having fixed response options for the strategy question may have obscured important distinctions and nuances in regard to strategy. For example, participants were only allowed to select one response to represent their primary strategy when they may have used a combination of strategies or varied their strategies across the course of the task. Additionally, those who selected a given response option may not actually represent a unified group, but distinct variations. This may be an explanation as to why those who viewed the display as a whole performed better than those who did not at three target presentations, but viewing displays as a whole was not associated with being in the high accuracy group.

The existence of the high and low accuracy performers also points to the main limitation of the studies. Namely, it was assumed that use of strategy would be consistent across individuals. Specifically, it was thought that the mere creation of groups (putting three items together in a display) would guarantee that participants would perceptually group the linguistic items if it were possible to do so. However, displaying identical items adjacent to one another does not appear to be sufficient, by itself, to produce perceptual grouping of linguistic stimuli in participants. Another important limitation was the relatively arbitrary criteria used to define the groups. Although a priori criteria for group membership were set, specifically the presence of a pattern similar to a SG effect vs. the presence of a pattern similar to a "homogeneity effect," this distinction was still largely based on researcher discretion.

Further research is needed in order to elucidate the conditions which lead participants to group linguistic stimuli as opposed to processing such stimuli sequentially. Specifically, systematic variation of bottom-up factors (e.g., proximity, color) and measurement of its effect on the number of participants who exhibit SG would be of interest. Additionally, provision of explicit instruction to participants to group displays would be necessary to determine whether the allocation of attention and explicit strategy use can have a meaningful impact on accuracy.

Repetition blindness is a robust effect, representing a failure at the junction of perception, semantics, and memory. Investigation of RB therefore is able to inform all three of these cognitive domains. Specifically, it provides insight into how language is perceived, accessed, and stored in the brain. The results of this study in particular revealed that under traditional RB conditions, whether a SG or homogeneity effect is observed might depend on individual differences in sensitivity to grouped items in a display.

Part III: Impact of grouping factors on repetition blindness

Perceptual grouping is a powerful phenomenon that allows individuals to understand and interpret their environment by organizing percepts into structured and meaningful wholes. These wholes may represent objects as simple as basic geometric shapes or as complex and multifaceted as a human being. Although grouping does not always require attention (Lamy et al., 2006; Moore & Egeth, 1997), it is clear that attention is attuned to the level of objects/units (Kahneman et al., 1992). Moreover, attentional resources deplete faster when searching between two perceptual units than inside of one unit (Desimone & Duncan, 1995). Accordingly, in situations where cognitive resources are limited and/or overtaxed, as is the case in repetition blindness, grouping represents a mechanism by which more information can be processed with the same limited resources. The present study seeks to determine the impact of specific grouping manipulations on repetition blindness using linguistic stimuli. As such, perceptual grouping will be discussed broadly along with the related concept of hierarchical processing. Finally, how grouping functions in the context of language and in other repetition blindness paradigms will be reviewed.

Gestalt principles are often evoked to describe perceptual organization and explain the structure of perceptual experience (Wagemans et al., 2012). Gestalt theory posits that structured wholes, which some believe to be composed of elementary sensations/parts, are greater than the sum of such parts and are considered the primary units of cognition (Wagemans et al., 2012). Further, these wholes arise from global processes and are generally thought to be perceived prior to recognition of their individual parts (Wagemans et al., 2012). Gestalt principles are used to describe how individuals are able to view “parts” as belonging together (i.e., grouping). They also appear to act across various levels of processing, both attentive and preattentive.

Perceptual grouping is a specific type of organizational phenomenon that explains why individuals perceive certain elements of the visual field as more united than others (Wagemans et al., 2012). The first principle of perceptual grouping described by Wertheimer (1923) was that of proximity, which states that items that are closer together are more often perceived as “going together.” Other principles of grouping include that of similarity (items similar in color, size, etc.); common fate (items that move together); symmetry (items that are part of a symmetric shape); parallelism (items that are parallel); continuity/good continuation (items that are aligned with each other); and closure (items that form a closed figure) (Wagemans et al., 2012). More recently established grouping principles include synchrony (items that change simulateneously; Alais, Blake, & Lee, 1998); common region (items within the same bounded area; Palmer, 1992); element connectedness (items that share a common border; Palmer & Rock, 1994); and uniform connectedness (regions having uniform properties; Palmer & Rock, 1994).

The question of whether grouping is a preattentive process or requires attention has been ubiquitous in the study of grouping, but a definitive answer has proven to be elusive. Early views described grouping as bottom-up and preattentive (e.g., Treisman, 1982). Later research, using implicit measures, promotes the view that perceptual grouping occurs both preattentively and with attention (Lamy et al., 2006; Moore & Egeth, 1997), and only with the allocation of attention (Wagemans et al., 2012). Additionally, different grouping principles appear to vary in their attentional demands with at least grouping by shape possible under conditions of inattention (Kimchi & Razpurker-Apfeld, 2004).

In addition to varying in attentional demands, grouping principles are not necessarily considered to have equal conceptual weight. For example, some are considered to be more general or overarching such as the principle of similarity (e.g., similar items are grouped together), which can also encompass the principles of common fate (e.g., items moving at similar velocities) and proximity (e.g., items positioned in similar areas) (Wagemans et al., 2012). The principle of uniform connectedness has been argued to be foundational or occurring earlier in the perceptual process in relation to other principles (Palmer & Rock, 1994), although this assertion has not been universally accepted (Peterson, 1994). Additionally, some principles have been expanded in recent years. For example, the principle of common luminance changes, an extension of common fate, posits that items that change luminance together tend to be grouped together, and was recently established by Sekuler and Bennett (2001).

Relatedly, the stage of visual processing at which grouping occurs might also depend on the principle being studied. According to Wagemans and colleagues (2012), grouping likely represents an ongoing, continuously updating process that occurs at multiple levels of perception. Palmer, Brooks and Nelson (2003) also argue that grouping is a multistage process, but offer two more nuanced explanations. Specifically, one possibility is that grouping occurs at minimum two times on two different representations: once on a preconstancy, two dimensional, retinal image-based representation and once on a postconstancy, three dimensional, object-based representation. The latter possibility most resembles Wagemans and colleagues (2012) view in that grouping is purported to occur as a continuously updating, iterative process that works on a single representation (Palmer et al., 2003).

Behrmann and Kimchi (2003) hypothesized that different types of perceptual grouping occur at different time points and at different levels in the visual system than others. Specifically, they posited that grouping by proximity and similarity occur earlier and at a lower level than grouping by closure. Beck and Palmer (2002) explored the time course of grouping principles by investigating their ability to be influenced by top-down processing. Specifically, they found that top-down processing in the form of expectation was found to be more influential on what they termed “extrinsic” grouping principles (i.e., grouping as a product of other elements in the display, such as common region) as compared to “intrinsic” grouping factors (i.e., grouping as a product of an inherent feature of the grouped items, such as grouping by color similarity). These top down influences were linked back to the time course at which each grouping principle acted, with later acting principles more vulnerable to top-down influences.

The time course of different principles has also been found to be associated with their relative strength. For example, grouping by proximity, which occurs relatively early (Behrmann & Kimchi, 2003; Ben-Av & Sagi, 1995; Han, Humphreys, & Chen, 1999) has been described as the most powerful grouping principle (Elder & Goldberg, 2002). In contrast, grouping that is characterized as weak or complex requires slow, effortful processing, which would necessarily occur later (Adam, Hommel, & Umiltà, 2003).

Perception of the parts of a visual array, the relationship of local parts to a global scene, and the visual processing of these components are central to discussions of hierarchical processing (Navon, 1977). Navon (1977) argues that for reasons of economy and efficiency, visual processing acts as a "multipass system" whereby cursory, global processing precedes, guides, and facilitates more detailed, local analysis. In general, individuals have been noted to initially process multi-element displays as single units or global structures and only later individuate the items (Behrmann & Kimchi, 2003; Navon, 1977). Further, Navon (1977) suggests that such local analysis occurs only when essential for completion of task demands. In a series of Stroop tasks, Navon (1977) used hierarchical stimuli (global letters composed of the same or different local letters) to demonstrate lack of interference from local elements when they were not necessary for successful task completion, while the inverse could not be found. In other words, participants were not able to subvert interference from the global letter when focused on local elements, implicating the primacy of global processing (Navon, 1977).

Hierarchical processing and a proposed multipass system have also been discussed in the context of fluent reading of text (McConkie & Zola, 1987; Rayner & Pollastek, 1989). Specifically, perception of the full global array of a spatially indexed page of text is processed initially. This array is then parsed into an object hierarchy composed of lines of text, words, and letters. Such parsing allows for efficient guidance of visual attention to a given level of the hierarchy based on task demands. Customarily, text is attended to at the level of word units and the selection of these units is based at least in part by their location (McConkie & Zola, 1987; Rayner & Pollastek, 1989). Note that similar to Navon's (1977) assertion, visual attention is only allocated to the very local, letter level if that information is necessary to complete the task (i.e., read or identify the word).

Bock, Monk, and Hulme (1993) suggested that in order for attention to be directed to a given level in McConkie and Zola's (1987) object hierarchy, the visual stimulus itself (e.g., a page of text) must first be decomposed into the appropriate parts (e.g., paragraphs, lines, and words). Given that gestalt grouping principles have already been implicated in the process of decomposition (Navon, 1977) and reading (Rayner & Pollastek, 1989), Bock and colleagues (1993) hypothesized that the principles of proximity (e.g., interletter spacing between and within words) and similarity (e.g., scale of letters) were the most likely candidates for this process. In fact, they found that when the scale of letters within a word was altered, reading times increased. It was argued that this effect was more likely due to disruption in grouping as opposed to disruption of feature recognition as the effect was found to be driven by the number of words disrupted as opposed to the number of letters altered (Bock et al., 1993).

Given that perceptual decomposition and establishment of an object hierarchy represent an initial, or perhaps prerequisite, step in reading, Williams and Bologna (1985) sought to determine whether grouping and reading ability were related. Specifically, they hypothesized that one's ability to selectively attend to elements in the same perceptual unit would be related to reading proficiency (Williams & Bologna, 1985). Using a card sorting procedure developed by Pomerantz and colleagues (Pomerantz & Garner, 1973; Pomerantz & Schwaitzberg, 1975), Williams and Bologna (1985) discovered that effects of grouping become more salient as reading ability decreases. In other words, poor readers had greater difficulty selectively attending to a single element within a perceptual unit, but were no different than their proficient reading peers in selectively attending to elements in separate perceptual units. These results held even when poor readers were provided with an effective strategy to properly guide selective attention (Williams & Bologna, 1985).

Perceptual grouping during reading has also been implicated in various Stroop experiments (Lamers & Roelofs, 2007; Reynolds, Kwan, & Smilek, 2010). By manipulating the grouping of words (e.g., increasing the space between the individual letters in the word) in their Stroop task, Reynolds and colleagues (2010) were able to predictably modulate the strength of the classic interference effect. Specifically, it was found that when the grouping of the color-words was reduced, so was the Stroop effect (Reynolds et al., 2010). Notably, increasing the spacing between letters has not been found to increase response latency in tasks requiring reading aloud (Mayall, Humphreys, & Olson, 1997) and tasks of semantic categorization of visually presented words when spacing did not exceed 2.25 spaces (Cohen, Dehaene, Vinckier, Jobert, & Montavont, 2008; Terry, Samuels, & LaBerge, 1976).

Given that grouping and repetition blindness are both phenomena that act at the level of perception and have been demonstrated with similar stimuli, it is not surprising that grouping and RB have both been found within a given task (de Haan & Rorden, 2010; Goldfarb & Treisman, 2011). Based on Desimone and Duncan’s (1995) suggestion that items within a perceptual group would not necessarily compete for attentional resources (as compared to competition between perceptual groups), de Hann and Rorden (2010) hypothesized that grouping would enhance perception of items by essentially rendering them non-competing. Moreover, they posited that grouping by similarity in particular would further enhance perception as it would not require the visual system to produce multiple tokens for a given type (as the “types” themselves would be different).

Accordingly, using simultaneous presentation of different, similar (e.g., "c" and "e"), and identical letters they were able to demonstrate RB for identical letters and grouping in the form of enhanced perception for letters with similar features. Goldfarb and Treisman (2011), on the other hand, found RB for two alternating colored symbols (i.e., dashes and dots) and grouping for non-alternating colored symbols. Their interpretation of these findings was that the non-alternating objects were grouped by color similarity and the resulting group was perceived as a single multi-faceted item (i.e., an object hierarchy) that only required a single episodic token.

These two studies demonstrated that it is possible to observe RB and grouping in a single experiment using relatively simple stimuli. Additionally, grouping processes have been implicated in the visual processing of language as described above. Moreover, the experiments described in Part I of this document seem to suggest that some individuals will group more complex stimuli such as four letter words into less conventional perceptual units (i.e., groups of identical words as opposed to phrases). However, another explanation for the data exists. Specifically, Kanwisher (1987) also described a refractory period hypothesis in which after the initial presentation of the target there is a period in which it cannot be activated again. Accordingly, the second presentation of the target often fails to reach the heightened threshold for activation and is thus not perceived. A third presentation of the target, however, may boost activation enough to reach this threshold.

Although the refractory period hypothesis has been criticized for its inability to account for RB that occurs for the first, rather than the second, target presentation (Neill et al., 2002; Wong & Chen, 2009), it remains prudent to rule out the influence of increased or summed activation as a mechanism behind the results found in Part I. One way to both rule out the refractory period hypothesis and provide further evidence that enhanced perception for three targets represents the influence of grouping is to manipulate the displays in line with known grouping principles. Although the similarity of color or proximity of the targets would not be expected to change the threshold of the refractory period or level of activation each target produced, it would be expected to enhance grouping.

The following experiments introduce grouping principles into the standard BSVP display used in Experiment 1 with the expectation that grouping for these displays will be enhanced in comparison to the original BSVP displays. Grouping advantage for enhanced displays is expected to take the form of higher accuracy at three target presentations and greater numbers of high accuracy performers for these displays as compared to the standard displays. Additionally, the relationship between proficiency of visual word recognition and grouping will be explored in adults via inclusion of a lexical decision task. This task is intended to mirror Williams and Bologna’s (1985) use of a diagnostic reading test to categorize “good” and “poor” readers, with the exception that it solely focuses on visual word recognition. Given that the ability to selectively attend to constituents of a perceptual group was the proposed link between reading ability and perceptual grouping, discrimination between words and pronounceable nonwords in a lexical decision task appropriately focuses the scope of assessment of reading ability in adults (Katz et al., 2012).

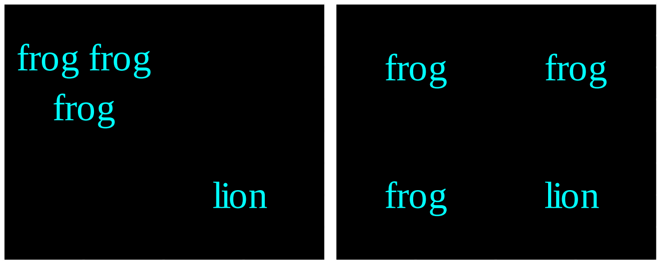
Experiment 2

Experiment 2 is based on grouping by proximity. Specifically, the influence of presenting three of the four words very close together spatially is compared to the standard BSVP display described in Part II. See Figure 2.1 for an example of the grouped by proximity vs. standard BSVP display. Additionally, participants received one of two sets of instructions for the enhanced displays. One set instructed participants that their primary task was to localize the grouped words and their secondary task was to indicate how many times they saw the target word in the entire display. In the second set of instructions, primary and secondary tasks were reversed so that the primary task was to indicate how many times they saw the target word. It was expected that accuracy would be higher at three presentations of the target word for the enhanced displays as compared to the standard displays and that accuracy would be the higher for those instructed to attend to the level of the group (i.e., those identifying the group's location) as the primary task as compared to those who for which it was their secondary task. A similar pattern was expected for the number of high accuracy performers found in each condition.

Participants also completed a lexical decision task comprised of words and pronounceable nonwords for the purpose of determining whether performance on this task reliably predicted performance on the primary task.

Figure 2.1

Enhanced vs. Standard Display



Method

Participants

Forty University of Windsor undergraduate psychology students were recruited for this experiment with 33 used in the analyses. Number of participants in all experiments exceeded the recommended sample size of 18 suggested by the medium effect size (Cohen's d = .56) found with previous studies of grouping and RB and a power analysis using an alpha level of .05 and G*Power software (Faul, Lang, & Buchner, 2007). Participants in this and the remaining studies described were required to have normal or corrected-to-normal vision as well as English as a first language and received partial course credit.

Stimulus Materials and Design

Stimulus materials for the main task consisted of the four-letter words with an orthographic neighborhood between three and four compiled from Wordmine2 (see Experiment 1 in Part II; Durda & Buchanan, 2006). Stimulus materials for the lexical decision task consisted of 50 ten-letter words with an orthographic frequency of less than 10 compiled from Wordmine2, and 50 pronounceable nonwords matched on length of subsyllabic segments, letter length, and transition frequencies compiled from Wuggy

(Keuleers & Brysbaert, 2010). See Tables 1 and 2 in Appendix A for word lists. Words were presented in size 12, Times New Roman font. The background screen was black and the words were turquoise.

The lexical decision task was a secondary task and, as such, will be described here in full. The lexical decision task was 100 trials of the above-described words and nonwords. These items remained on the screen until the participant responded. Participants completed this task prior to the primary task. First, they viewed the following instructions on the computer screen, “In this task, you will view a series of words. Some of the words are real words and some are made up. For example, ‘dog’ is a real word and ‘bex’ is a made up word. As soon as you can identify the word as real or made up, press the corresponding button on the keypad. Respond as quickly as you can without making mistakes.” Following these instructions they viewed 100 trials of the above-described randomly presented words and nonwords.

The experimental design for the main task is a 2 x 2 x 3 mixed design with instructions (targets vs. location) as a between subject factor, display as a within subjects factor (enhanced vs. standard), and number of targets as a within subjects factor (one, two, or three). Outcome variables include mean percent correct for each number of targets as well as overall number of high accuracy performers for each task and each set of instructions.

Enhanced and standard displays were presented in blocks, with the order of block presentation randomized across participants in a counterbalanced design. Instructions were also randomized and counterbalanced across participants. The trials included in the standard display block were similar to those described in Part I: Experiment 4, but with the trials consisting of less than four total words removed. This brought the total number of trials for this task down to 80, making the total length of the experiment more tolerable for participants.

For the enhanced display block, participants viewed 10 practice trials and 160 experimental trials presented in BSVP format. The experimental trials were composed of 40 trials with four unrepeated words not including the target word; 40 trials with four unrepeated words including one presentation of the target word; 40 trials that included four words with one repetition, i.e., two presentations of the target word displayed across a diagonal of the square; and 40 trials that included four words with three presentations of the target. In each block of 40 trials, 20 trials included three items that were grouped by proximity and contained all the targets, and 20 trials included a similar grouping that did not contain all of the targets. Order of trials was randomized. Trials in which the grouping did not contain all the targets were intended to reduce response bias based on the expectancy that the grouping would contain all the targets. These trials were not included in the analyses.

Trial exposure duration was based on previous experiments and was set for all participants at 100ms. The display as a whole was centrally located on the computer monitor with items presented simultaneously in a square that was contained within 4X4 degrees of visual angle.

Apparatus and Procedure

Participants performed this task individually in normal room illumination. The task was executed on a PC using the Windows 7 operating system and DirectRT software (Jarvis, 2010). Responses were made on a keyboard labeled for the number of target items seen (zero through four) and location of the group (upper right, upper left, lower right, lower left) along with a button designated to initiate each trial. Each button press was mapped to corresponding numbers in the output file.

Following the lexical decision task, participants then completed the main task. Participants entered their gender and age using the keyboard and then viewed the appropriate instructions on the screen. For the standard display block, participants viewed the following instructions, "In this task, you will see a rapidly presented display of words. There will be four words in the display. At the start of each trial a single word will be presented; this is the target word. After the display of words has been presented, you will be prompted to indicate how many times you saw the target word in the display. As soon as you have a single numerical response in mind, respond with the corresponding number on the keypad."

For the enhanced block, those with location as a primary task viewed the following instructions, "In this task, you will see a rapidly presented display of words. There may be as few as two or as many as four words in each trial. You have two tasks. Your PRIMARY task is to locate the group of words. The group will be multiple words clustered together. Your SECONDARY task is to indicate how many times you saw the target word in the display. The target word was the single word displayed at the start of the trial. After the display of words has been presented, you will be prompted to indicate 1) where the grouped words were located and 2) how many times you saw the target. As soon as you have a response in mind, respond with the corresponding location and then number on the keypad." For those with number of targets as the primary task, the instructions were altered to reflect that, but otherwise had the same wording.

Participants then performed ten practice trials for the given block. The experimenter remained in the room for three practice trials to ensure that the participant understood the task demands. To initiate each trial, participants pressed a button labeled "OK." Each trial began with the presentation of the target word, centrally located on the screen, for 1000ms. The target was followed by a blank screen for 500ms to ensure it was perceptually distinct from the BSVP display. The BSVP display consisted of one of the above described trial types and was be preceded and followed by stimulus masks composed of four centrally presented asterisks, presented for 100ms each. Several prompts then appeared on the screen reading, "Where?" followed by "How many?" (or vice versa depending on which task was primary) or just "How many?" for the standard task. These prompts remained on the screen until the participant pressed a button on the keyboard corresponding with the location of the group or number of targets he or she saw in the BSVP display. Participant accuracy (percent correct per condition) and response times were recorded.

As participants initiated each trial with a button press, the experiment was self-paced. Time to completion for the entire task was less than 60 minutes.

Results

A mixed between-within subjects ANOVA was conducted on the accuracy (mean percent correct) data, with instructions as a between subjects factor; display and number of target presentations as within subjects factors; and order entered as a covariate. Pairwise comparisons were made with Bonferroni corrections. Again, cases were removed if a participant's accuracy on the unrepeated conditions for the standard or enhanced display was below 35%. For the lexical decision task, cases were removed if a participant's accuracy fell below 70%. All following analyses were conducted in this manner unless otherwise stated.

Seven participants were excluded due to below cut-off performance on one or both tasks. Three of these participants were told that their primary task was to identify the number of targets.

The overall ANOVA for accuracy revealed no main effect or interactions involving instructions. As such, the following analyses were collapsed across instructions. A large main effect was found for targets, $F(2, 62) = 6.90$, $p = .002$, $\eta^2 = .18$. Compared to the unrepeated condition (M = 62%, SE = 1.8%, CI = 58-65%), an RB effect was found at two (M = 46%, SE = 3.3%, CI = 40-53%, $p < .001$) and three (M = 44%, SE = 3.1%, CI = 38-51%) target presentations. No difference was found between two and three target presentations.

No effect was found for display, however, a large display by targets interaction was revealed $F(2, 62) = 6.54$, $p = .003$, $\eta^2 = .17$. An ANOVA for accuracy at three target presentations by display, controlling for order found a large effect of display, $F(1, 31) = 6.44$, $p = .016$, $\eta^2 = .17$, whereby participants performed better at three target presentations on the enhanced displays (M = 47%, SD = 19%, CI = 40-53%) as compared to the standard displays (M = 42%, SD = 22%, CI = 34-50%). Descriptive statistics are presented in Figure 2.2.

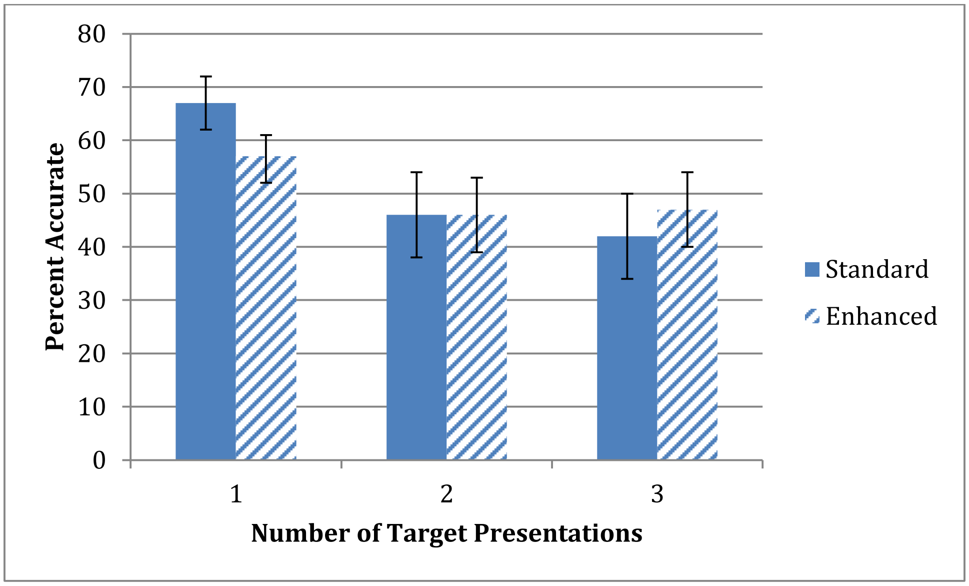
High vs. low accuracy performers were identical in number for each display (14 and 19, respectively). Only 55% of participants remained in the same group of performers across tasks. See Figure 11 for graphical depiction of high and low accuracy performers across all enhanced displays.

Given that the enhanced display produced greater accuracy at three target presentations, but not more high accuracy performers, it was hypothesized that this display was perhaps just enhancing the accuracy of those that were categorized as high accuracy performers. An ANOVA comparing performance at three target presentations on each display with high vs. low accuracy performer designation as a between-subjects variable and experiment order as a covariate confirmed this suspicion. For participants categorized as high accuracy performers on the enhanced displays, accuracy was greater at three target presentations on the enhanced as compared to the standard displays, $F(1, 28) = 7.00$, $p = .013$, $\eta^2 = .20$.

In regard to the lexical decision task, no participants were excluded. Performance on this task in terms of accuracy and reaction time was not found to significantly correlate with performance at three target presentations of enhanced displays. See Appendix C for additional reporting of results.

Figure 2.2

Mean Accuracy by Number of Target Presentations and Display



Discussion

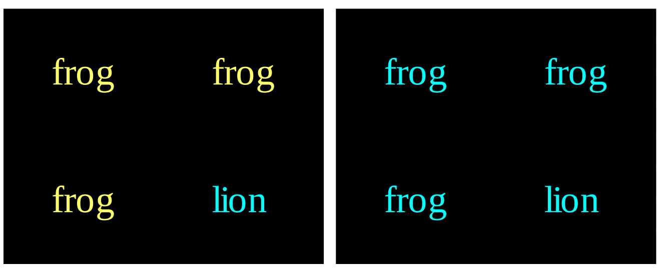
Experiment 2 revealed mixed results of the impact of grouping displays by proximity on repetition blindness. Although participants demonstrated increased accuracy at three presentations of the enhanced display as compared to the standard display, both displays produced the same number of high accuracy performers. Follow-up analyses revealed that the manipulation actually enhanced the accuracy of those that were categorized as high accuracy groupers, rather than produced more high accuracy performers. Additionally, instructing participants to direct their attention to the level of the group of words did not produce increased accuracy. Finally, performance on enhanced displays at three target presentations was not associated with performance on the lexical decision task.

Experiment 3

Experiment 3 groups by color similarity. In this experiment the standard BSVP display was compared to the effect of presenting three of the four words in one color and the fourth word in another color. See Figure 3.1 for an example of the grouped by color similarity vs. standard BSVP display. As in Experiment 2, participants received one of two sets of instructions for the grouped displays. The pattern of results hypothesized in Experiment 2 was also expected.

Figure 3.1

Enhanced vs. Standard Display



Method

Participants

Forty University of Windsor undergraduate psychology students participated in this experiment, with data from 32 used in the analyses.

Stimulus Materials and Design

Stimulus materials and design were the same as used in Experiment 2 with the exception that instead of the words being grouped by proximity, they were grouped by color. Specifically, the grouped words appeared in yellow and the instructions reflected this change (i.e., "The group will be multiple words presented in yellow...").

Apparatus and Procedure

The apparatus and procedure were the same as used in Experiment 2.

Results

Eight participants were excluded due to below cut-off performance on one or both tasks. Four of these participants were told that their primary task was to identify the number of targets.

The overall ANOVA for accuracy revealed large main effects for display, $F(1, 29) = 17.61$, $p < .001$, $\eta^2 = .38$ and number of targets, $F(2, 58) = 4.71$, $p = .013$, $\eta^2 = .14$. Display was found to be non-significant in the pairwise comparisons. Upon examination, it was found that the initial apparent differences in display were actually being driven by experiment order. Compared to the unrepeated condition (M = 64%, SE = 2.4%, CI = 59-69%), an RB effect was found at three (M = 45%, SE = 3.3%, CI = 39-52%, $p < .001$) but not two (M = 55%, SE = 3.5%, CI = 48-69%) target presentations.

Large display by number of targets, $F(2, 58) = 12.65$, $p < .001$, $\eta^2 = .30$ and display by instructions, $F(1, 29) = 5.48$, $p = .026$, $\eta^2 = .16$ interactions were observed. Despite demonstrating no difference between accuracy at one target presentation, individuals performed better when viewing enhanced displays at both two (M = 56%, SE = 3.7%, CI = 49-64%, $p < .004$) and three (M = 47%, SE = 3.7%, CI = 40-55%, $p < .001$) target presentations as compared to standard displays (two targets: M = 53%, SE = 3.6%, CI = 45-60%; three targets: M = 43%, SE = 3.2%, CI = 38-50%). In regard to the display by instructions interaction, participants who were told that their primary task was the group, performed worse when viewing enhanced displays (M = 51%, SE = 3.5%, CI =

44-58%, p = .026) as compared to standard displays (M = 55%, SE = 3.4%, CI = 48-62%). Descriptive statistics are presented in Figure 3.2.

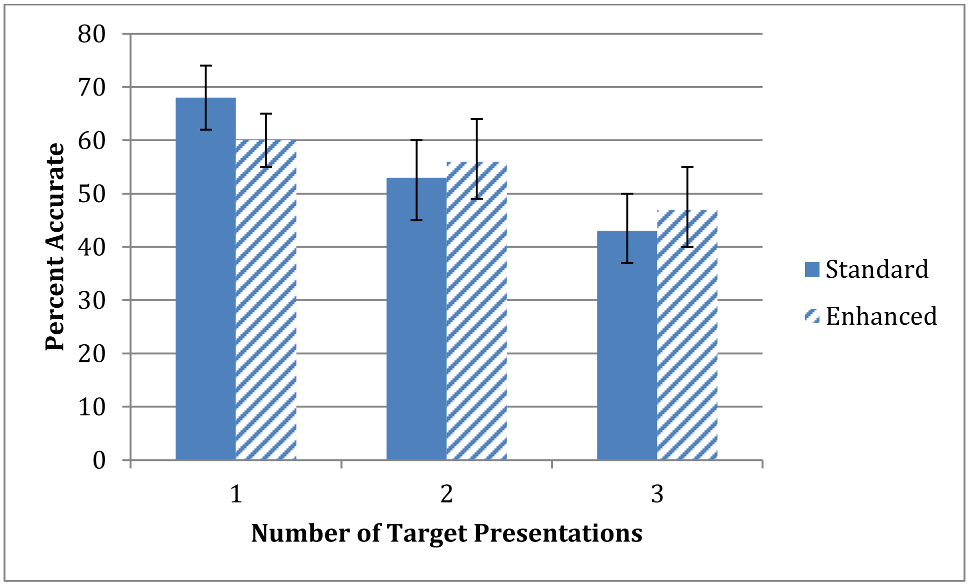
There was no difference in number of high vs. low accuracy performers across displays. Only 63% of participants remained in the same group of performers across tasks. See Figure 7 for graphical depiction of high and low accuracy performers across all enhanced displays.

Again, it was hypothesized that the enhanced display was improving the accuracy of those that were already likely to be categorized as high accuracy performers. An ANOVA comparing performance at three target presentations on each display with high vs. low accuracy performer designation as a between-subjects variable and experiment order as a covariate again confirmed this suspicion. For participants categorized as high accuracy performers on the enhanced displays, accuracy was greater at three target presentations on the enhanced as compared to the standard displays, $F(1, 29) = 5.74$, p = .023, η^2 = .17.

In regard to the lexical decision task, 1 participant was excluded for below cut off accuracy. Performance on this task in terms of accuracy and reaction time was not found to significantly correlate with performance at three target presentations of enhanced displays. See Appendix C for additional reporting of results.

Figure 3.2

Mean Accuracy by Number of Target Presentations and Display



Discussion

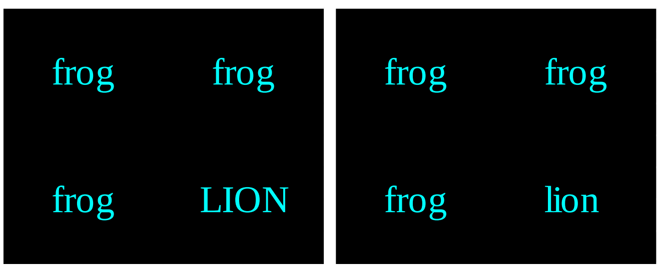
As in Experiment 2, participants demonstrated increased accuracy – this time at both two and three target presentations – when viewing the enhanced displays, but the enhanced displays did not produce a greater number of high accuracy performers. Instead, as in Experiment 2, the enhanced display increased the accuracy of those categorized as high accuracy performers. Additionally, it was observed that the instruction to attend to displays at the level of the group reduced accuracy instead of augmenting it as predicted. This may suggest that instead of facilitating perception, emphasizing the importance of the group and its location may have detracted from the task of enumerating targets. Finally, again as in Experiment 2, performance on enhanced displays at three target presentations was not associated with performance on the lexical decision task.

Experiment 4

Experiment 4 was based on grouping by similarity of size and shape (i.e., letter case). Again, the standard BSVP display was compared to the effect of presenting three of the four words in lowercase and the fourth word in uppercase. See Figure 4.1 for an example of the grouped by case vs. standard BSVP display. As in previous experiments, participants received one of two sets of instructions for the grouped displays. The pattern of results hypothesized in previous experiments was also expected.

Figure 4.1

Enhanced vs. Standard Display



Method

Participants

Sixty University of Windsor undergraduate psychology students participated in this experiment, with data from 45 used in analyses. A greater number of participants was required for this experiment than previous experiments based on a post-hoc power analysis with the original 40 participants collected (observed power = .42 for a primary analysis) and the number of participants that needed to be excluded.

Stimulus Materials and Design

Stimulus materials and design were the same as used in previous experiments with the exception that instead of the words being grouped by proximity or color, they were grouped by size and shape (i.e., case). The grouped words appeared in lowercase and the instructions again reflected this change (i.e., "The group will be multiple words presented in lowercase...").

Apparatus and Procedure

The apparatus and procedure were the same as used in Experiments 2 and 3.

Results

Fifteen participants were excluded due to below cut-off performance on one or both tasks. Eight of these participants were told that their primary task was to identify the number of targets.

The overall ANOVA for accuracy revealed large main effects for display, $F(1, 42) = 6.98$, $p = .012$, $\eta^2 = .14$; task instructions, $F(1, 42) = 5.09$, $p = .029$, $\eta^2 = .11$; and number of targets, $F(1.89, 79.20) = 6.82$, $p = .002$, $\eta^2 = .14$[10]. Specifically, participants performed better overall on the standard task (M = 56%, SE = 2.3%, CI = 51-61%) as compared to the enhanced task (M = 51%, SE = 2.4%, CI = 46-55%). They also performed better when told that their primary task was to identify the number of targets (M = 58%, SE = 3.2%, CI = 52-65%) as compared to when they were told that their primary task was to locate the group (M = 48%, SE = 3.1%, CI = 42-55%). In regard to the number of targets, compared to the unrepeated condition (M = 62%, SE = 1.8%, CI = 59-66%), an RB effect was found at two (M = 47%, SE = 2.9%, CI = 41-53%, $p < .001$) and three (M = 51%, SE = 3.1%, CI = 44-57%, $p = .001$) target presentations. No difference was found between two and three target presentations.

[10] Huynh-Feldt correction used for violation of assumption of sphericity.

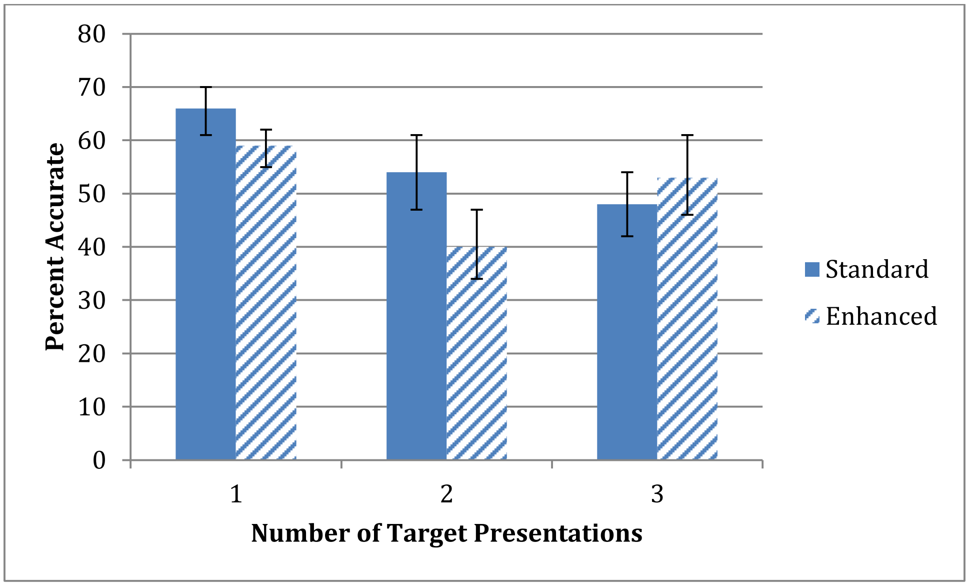
A large display by number of targets interaction was observed, $F(2, 84) = 8.46$, $p < .001$, $\eta^2 = .17$. When participants viewed the standard display, they performed better on both one (M = 66%, SE = 2.3%, CI = 61-71%, $p = .002$) and two (M = 54%, SE = 3.2%, CI = 48-61%, $p < .001$) target presentations as compared to when they were viewed the same number of targets in the enhanced displays (one target: M = 59%, SE = 1.9%, CI = 55-62%; two targets: M = 40%, SE = 3.2%, CI = 34-47%). When compared to the pattern of performances found in other tasks (See Table 10 in Appendix C), this was the only experiment in which the enhanced condition produced greater RB at two target presentations. Conversely, participants performed better at detecting three targets when viewing the enhanced displays (M = 53%, SE = 3.7%, CI = 46-61%, $p = .038$) as compared to the standard displays (M = 48%, SE = 3.0%, CI = 42-54%). Descriptive statistics are presented in Figure 4.2.

Participants were more likely to be classified as high accuracy performers when viewing enhanced displays (n = 35) as compared to standard displays (n = 17), $\chi^2(1) = 11.42$, $p < .001$. Only 36% participants remained in the same group of performers across conditions. See Figure 7 for graphical depiction of high and low accuracy performers across all enhanced displays.

In regard to the lexical decision task, 1 participant was excluded for below cut off accuracy. Performance on this task in terms of accuracy and reaction time was not found to significantly correlate with performance at three target presentations of enhanced displays. See Appendix C for additional reporting of results.

Figure 4.2

Mean Accuracy by Number of Target Presentations and Display



Discussion

Displays grouped by case yielded both increased accuracy at three presentations of the target item and an increased number of high accuracy performers. This suggests that enhancing the saliency of the group of words improved perception for those words. Conversely, this form of grouping also produced greater RB for the single repetition, suggesting that this form of grouping can create a greater disadvantage for non-homogenous groups. Direct instruction to attend to the level of the group as a primary task actually hindered performance, indicating a cognitive cost to prioritizing the location of the group over the number of targets. A cognitive cost was also apparent in the enhanced task as participants performed worse at one and two target presentations as compared to the standard task. This likely reflects a depletion of cognitive resources as the requirement to perform two tasks necessarily divides attention. Finally, similar to

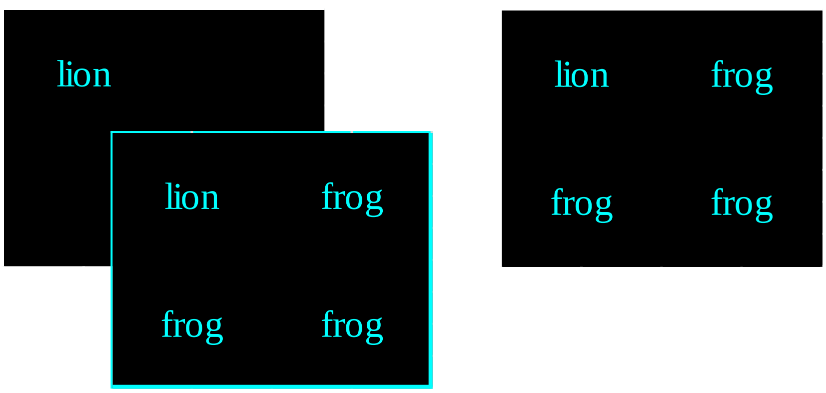
Experiments 2-3, performance on the enhanced displays at three target presentations was not associated with performance on the lexical decision task.

Experiment 5

Experiment 5 was based on grouping by common fate. Again, the standard BSVP display was compared to the effect of presenting three of the four words 100ms after the onset of the first word. See Figure 5.1 for an example of the grouped by common fate vs. standard BSVP display. As in previous experiments, participants received one of two sets of instructions for the grouped displays. The pattern of results hypothesized in Experiment 2 was also expected.

Figure 5.1

Enhanced vs. Standard Display



Method

Participants

Forty University of Windsor undergraduate psychology students participated in this experiment, with data from 36 used in analyses.

Stimulus Materials and Design

Stimulus materials and design were the same as used in Experiments 2-4 with the exception that the words were grouped by common fate (i.e., time of onset). The grouped words appeared 100ms after the first word and the instructions again reflected this change (i.e., “The group will be multiple words presented slightly later...”).

Apparatus and Procedure

The apparatus and procedure was the same as used in Experiments 2-4.

Results

Four participants were excluded due to below cut-off performance on one or both tasks. Two of these participants were told that their primary task was to identify the number of targets.

The overall ANOVA for accuracy revealed large main effects for display, $F(1, 33) = 7.22$ $p = .011$, $\eta^2 = .18$ and number of targets, $F(2, 66) = 5.32$, $p = .007$, $\eta^2 = .14$. Display was found to be non-significant in the pairwise comparisons. Compared to the unrepeated condition (M = 64%, SE = 2.2%, CI = 60-69%), an RB effect was found at two (M = 52%, SE = 2.6%, CI = 46-57%, $p < .001$) and three (M = 48%, SE = 3.3%, CI = 41-55%, $p < .001$) target presentations. No difference was found between two and three target presentations. Descriptive statistics are presented in Figure 5.2.

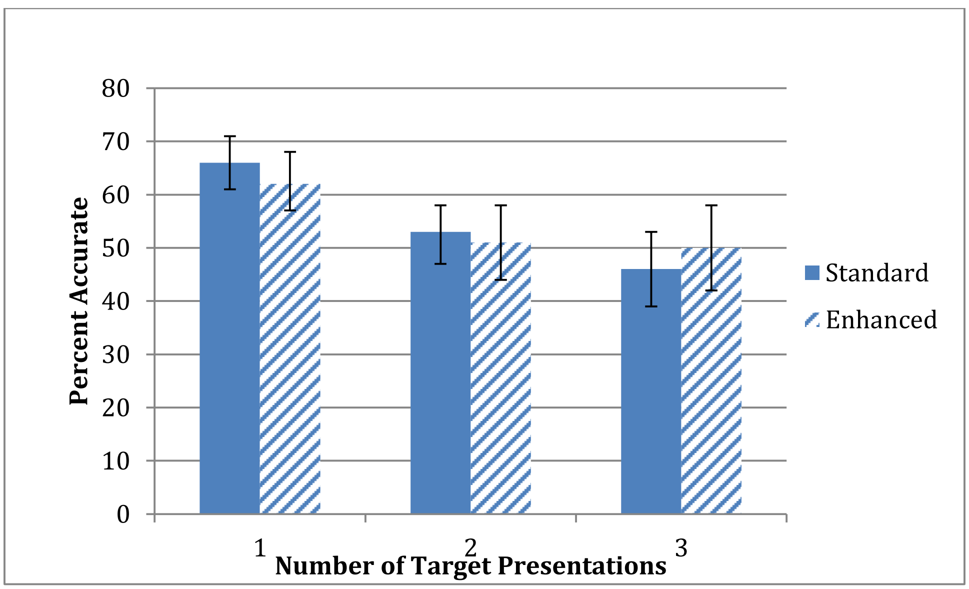
A large instructions by display, $F(1, 33) = 5.14$, $p = .03$, $\eta^2 = .14$ interaction was observed, but was found to be non-significant in the pairwise comparisons as this effect, too, was driven by order of experiments.

There was no difference in number of high vs. low accuracy performers across displays. Only 67% of participants remained in the same performer group across conditions. See Figure 7 for graphical depiction of high and low accuracy performers across all enhanced displays.

In regard to the lexical decision task, 2 participants were excluded for below cut off accuracy. Performance on this task in terms of accuracy and reaction time was not found to significantly correlate with performance at three target presentations of enhanced displays. See Appendix C for additional reporting of results.

Figure 5.2

Mean Accuracy by Number of Target Presentations and Display



Discussion

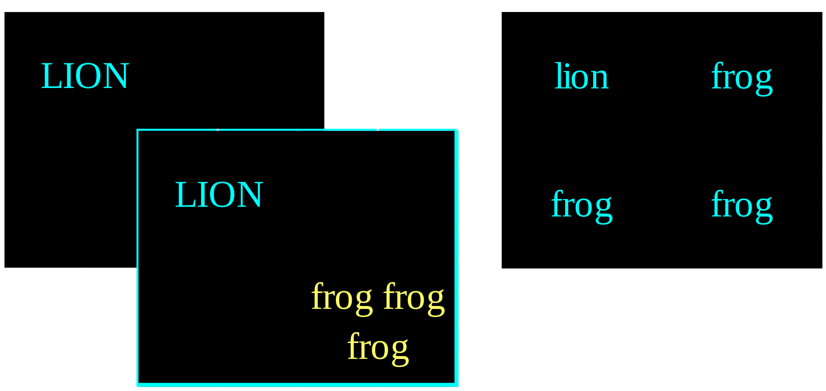
Grouping by common fate did not impact performance on this task as evidenced by a lack of improvement in performance on the enhanced task at three target presentations and similar numbers of high accuracy performers across displays. Similarly, performance on the enhanced task at three target presentations was not associated with performance on the lexical decision task.

Experiment 6

Experiment 6 used a combination of all the principles outlined in Experiments 2-5. Here the standard BSVP display was compared to the effect of presenting three of the four words very close spatially, in yellow, in lowercase, and 100ms after the onset of the fourth word. This combination was used to ensure maximal saliency of the group. See Figure 6.1 for an example of the grouped by multiple factors vs. standard BSVP display. As in Experiments 2-5, participants received one of two sets of instructions for the grouped displays. The pattern of results described in Experiments 2-5 was also expected.

Figure 6.1

Enhanced vs. Standard Display



Method

Participants

Sixty University of Windsor undergraduate psychology students participated in this experiment, with 41 used in analyses. As in Experiment 4, a greater number of participants was required for this experiment as compared to previous experiments based on a post-hoc power analysis with the original 40 participants collected (observed power = .42 for a primary analysis) and the number of participants that needed to be excluded.

Stimulus Materials and Design

Stimulus materials and design were the same as used in Experiments 2-5 with the exception that the words were grouped by all of the previously described principles. The instructions again reflected this change (i.e., "The group will be multiple words clustered together, yellow, lower case, and presented slightly later.").

Apparatus and Procedure

The apparatus and procedure will be the same as used in Experiments 2-5.

Results

Nineteen participants were excluded due to below cut-off performance on one or both tasks. Nine of these participants were told that their primary task was to identify the number of targets.

The overall ANOVA for accuracy revealed a large main effect for number of targets, $F(2, 76) = 7.719$, $p = .001$, $\eta^2 = .17$. Compared to the unrepeated condition (M = 60%, SE = 2.2%, CI = 56-64%), an RB effect was found at two (M = 45%, SE = 2.6%, CI = 40-50%, $p < .001$) and three (M = 42%, SE = 2.8%, CI = 37-48%, $p < .001$) target presentations. No difference was found between two and three target presentations. Descriptive statistics are presented in Figure 6.2.

There was no difference in number of high vs. low accuracy performers across displays. Only 66% of participants remained in the same performer group across conditions. See Figure 7 for graphical depiction of high and low accuracy performers across all enhanced displays.

In regard to the lexical decision task, no participants were excluded for below cut off accuracy. Performance on this task in terms of accuracy and reaction time was not found to significantly correlate with performance at three target presentations of enhanced displays. See Appendix C for additional reporting of results.

Figure 6.2

Mean Accuracy by Number of Target Presentations and Display

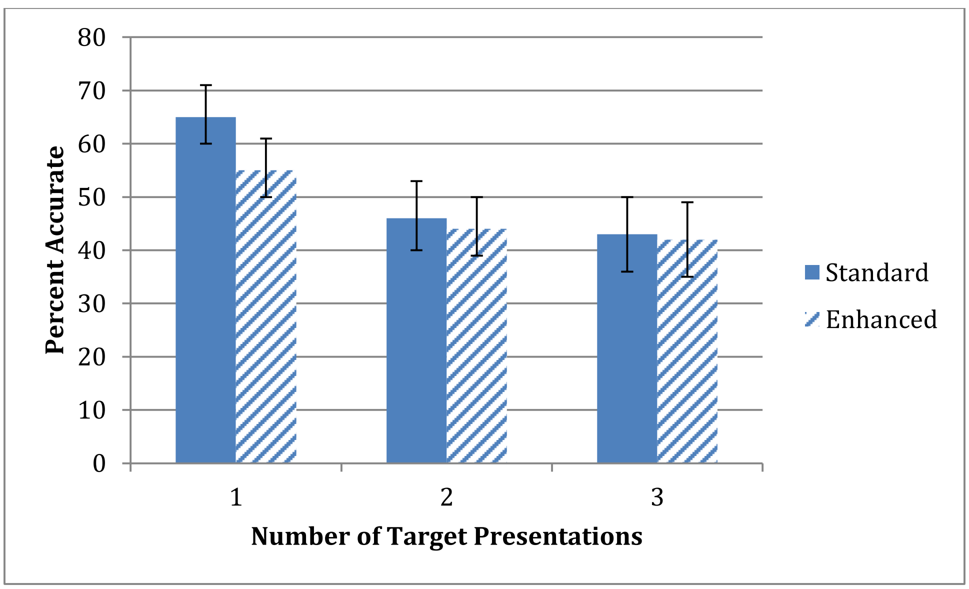
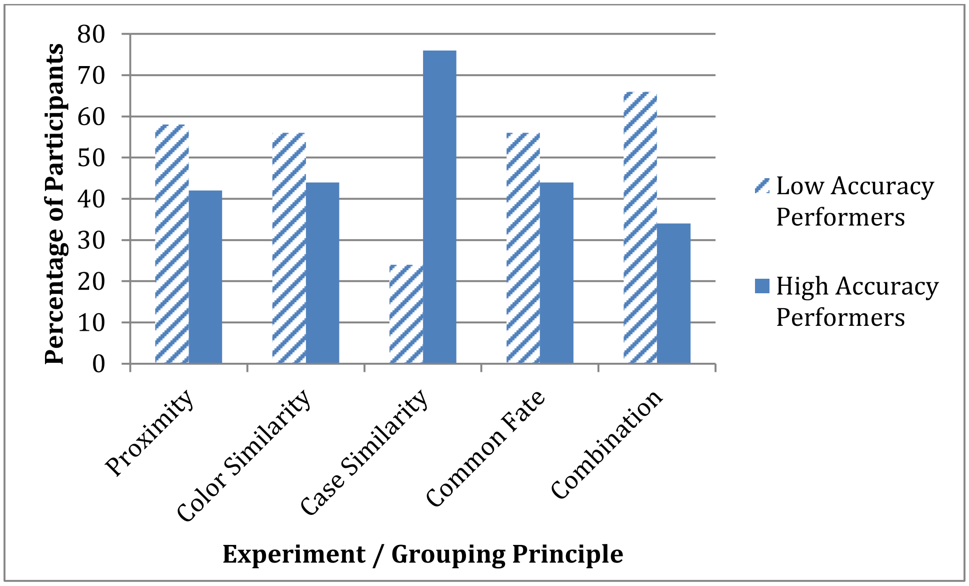


Figure 7

Percentage of Participants by Experiment and Performance



Discussion

Grouping by a combination of factors did not impact performance on this task as evidenced by a lack of improvement in performance on the enhanced task at three target presentations and similar numbers of high accuracy performers across displays. This suggests that when it comes to grouping words, more is not better. In other words, the overall saliency of the groups does not seem to be the defining factor in whether grouping can impact repetition blindness. Finally, as has been found in all previous experiments, performance on the enhanced task at three target presentations was not associated with performance on the lexical decision task.

General Discussion

Overall, the results of these experiments suggest that different grouping principles have differing effects on linguistic stimuli in a repetition blindness paradigm. The strongest effect was found when items were grouped by letter case similarity. Specifically, this manipulation produced an overall greater number of high accuracy performers and improved accuracy for all participants at three target presentations. When items were grouped by proximity or color similarity, accuracy was improved at three target presentations, but a greater number of high accuracy performers was not produced. Finally, when items were grouped by common fate or a combination of all principles, no benefit of grouping was observed.

The strength of the case similarity grouping is at first surprising, as this display appeared to be the least visually salient (See Figure 4.1) and, anecdotally, seemed to be the principle that produced the most confusion for participants in regard to learning which items were to be considered a group. Additionally, this principle produce a distinct pattern of performances across conditions not seen in other experiments. Namely, it produced greater RB at two target presentations. One explanation for these unique results is that this form of grouping is the most inherently linguistic. The strength of grouping demonstrated by the greater number of high accuracy performers mirrors the effect of protection from repetition blindness produced by grouping phrases into syntactically correct parsings (Abrams et al., 1996). Similarly, it is likely the most commonly encountered form of grouping during reading in naturalistic circumstances. As such, participants may be necessarily more attuned, or more inclined, to parse words by case in the same way they are inclined to parse a page of text into an object hierarchy composed of lines and words (McConkie & Zola, 1987; Rayner & Pollastek, 1989).

Given that people are explicitly taught to parse a page of text in a specific way when learning to read and have extensive experience with this form of parsing as it pertains to linguistic items, it follows that those grouping principles less commonly encountered during reading may produce smaller effects on linguistic stimuli. This likely explains the less dramatic results produced by both proximity and color similarity grouping. Given that the number of high accuracy performers did not increase across these experiments, it could be that these manipulations only served to heighten the saliency of the group to those already likely to perform well on this task.

Despite the parallel between the task involving grouping by color similarity and Goldfarb and Treisman's (2011) study, which included colored dots and slashes, the results reported here are much less striking. This difference may also be attributable to the automaticity of linguistic processing and its ability to override our tendency to group. This primacy of linguistic processing when stimuli consist of words is present in Stroop's (1935) namesake task, as well as confirmed by research that documents reduction in the Stroop effect when the grouping of the word itself is degraded (Reynolds et al., 2010).

Grouping that included a time component (i.e., common fate and combination) did not impact participants' performance. This is unlikely due to this principle being relatively weaker or less salient than other principles, as its presence seemed to negate the effect of principles demonstrated to have at least some effect (i.e., case similarity, proximity, and color similarity). One explanation for this startling absence of grouping may be that the time component broke up the full display to such a degree that it was no longer perceived to be a whole composed of two groupings. Specifically, participants may have processed the first, ungrouped word on the screen and then shifted attention away from this word entirely when the following three words appeared. This may have resulted in perceiving the latter three words as a secondary display with items that were visually similar to each other and more resembling conditions under which the homogeneity effect was observed (Mozer, 1989).

A consistent finding across all experiments was that explicitly prioritizing the level of the group to participants via task instruction did not increase the effect of any grouping principle. In fact, when items were grouped by case or color similarity, it worsened performance across number of targets. This suggests that prioritizing the task of locating the group of words sometimes came at a cognitive cost to the task of enumerating the number of targets. It also suggests that explicitly directing attention first to the level of the group was not required to get the full benefit of the grouping principles. Such an implication echoes the parallel finding in Parts I and II that explicit strategy use by participants did not influence performance.

Another consistent finding across experiments was that performance on the lexical decision task was not correlated with performance at three target presentations on any of the enhanced tasks. This may be due to several factors. The association between grouping and reading ability may be something that is only found in inexperienced readers or children in a particular stage of development. Another factor may be that the sample used in these experiments were most likely average readers or better, as it was a University student sample. Additionally, the experiments were advertised to students as rapid reading tasks, which may have tacitly deterred below average or poor readers from volunteering.

In sum, different perceptual grouping factors were found to have variable effects on linguistic items in a repetition blindness paradigm. This suggests that presence of high accuracy performers is related to individual differences in responsiveness to such grouping, as opposed to individual differences in responsiveness to repeated stimuli during a refractory period. Given the overall pattern of the effect (i.e., grouping by case similarity outperforming the more visually salient and traditionally robust grouping by proximity), it also suggests that words are not visually organized in the same way as other objects.

These findings have implications for both the perceptual grouping and RB literature. As perceptual grouping did not impact words in the same way it has been found to impact other objects (e.g., Elder & Goldberg, 2002; Goldfarb & Treisman, 2011), it may be important to consider the type of item and the type of processing when discussing the influence of various grouping principles. In regard to RB, perceptual grouping or SG may better account for and tie together various other findings in the literature. Specifically, these phenomenon could explain reductions in RB when BSVP as opposed to RSVP is used (e.g., Kanwisher, 1991) as well as the finding of reduced RB when intervening items are not present (Luo & Caramazza, 1996)

This knowledge is also of use to a wider variety of different professionals. Book publishers and reading teachers may find attending to and exploiting these properties of words useful in their organization of materials or teaching strategies. Additionally, this research may be useful in the study of human factors and its implementation. Grouping by proximity has been described as an important factor in improving the readability of computer-generated alphanumeric displays (Tullis, 1983). Similarly, grouping by proximity is also emphasized in the design of complex interfaces, such as cockpit design. Wickens and Carswell (1995) describe using this principle to group different sources of information that are needed to complete a given task. Given the results of this study, however, grouping by letter case similarity might also ease information processing in these contexts.

The primary limitation of this study was the demographically restricted sample. As described above, a University student sample that chose to participate in a study involving rapid reading likely represents average to above average readers. Use of largely proficient readers likely reduces variability in performance, which in turn may conceal important effects, particularly as they relate to the lexical decision task. Additionally, the sample may have been further restricted by the imposition of a set exposure duration for stimuli. Specifically, a set exposure duration was chosen as a result of ceiling effects when exposure durations were individualized (see Part I). The exposure duration chosen was likely too rapid for a portion of participants, as evidenced by those that failed to achieve a requisite accuracy of 35% for unrepeated items. If these participants also represented less proficient readers, important variability was lost.

Further research is needed to determine the pattern of this effect across the lifespan. For example, younger children might be expected to show a pattern of performance that is more consistent with visual organization of the natural world (i.e., strong effects of proximity grouping vs. case similarity grouping) given their relative inexperience with reading. This pattern then would be expected to shift with increased reading proficiency. Likewise, research conducted with participants with a wider range of reading proficiency and individualized exposure would be important to capture the most accurate picture of the effect of perceptual grouping on linguistic stimuli. Finally, future studies manipulating additional, inherently linguistic grouping principles (e.g., bolded or italicized font) is needed to further support these conclusions.

Conclusion: Parts I-III

In sum, the results described herein do not suggest a clear cut primacy of RB or SG for linguistic items. Instead, it demonstrates that linguistic processing interacts with both RB and perceptual grouping, favoring SG when grouping is inherently linguistic and RB when the form of grouping is not commonly encountered in written text. This is true regardless of the apparent perceptual saliency of the grouping principle, effectively overriding our tendency to group. It is also true regardless of the explicit strategy used to process items, suggesting an automaticity to the interaction between linguistic processing and RB and SG. Specifically, attention explicitly directed toward the level of the group – by both spontaneous strategy use by participant and imposed strategy use by experimental design – did not alter a participants' tendency toward RB or SG. These characteristic ways words, as compared to shapes, behave in an RB paradigm ultimately reiterate that words are processed in an inherently different way than other visual patterns.

This series of experiments has answered some questions regarding the characteristic response to linguistic stimuli presented in an RB paradigm. It has also elaborated on some conditions under which RB or SG will be more likely to occur, revealing a distinct pattern of performances across various conditions that is likely strongly influenced by automatic, linguistic processing. In addition to answering these questions, it has likewise raised a number of additional questions regarding the relationship between these phenomenon and linguistic processing. For example, at what point in the lifespan does linguistic processing override more pre-linguistic principles of perceptual organization when viewing text? To that extent this research has contributed to the literature through both the findings reported herein and the avenues described for future experimentation as described in the preceding section.

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Appendix A

Table 1

Words Used in RSVP or BSVP displays in Experiments 3 – 10

Words					
ABLE	DEFY	GOAL	LOAF	REEF	THUS
ACHE	DENY	GOLF	NAVY	REIN	TIER
ACID	DIAL	GORY	NEON	RISK	TOGA
ACRE	DRIP	GREY	OAFS	ROSY	TROD
ACTS	DROP	GULF	OAKS	RUIN	TROT
AEON	DRUG	GULP	OILS	SALT	TUBA
AIRY	DUAL	HALO	OILY	SELF	TUBE
ALAS	DUCT	HOBO	ONTO	SHUN	TUNA
ALOE	DULY	HURT	OPEN	SIGH	TURF
ASKS	ERAS	HYPE	OURS	SIZE	TYKE
AUNT	EVEN	ICES	OVER	SNIP	UNTO
AVID	EXES	INKS	OXEN	SNUB	USER
AXON	FISH	INTO	PITY	SOAK	VARY
BIRD	FOLK	IRIS	PLAN	SODA	VEIN
BLAB	FREE	IRKS	PLEA	SOFA	VERB
BLIP	FROG	JOIN	PLUG	SOUL	VIAL
BLOC	FUEL	JURY	POET	STUB	YAKS
BODY	FUND	KEYS	PREP	STUD	YELP
BRED	FURY	KNOB	PREY	STUN	YULE
CHEF	FUSE	KNOT	PULP	SUCH	
CHUG	GALA	LADY	PUTT	SURF	
CLUE	GIRL	LAZY	QUAD	TECH	
COAX	GLUT	LION	QUIZ	TEXT	
DEBT	GNAT	LISP	RACY	THIS	

Note. Descriptive Note. Compiled from Wordmine2, Durda, K. & Buchanan, L. (2006).

WordMine2 [Online] Available: http://web2.uwindsor.ca/wordmine

Appendix B

Table 2

Word List for Lexical Decision Task

Words	Nonwords	Words	Nonwords
resiliency	refolierry	ineligible	inusipitri
testaments	fustamence	construing	corscrying
manhandled	sunhangled	detergents	deterfists
silhouette	sopcouette	theologian	wheucodian
intermixed	interbalds	fragrantly	graspently
recruiting	resmeaning	immigrates	itriblates
recitation	didigation	resurgence	resardance
dismissals	disfindals	supervised	superholes
petitioned	bevisioned	degeneracy	seluberamy
propulsive	prononsive	coniferous	dimifetous
depositing	memiziting	rehearsing	rezouching
bamboozles	bammoebres	expiration	autigation
marinating	pomilating	stimulants	chomulance
epitomizes	elomusizes	crocodiles	crugodight
commending	combashing	furnishing	furbessing
disavowals	disabagads	penmanship	penmantram
advertised	advermerns	absconding	authunding
colloquial	cospuchial	haughtiest	latchtiers
prognostic	proddustic	messengers	sessenpest
gradations	clonations	ironically	ilubinarly
geographer	weotraphal	compensate	compenpent
defensibly	dejardibly	unforeseen	unfongboon
chivalrous	trevalhous	elaborates	evifomates
unbalanced	unmelarked	blustering	grottering
personable	manponable	coarseness	boarsemess

Note. Descriptive Note. Compiled from Wuggy, Keuleers, E. & Brysbaert, M. (2010)

Wuggy [Online] Available: http://crr.urgent.be/programs-data/wuggy

Appendix C

Table 3

Additional Accuracy Results for Experiment 1

Analysis	Statistic	*p*
Omnibus ANOVA		
Main effect: Stimuli	$F(1, 71) = 3.86$	.053
Main effect: Order	$F(1, 71) = 2.44$	.123
Stimuli by Format	$F(1, 71) = 12.59$	.001
Stimuli by Order	$F(1, 71) = .15$	.703
Stimuli by Order by Format	$F(1, 71) = 5.60$	.021
Targets by Order	$F(1.95, 138.51) = 1.45$	.238
Targets by Order by Format	$F(1.95, 138.51) = 3.10$	.050
Stimuli by Targets	$F(2, 142) = .99$	.374
Stimuli by Targets by Format	$F(2, 142) = 9.31$	.000
Stimuli by Targets by Order	$F(2, 142) = .02$	.980
Stimuli by Targets by Format by Order	$F(2, 142) = 3.96$	.021
Letters: Group membership and Strategy	$\Phi = .11$	.797
Letters: Strategy by accuracy at three targets	$t(34) = 1.72$	.095
Words: Group membership and Strategy	$\Phi = .16$	.263

Table 4

Additional RT Results for Experiment 1

Analysis	Statistic	*p*
Letters ANOVA		
Main effect: Group membership	$F(1, 52) = .55$	.460
Words ANOVA		
Main effect: Group membership	$F(1, 55) = 1.66$	.204

Table 5

Additional Results for Experiment 2

Analysis	Statistic	*p*
Omnibus ANOVA		
Main effect: Instructions	$F(1, 30) = .16$	.694
Display by Instructions	$F(1, 30) = 1.30$	.263
Targets by Instructions	$F(2, 60) = .94$	.396
Display by Targets by Instructions	$F(2, 60) = .49$	.641
Accuracy ANOVA		
Main effect: Display	$F(1, 31) = 1.19$	.283
Accuracy at three targets eBSVP		
LDT Accuracy	$r = -.12$	.503
LDT RT	$r = -.09$	.634

Table 6

Additional Results for Experiment 3

Analysis	Statistic	*p*
High vs. Low by Display	$\chi^2(1) = 2.49$	.114
Accuracy at three targets eBSVP		
LDT Accuracy	$r = .24$	.201
LDT RT	$r = .16$	.383

Table 7

Additional Results for Experiment 4

Analysis	Statistic	*p*
Accuracy at three targets eBSVP		
LDT Accuracy	$r = .12$	.540
LDT RT	$r = .09$	.650

Table 8

Additional Results for Experiment 5

Analysis	Statistic	*p*
High vs. Low by Display	$\chi^2(1) = .94$	.334
Accuracy at three targets eBSVP		
LDT Accuracy	$r = .26$	.145
LDT RT	$r = .10$	.568

Table 9

Additional Results for Experiment 6

Analysis	Statistic	*p*
High vs. Low by Display	χ^2 (1) = .82	.365
Accuracy at three targets eBSVP		
LDT Accuracy	*r* = .26	.188
LDT RT	*r* = -.28	.164

Table 10

Pattern of means and change scores across conditions and experiments and collapsed across type of performers

	1	2	3	1 vs. 2	2 vs. 3	1 vs. 3
Proximity						
Standard	67	46	42	-21	-4	-25
Enhanced	57	46	47	-11	1	-10
Standard vs. Enhanced	-10	0	5	10	5	15
Color Similarity						
Standard	68	53	43	-15	-10	-25
Enhanced	60	56	47	-4	-9	-13
Standard vs. Enhanced	-8	3	4	11	1	12
Case Similarity						
Standard	66	55	49	-11	-6	-17
Enhanced	58	40	53	-18	13	-5
Standard vs. Enhanced	-8	-15	4	-7	19	12
Common Fate						
Standard	64	52	45	-12	-7	-19
Enhanced	59	49	51	-10	3	-8
Standard vs. Enhanced	-5	-3	6	2	10	9
Combination						
Standard	65	46	43	-19	-3	-22
Enhanced	46	45	42	-1	-3	-4
Standard vs. Enhanced	-19	1	1	18	0	18

Vita Auctoris

NAME:	Andrea Jackson
PLACE OF BIRTH:	Milwaukee, Wisconsin
YEAR OF BIRTH:	1985
EDUCATION:	Milwaukee Area Technical College 2006, GED University of Wisconsin-Waukesha 2004-2007 University of Wisconsin-Milwaukee 2007-2009, BA University of Windsor 2011-2013, MA