THE ROLES OF PROCESSING TIME
AND STRATEGIC FACTORS
IN PERCEPTUAL
BLINDNESS

By

KATHLEEN MARIE MAROHN

Bachelor of Arts
University of Arizona
Tucson, Arizona
1975

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1986

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Thesis Approved:

Larry Hochhaus

Thesis Advisor

Robert F. Stanners

Kenneth D. Sandvold

John R. Sonn

Norman N. Durham

Dean of the Graduate College

Abstract

In consecutive repetition priming, which is the presentation of a target word 500 ms after the same word has been presented, subjects evidence "perceptual blindness," shorter duration judgements and poorer identification accuracy for repeated targets. The current series of experiments sought to learn the extent of circumstances under which perceptual blindness occurs. Experiment 1 involved a manipulation of stimulus onset asynchrony (SOA) and showed that SOA values longer than 500 ms allow reprocessing to occur. Experiment 2, with a variable density of repetitions, showed lessened perceptual blindness under high density of repetitions. Finally, subjects in Experiment 3, who were told that in 50% of the trials the target word was a repetition of the priming word, showed reduced inhibition effects for repeated targets. Overall, the data show that added processing time between prime and target allows better perception of repeated targets and that the bias of subjects against perception of repeated targets can be partially eliminated by factors designed to affect subject strategies. Theories to explain perceptual blindness and the automatic and strategic components of perceptual blindness were also discussed.

The Roles of Processing Time and Strategic Factors in Perceptual Blindness

Possible mechanisms of perceptual blindness. Jacoby and Dallas (1981) were the first to document the phenomenon of "relative perceptual fluency," which is the perceptual enhancement of a stimulus upon subsequent recognition testing as a consequence of prior study of that stimulus. Witherspoon and Allan (1985) subsequently demonstrated the "misattribution hypothesis" of perceptual fluency when their subjects falsely attributed longer presentation durations to familiar items. In our earlier work (Marohn & Hochhaus, 1988b), we sought to connect the mechanism of semantic priming with perceptual fluency and to confirm the effects of priming on identification accuracy (Tulving & Gold, 1963). Our method involved sequential computer presentation of pairs of words under three conditions: (a) unrelated, priming word paired with an unrelated word; (b) semantic, priming word paired with a related word; and (c) repetition, priming word paired with itself. Immediately following the 500 ms prime the target word appeared, two lines lower on the screen, for either 16 or 32 ms in a random order. This very brief target presentation was followed by a 1-s mask of five ampersands. We labeled this method consecutive priming because of the very brief SOA between priming word and target word. In this procedure, consecutive repetition priming and consecutive semantic priming produced dramatically different effects on relative perceptual fluency.

Semantic priming significantly facilitated relative perceptual fluency as we expected. Compared to the unrelated targets, semantically related targets had longer apparent durations and greater identification accuracy. In contrast, immediate repetition priming did not enhance target perception (repeated targets had significantly shorter apparent durations and poorer accuracy). den Heyer, Goring, and Dannenbring (1985) presented evidence that semantic priming and word repetition affect separate stages of word recognition. If this is true, similar effects on perceptual fluency need not be expected.

A follow-up study (Marohn & Hochhaus, 1988a) determined that the paradoxical results for repetition priming were not merely a consequence of the exact physical repetition of the priming stimulus in the target word. In this experiment, the priming word was changed to lowercase letters while the target word remained in uppercase letters. This change in letter case format was expected to enhance the subject's perception of the repeated target and to produce the longer perceived durations and greater identification accuracy associated with perceptual fluency. However, poorer word identification accuracy and shorter judged durations in the consecutive repetition condition persisted. It appears that consecutive repetition priming produces a unique phenomenon such that the subject fails to perceive the second presentation. It is my belief that reduced processing of the target word produces this "perceptual blindness," the logical opposite of perceptual fluency.

Reduced processing of the target word in consecutive repetition may affect the subject's perception. There may be a definable boundary for when reprocessing of a repeated item is able to occur. It could be speculated that on one side of this boundary reprocessing does occur while on the other side it fails to occur in a fashion similar to the psychological refractory period. Calfee (1975) defines the psychological refractory period as an interval of time following the onset of a stimulus and response pair such that processing a subsequent stimulus is delayed.

Morotomi (1981) suggested that the effect of a pretarget, even when masked, caused inhibition rather than facilitation of subsequent repeated stimulus processing. Morotomi's results demonstrated that reduced recognition of a posttarget occurred when that posttarget was identical to a pretarget (as in consecutive repetition priming). Morotomi stated that this effect could be classified as support for the interruption theory of masking because the pretarget inhibits processing of the posttarget. Similarly, perceptual blindness may occur because the priming word disrupts processing for repeated targets analogous to a process of masking.

MacKay (1987) has developed a node structure theory of perception and action which may provide another model for perceptual blindness as well. According to this view, mental nodes are theoretical constructs; the basic properties of nodes (priming and activation) are analogous to the basic properties of neurons (potentiation and spiking). One of the central concepts of node structure theory is the process of self-inhibition of mental nodes; a process MacKay sees as analogous with the psychological refractory period.

Self-inhibition is a brief period of reduced excitability that follows node activation. MacKay argues that the mental nodes must become self-inhibited following activation to ensure that internal feedback (bottom-up priming) which results from the activation of subordinate nodes does not lead to repeated (reverberatory) reactivation of the higher level nodes. Stated another way, without self-inhibition the system might go into something like convulsions in a traumatized cortex. MacKay's recovery function illustrates how the activation level of a priming word first falls below the resting level (self-inhibition) at the termination of activation and then rebounds at the beginning of the hyperexcitability phase. The higher the node in the perceptual hierarchy, the longer the duration of self-inhibition. Thus self-inhibition reflects complex neuronal interactions and perceptual blindness may occur as a consequence of the self-inhibition process.

Kanwisher (1987) who coined the term "repetition blindness" attributed the phenomenon to a failure to assign a separate token identity to a given type node which had been previously token individuated. The token individuation hypothesis states that "repetition blindness is blindness to the word as a distinct token rather than blindness to the word itself" (p. 131). By token Kanwisher appears to refer to registration of specific episodic information. In a repeated target the type node is activated but it is unable to be token individuated. There is a period of inhibition during which token individuation cannot occur. Thus the token individuation hypothesis can also be a model to explain perceptual blindness.

Another possible mechanism for perceptual blindness has to do with a bias, on the part of the subject, against the perception of repetitions in the consecutive priming task. This bias may have to do with strategic factors or may concern the task as a whole. Thus the subjects' performances may depend on their expectations of the task.

Prior evidence for reduced processing and strategic views of perceptual blindness. Evidence for reduced processing for repeated items has been reported in studies of repetition effects on memory (Jacoby, 1978; Cuddy & Jacoby, 1982; Rose, 1984). den Heyer, Briand, and Dannenbring (1983) referred to error rate as an indication of diminished prime processing. Jacoby and Dallas (1981) also make a distinction between massed and spaced repetitions in a study list. They found spaced repetitions more effective for enhancing recognition memory due to the increased likelihood of reprocessing of the repeated words.

Consecutive repetition priming involves the brief stimulus onset asynchrony (SOA) of 500 ms. Brief SOAs have been shown to delay processing of the target until prime processing has reached completion (den Heyer, et al., 1983; Lorch, 1982; Schmidt, 1976). de Groot (1984) has also demonstrated that a longer SOA is needed to capture the attention of the subject. A longer SOA would also allow the mental nodes to return to their resting level of optimal priming (MacKay's node structure theory) or a type representation to be token individuated (Kanwisher's token individuation hypothesis).

According to Posner and Snyder's (1975) dual process model, priming involves two distinct processes, one of which is an automatic factor and the other of which is a strategic factor. A common characterization of these factors in reaction time data is that, relative to a neutral prime (XXXXX), automatic processing gives priming with no costs while strategic processing produces benefits, but at the cost of processing time for unrelated pairs (Neely, 1977). Automatic priming occurs very quickly without any effort on the part of the subject. In contrast, strategic priming is relatively slow and requires the attention of the subject. This attention-induced priming is also influenced by expectancy (den Heyer, 1985).

The proportion of related words has been varied to ascertain what effect an increased proportion of related words has on the subject's task strategy due to their raised expectancy for related words (den Heyer, 1985; de Groot, 1984; Tweedy & Lapinsky, 1981). The amount of facilitation for related targets increases as a function of the proportion of related pairs. This change in facilitation is known as the proportion effect, the higher the proportion of related words the greater the priming effect.

Strategic factors have also been in evidence when the instructions given to subjects were manipulated. Schmidt (1976) demonstrated that a change in written instructions leads to an expectancy on the part of the subject. With a heightened expectancy, subjects subsequently develop an adaptive strategy to the task.

The current research. The present series of experiments continued the investigation into the effects of priming on apparent stimulus duration and perceptual fluency. Experiment 1 involved a manipulation of stimulus onset asynchrony (SOA). Lengthening the interval between the priming word and the target word was expected to increase the possibility of the subject reprocessing the repeated word. Several theoretical positions support this prediction; with the longer SOA, the mental nodes would be ready for reactivation or, alternatively, the type representation of the word would have time to be token individuated. Thus, the perceptual blindness of consecutive repetitions was expected to decrease at a longer SOA because of reprocessing of the repetition. The four SOAs were 250 ms, 500 ms, 750 ms, and 2000 ms.

Experiment 2 utilized an increased proportion of repetitions (the high density group) in an effort to produce greater priming. With a greater density of repeated words perceptual blindness may be lessened. When the density of repetitions is high, subjects should expect repetitions. This raised expectancy may lead to benefits for repeated targets and costs for the unrelated targets according to the dual process model. The degree to which perceptual blindness is eliminated by this manipulation or is changed to positive repetition priming should indicate the degree to which the perceptual blindness effect is due to automatic and strategic processes.

Thus in Experiment 2, the proportion effect was predicted. The proportion effect in turn may modify the subject's initial bias against the perception of repetitions. If the proportion effect were not evidenced the data would imply that subjects have a built-in, nonmodifiable bias against the perception of repetitions which cannot be altered by strategic factors.

Experiment 3 was also designed to document any strategic factors that subjects might utilize. In a manner similar to Schmidt (1976), half of the subjects were given written instructions stating that of the 80 pairs of words 40 were repetitions. With this added knowledge, subjects may have an advantage as they may know what to expect in the targets. This expectancy was expected to facilitate word identification and duration judgements in the repetition condition.

Hypotheses and predictions. In each of the proposed experiments a change in the phenomenon of perceptual blindness as measured by duration judgements and word identification accuracy was anticipated. The longer SOAs (750 ms and 2000 ms) in Experiment 1 were expected to increase the subject's ability to reprocess the priming word when the target word is presented. As a result of reprocessing, a decrease in perceptual blindness as evidenced by longer apparent duration judgements and greater word identification accuracy was predicted. At the shorter SOAs perceptual blindness was expected to continue to occur.

In Experiment 2, the increased proportion of repetitions in the high density group was expected to produce a raised expectancy for repetitions. Greater priming and a decrease in perceptual blindness due to the proportion effect were predicted. In contrast, the low density group and the medium density group, with the decreased proportion of repeated words, were both expected to continue to experience perceptual blindness.

The manipulation of the written instructions in Experiment 3 may modify any initial bias against the perception of repetitions and may produce a decrease in perceptual blindness due to strategic factors. The advantage of being in the informed group would lead to greater word identification accuracy and longer duration judements for this group.

Implications and possible conclusions. As a result of the current experiments, we may learn the extent of circumstances that produce the paradoxical results for consecutive repetition priming. The range of SOAs at which perceptual blindness occurs may be determined. Finally, evidence that perceptual blindness is based (in part) on modifiable subject strategies may be obtained from Experiments 2 and 3.

Experiment 1

The purpose of Experiment 1 was to broaden our knowledge of circumstances that produce the paradoxical results for consecutive repetition priming. The range of prime to target SOAs at which perceptual blindness occurs was evaluated.

Method

Subjects. Twenty-six Introductory Psychology students at Oklahoma State University participated in this experiment. They received a small amount of class credit for their efforts.

Materials. A word pool of 258 words was selected from the Kucera and Francis (1967) norms. The mean frequency value for the target words was 400.29 (range of 212 to 1599 occurrences per million words of text). Practice and test words were paired under two conditions: (a) unrelated condition, priming word paired with an unrelated word and (b) repetition condition, priming word paired with itself. The four SOA times were 250 ms, 500 ms, 750 ms, and 2000 ms.

An Apple //c computer was used to present the words. The mean length of words was 5.05 letters (range 4 - 7 letters). The priming words were lower case and the target words were upper case. The visual angles per letter were .56 degrees for height and .32 degrees for width. The viewing distance was approximately 63.5 cm.

Procedure. The subjects were tested individually. The experimenter remained with the subject at all times during testing. The subjects sat directly in front of the computer screen while the words flashed on the screen. They read instructions defining their task in each phase of testing. A session lasted approximately 30 min and consisted of two phases.

Phase 1: Pretraining for Time Judgements. This practice phase served to orient the subjects to the duration judgement task. Subjects were able to gain experience with judging the durations of very brief presentations. Phase 1 also served as a check as to whether the subjects were performing the task or merely responding at chance. A trial began when the message "Press Return When Ready" appeared on the screen. When the subject pressed the "return" key, the message was erased and two horizontal 1.75-cm lines (with 4.76-mm vertical separation) appeared and remained as a marker for 500 ms. The lines oriented the subjects to the location where the string of five characters (ZZZZZ) would next appear. The string of Z's was presented for 20, 160, 300, or 440 ms durations. The software clock of Deiner and Smee (1984) was used. Any presentation durations given in this paper are only approximations due to the use of an Apple //c which could not be synchronized with the raster-scanner.

The times employed in Phase 1 were chosen on the basis of a pilot study which found, on average, the subjects performed at about 50% correct. A score of 25% is chance in this task. The task for this phase was to categorize each duration by pressing 1, 2, 3, or 4 on the computer keyboard, with 1 representing the shortest presentation and 4, the longest presentation. There were 50 trials, with the four durations occurring in random order.

Phase 2: Test. Subjects read instructions indicating that they were to identify the target word and to judge the duration of its presentation on the screen. Spoken identification of target words was recorded by the experimenter. A test trial began when the message "Press Space Bar When Ready" appeared. A 500 ms presentation of the priming word appeared in the center of the screen. (In the 250 ms SOA condition the prime presentation was 250 ms.) After each priming word was presented, the target word appeared two lines lower on the screen for either 16 or 32 ms in a random order. A 1-s mask of five ampersands followed the target presentation. Phase 2 involved the two presentation times combined factorially with the two pair conditions, unrelated and repetition, and the four SOAs. There were 160 presentation trials of paired words consisting of 10 instances of each of the 16 combinations of conditions. The order of the 160 trials was random.

Results

The results of Phase 1 were consistent with prior experiments; subjects were able to categorize the durations at 58% accuracy. The apparent duration data of Phase 2 were analyzed with a 2 X 2 X 4 repeated-measures analysis of variance. The factors were duration (16 ms and 32 ms), pair-type (unrelated and repetition conditions) and SOA (250 ms, 500 ms, 750 ms, and 2000 ms). The difference in apparent duration for the short (M = 1.66) and long (M = 2.03) presentations was significant, $F(1, 25) = 87.30$, $p < .0001$. Thus subjects accurately judged the 16 ms presentation as significantly shorter than the 32 ms presentation.

As in previous studies, the judged duration means of the unrelated condition were significantly longer than those of the repetition condition, $F(1, 25) = 21.86$, $p < .0001$. The means for each pair-type were as follows: unrelated, 1.95, and repetition, 1.75. There was no interaction between duration and pair-type, $F(1, 25) = 0.01$, $p > .05$. Thus the difference between short and long durations was constant for both the unrelated and the repetition conditions.

Across the four SOAs, significant differences occurred between the shorter and longer SOAs, $F(3, 75) = 10.13$, $p < .0001$. The apparent duration means for each SOA were as follows: 250 ms, 1.65; 500 ms, 1.67; 750 ms, 2.03; and 2000 ms, 2.05. Newman-Keuls analysis of the SOA effect showed that the two short SOAs differed significantly from the two longer SOAs. Neither the 250 ms and 500 ms SOAs nor the 750 ms and 2000 ms SOA differed significantly from one another. There was no interaction between duration and SOA, $F(3, 75) = 0.14$, $p > .05$; that is, the short duration was consistently rated as shorter than the long duration for each of the four SOAs.

There was a significant interaction between pair-type and SOA, $F(3, 75) = 5.69$, $p < .005$. Simple effects analyses (Kirk, 1982) found significant differences between the unrelated and the repetition conditions for the three shorter SOAs. However, pair-type was nonsignificant at the 2000 ms SOA. There was no three-way interaction between duration, pair-type, and SOA, $F(3, 75) = 0.87$, $p > .05$.

The identification accuracy data of Phase 2 were analyzed with a 2 X 2 X 4 repeated-measures analysis of variance with factors of duration, pair-type, and SOA. Across all conditions the average number of errors was 34.29 out of 160 presentations (21%). Of these errors 23.91 (70%) were from the 16 ms duration and 10.38 (30%) were from the 32 ms duration. Thus the short duration had significantly more errors than the long duration, $F(1, 25) = 85.32$, $p < .0001$.

Overall errors in each pair-type were 16.98 (49.5%) for the unrelated condition and 17.31 (50.5%) for the repetition condition; a nonsignificant result, $F(1, 25) = 0.02$, $p > .05$. There was a significant difference in error rate among the SOAs, $F(3, 75) = 46.66$, $p < .0001$. Error data across SOA conditions were as follows: 250 ms, 15.28 (45%); 500 ms, 12.09 (35%); 750 ms, 4.00 (12%);

and 2000 ms, 2.92 (8%). All pairwise comparisons in a Newman-Keuls analysis of the SOA effect were significant.

There was no interaction between duration and pair-type, $F(1, 25) = 0.19$, $p > .05$; the effects of duration were constant for each pair-type. Duration and SOA produced a significant interaction, $F(3, 75) = 12.50$, $p < .0001$, which reflects significant differences between the 16 ms and 32 ms durations across the four SOAs. The differences in errors between the two durations at each SOA were as follows: 250 ms, 5.96; 500 ms, 3.92; 750 ms, 2.16; and 2000 ms, 1.46. There was progressively less difference in error rate for the short and long durations as SOA increased. Identification accuracy for the short duration was approaching the accuracy of the long duration as SOA lengthened. However, simple effects analyses showed that these short vs. long differences were all significant.

Insert Figure 1 about here

In error scores there was a significant interaction between pair-type and SOA, $F(3, 75) = 4.15$, $p < .01$ (see Figure 1). Simple effects analyses found nonsignificant differences for the unrelated and repetition conditions at 250 ms, 750 ms, and 2000 ms. The unrelated condition had significantly better identification accuracy than the repetition condition at the 500 ms SOA. There was no three-way interaction among duration, pair-type, and SOA, $\underline{F}(3, 75) = 2.46$, $\underline{p} > .05$.

Discussion

Experiment 1 replicated our prior work on perceptual blindness at the shorter SOAs. Subjects continued to accurately judge the target words according to their short and long durations and, overall, the unrelated condition continued to display longer apparent duration than the repetition condition. Duration judgements of the target word varied across SOA, shorter ratings were given for the 250 ms and 500 ms SOAs and significantly longer ones for the 750 ms and 2000 ms SOAs. A longer SOA appears to increase the duration judgement ratings; that is, the subjects judged the target word as being longer in duration as SOA lengthened which may, in part, represent a decrease in perceptual blindness due to the longer SOA. Thus longer SOAs may allow increased processing time as expected. Following from MacKay's (1987) mental node theory, the longer SOAs enabled the node to return to resting level and could thus be reactivated at the 750 ms and 2000 ms SOAs. The token individuation hypothesis also allows for a decrease in the inhibition to token individuate with the passage of time.

One of the most important results can be seen for the pair-type factor as SOA lengthens. For the three shorter SOAs, subjects continued to display significantly longer duration judgements for the unrelated condition in comparison to the repetition condition. However, for the 2000 ms SOA, the difference between the two pair types was nonsignificant which again reflects the elimination of perceptual blindness for the longest SOA. Thus, subjects increased their duration judgements of the repeated targets which brought those judgements closer to the unrelated condition judgements. A follow-up question would be how long an SOA would be needed to show facilitation.

On the identification accuracy variable, the short duration (16 ms) had significantly more errors than the long duration (32 ms) as in prior experiments. The shorter SOAs (250 and 500 ms) had significantly greater error rates than the two longer SOAs (750 and 2000 ms). Thus lengthening SOA does increase identification accuracy as anticipated. It may be easier to see the words when they are presented for a longer time (32 ms) and when processing time is increased as in the longer SOAs.

The overall main effect of pair-type for the identification accuracy variable was nonsignificant. From the simple effects test, the differences in pair type were nonsignificant for 250 ms, 750 ms, and 2000 ms

SOAs. Only at the 500 ms SOA, the unrelated condition displayed significantly better identification accuracy than the repetition condition. The increased processing time in the longer SOAs may allow the subjects to reprocess the repeated targets which would explain the nonsignificance in pair type for the 750 ms and 2000 ms SOAs. This nonsignificance may represent a decrease in perceptual blindness for repeated targets, a result which was predicted. One possible explanation for the nonsignificant difference in the 250 ms SOA is the method of presentation. The priming word had a 250 ms presentation and therefore was undoubtedly less salient. Node activation or token individuation of the prime itself may have failed to occur as a result of the shortened prime duration.

Experiment 2

The purpose of Experiment 2 was to evaluate the role of strategic factors in perceptual blindness. To do so, the density of repeated targets was manipulated across independent groups.

Method

Subjects. Sixty Oklahoma State University student volunteers participated in this experiment and received extra credit in their psychology classes.

Materials. The materials were identical to Experiment 1 with the exception that only the one SOA of 500 ms was used and the proportion of repetitions was varied. The low density group had 10 repetitions among the 80 presentations, the medium density group had 40 repetitions among the 80 presentations, and the high density group had 70 repetitions among the 80 presentations.

Procedure. This experiment also consisted of two phases. Phase 1 was identical to Phase 1 in the previous experiment.

Phase 2: Test. The priming word was presented for 500 ms. Immediately following an SOA of 500 ms, the target word flashed on the screen. The target durations were as in Experiment 1, 16 ms and 32 ms. Again, the subject was asked to identify the target word. The experimenter wrote the subject's responses for later evaluation of accuracy. After identification, the subject judged the duration of the target word on the same scale as in the earlier experiment. For each density group there were 80 presentation trials representing a random order of repeated and unrelated pairs for the low (10:70), medium (40:40), and high (70:10) density groups, respectively.

Results

In Phase 1, subjects were again consistent with duration judgements of the Z's at 51% accuracy. Phase 2 judged duration data were analyzed with a 2 X 2 X 3 mixed design analysis of variance with repeated measures on two factors, duration (16 msec and 32 msec) and pair-type (unrelated and repetition conditions), and with a between independent groups analysis on the group factor (low, medium, and high density).

The 16 ms duration was judged significantly shorter than the 32 ms duration, $F(1, 57) = 45.81$, $p < .0001$. The means were: short, 1.70 and long, 1.93. For the pair-type factor, the unrelated condition had significantly longer judged durations than the repetition condition, $F(1, 57) = 45.40$, $p < .0001$. The judged duration means for each pair-type were: unrelated, 1.96 and repetition, 1.67. The differences in the density group factor were nonsignificant, $F(2, 57) = 2.71$, $p > .05$. Duration judgement means for the three groups were as follows: low density, 1.82; medium density, 1.64; and high density, 1.99.

The following two-way interactions were nonsignificant: group by duration, $F(2, 57) = 1.35$, $p > .05$; group by pair-type, $F(2, 57) = 1.25$, $p > .05$; and duration by pair-type, $F(1, 57) = 0.73$, $p > .05$. Thus, the differences between short and long durations were constant for the three density groups and the two pair types. The difference in the pair-type factor was also constant for the three density groups.

There was a significant three-way interaction between group, duration, and pair-type, $F(2, 57) = 4.97$, $p < .05$. Simple effects analyses isolated a significant interaction of pair type by density groups only for the

32 ms duration, $F(2, 114) = 3.98$, $p < .05$. Analysis of simple simple effects ascertained that the three-way interaction was due to a nonsignificant difference in the pair-type factor at the 32 ms duration in the high density group (see Figure 2). All other levels were significantly different at the .05 level.

Insert Figure 2 about here

The identification accuracy data (expressed as percent error) were also analyzed with a 2 X 2 X 3 mixed analysis of variance. The factors were duration, pair-type, and group. The error data are given in percentages because of the variation in the number of repetitions for the low, medium, and high density groups. The average error rate, across all conditions, was 26.68%. The density group factor difference was nonsignificant, $F(2, 57) = 1.64$, $p > .05$. The mean error percentages for each group were: low density, 28.55; medium density, 31.56; and high density, 19.93.

The short duration again evoked significantly more errors, $F(1, 57) = 83.37$, $p < .0001$. The error percentages were: short (16 ms), 36.24, and long (32 ms), 17.12. The unrelated condition had significantly fewer errors than the repetition condition, $F(1, 57) = 18.34$, $p < .0001$. The error percentages for pair-type were: unrelated, 17.99 and repetition, 35.37.

There was a significant group by pair-type interaction, $F(2, 57) = 4.18$, $p < .05$. The interaction is displayed in Figure 3. The differences between the unrelated and the repetition accuracy for each group were as follows: low density, 26.90; medium density, 24.37; and high density, 0.85. A Newman-Keuls analysis of the contrasts between pair types showed the unrelated vs. repetition differences in the low and medium density groups differed significantly from the unrelated vs. repetition difference in the high density group, but did not differ from one another.

Insert Figure 3 about here

The group by duration interaction was nonsignificant, $F(2, 57) = 0.18$, $p > .05$. Error rates for the short and long durations were constant across the density groups. There was also no significant duration by pair-type interaction, $F(1, 57) = 0.45$, $p > .05$; that is, the effects of duration were constant for each pair type. Finally, the three-way interaction between group, duration, and pair-type was also nonsignificant, $F(2, 57) = 2.95$, $p > .05$.

Discussion

The results of Experiment 2 display a divergence for the two dependent variables. The duration judgement variable may not be as readily modifiable as the identification accuracy variable; the differences between duration judgements of repeated and unrelated targets were only nonsignificant at the 32 ms duration in the high density group. In contrast, differences in identification accuracy for repeated and unrelated targets at high density were nonsignificant at both durations.

Subjects in Experiment 2 continued to accurately judge the 16 ms duration as significantly shorter than the 32 ms duration. Again subjects had significantly longer duration judgements overall for the unrelated condition. However, from the simple effects analyses, there was no significant difference in pair type at the 32 ms duration in the high density group. Thus for the long duration in the high density group, subjects did not judge the unrelated condition as significantly longer than the repetition condition. The increased number of repetitions in the high density group decreased perceptual blindness at the 32 ms duration. In contrast, however, the predicted effect of density did not appear in 16 ms targets. The mixed results for the duration judgement variable are the basis for my assertion that the primary effect of the density groups manipulation is on identification accuracy which showed a clearer, more consistent pattern of density effects.

For the accuracy data, the short duration evoked more errors than the long duration which demonstrates that a longer presentation time facilitates word identification accuracy. As a main effect, the unrelated condition evoked fewer errors than the repetition condition. However, the high density group at both the short and long durations produced a nonsignificant pair-type difference for identification accuracy. This nonsignificance in the high density group appears to be based on a decrease in perceptual blindness for the repetition condition (see Figure 3). The increased repetitions for the high density group elicited the proportion effect and as a result, the predicted decrease in perceptual blindness for the high density group. Again, it is clear that the high density group overcame any initial bias against repetitions and successfully identified the repetitions. The proportion effect raised their expectancy to perceive repetitions and with a raised expectancy perceptual blindness decreased. Therefore, we conclude that strategic factors do affect perceptual blindness. To further determine the effect of strategic factors, Experiment 3 was undertaken.

Experiment 3

Experiment 3, like Experiment 2, was designed to further investigate strategic factors in the perceptual blindness phenomenon. In this experiment, however, instructions were used to manipulate strategies.

Method

Subjects and Materials. Forty Oklahoma State University student volunteers participated in this experiment for extra credit. The materials were identical to Experiment 2.

Procedure. This experiment also consisted of two phases. Phase 1 was identical to Phase 1 in the previous experiment.

Phase 2: Test. This phase was identical to Experiment 2 with the exception that only the one density of 40 repetitions was used and the written instructions differed for the two groups. The informed group was told that there would be 50% repetitions in the pair presentations. After informed subjects read the written instructions, the experimenter added a verbal explanation that in one half of the presentations the second word would be the same as the first word.

Results

In Phase 1, subjects had a mean accuracy rate of 56% in their duration judgements of Z's. The duration judgements of Phase 2 were analyzed with a 2 x 2 x 2 mixed analysis of variance. The factors of duration (16 ms and 32 ms) and pair-type (unrelated and repetition condition) were repeated measures factors and the group (informed and uninformed groups) factor was a between independent groups factor. The 16 ms duration was rated as significantly shorter than the 32 ms duration, F(1,

38) = 68.83, $p < .0001$. The means for the short and long durations were 1.67 and 2.01, respectively. For the pair-type factor, the unrelated targets were judged as significantly longer in duration than the repeated targets, $F(1, 38) = 26.05$, $p < .0001$. The pair-type duration means were: unrelated, 1.93 and repeated, 1.75. The differences in duration judgements for the group factor were nonsignificant, $F(1, 38) = 1.10$, $p > .05$.

The group by duration and the pair-type by duration interactions were both nonsignificant, $F(1, 38) = 0.69$, $p > .05$ and $F(1, 38) = 0.87$, $p > .05$, respectively. Thus the differences for both the group factor and the pair-type factor were constant at the 16 ms and 32 ms durations. The group by pair-type interaction was significant, $F(1, 38) = 5.65$, $p < .05$. This interaction is shown in Figure 4.

Insert Figure 4 about here

Simple effects analyses found a significant difference between the unrelated (M = 2.05) and repeated (M = 1.78) targets only for the uninformed group. Pair-type duration means (unrelated, 1.81 and repeated, 1.72) for the informed group were not significantly different. Finally, there was no three-way interaction between the duration, pair-type and group factors.

The identification data were also analyzed with a 2 X 2 X 2 mixed analysis of variance. The factors were duration, pair-type, and group. Across all conditions the overall error rate was 26.65%. The 16 ms duration continued to evoke significantly more errors than the 32 ms duration, $F(1, 38) = 64.91$, $p < .0001$. Error percentages for each duration were: short, 35.56 and long, 15.75. The difference in accuracy for the unrelated and the repeated targets was nonsignificant, $F(1, 38) = 0.19$, $p > .05$. Accuracy was also not significantly different for the informed and uninformed groups, $F(1, 38) = 0.32$, $p > .05$.

The group by duration and pair-type by duration interactions were both nonsignificant, $F(1,38) = 0.58$, $p > .05$ and $F(1, 38) = 1.44$, $p > .05$, respectively. Thus the effects of the short and long durations were constant for the informed and uninformed groups and for the unrelated and repeated pairs. The group by pair-type interaction was significant, $F(1, 38) = 7.42$, $p < .01$; that is, the differences in accuracy for the unrelated and repeated pairs were not constant for the informed and the uninformed groups. Simple effects analyses found a significant difference between the pair types for the uninformed group but no significant difference for the informed group.

Insert Figure 5 about here

There was a significant three-way interaction, shown in Figure 5, between the duration, group, and pair-type factors, $F(1, 38) = 5.20$, $p < .05$. Simple simple effects analyses illustrated the reasons for this three-way interaction. For both short and long durations in the uninformed group, the repeated targets had significantly more errors than the unrelated targets. However, for the short duration in the informed group, there was a cross-over with the unrelated targets evoking more errors than the repeated targets. For the long duration in the informed group the unrelated targets again had more errors than the repeated targets but this time the difference was nonsignificant.

Discussion

The results of Experiment 3 for the duration and pair-type main effects were consistent with the previous experiments. The short duration continued to be accurately perceived as significantly shorter than the long duration. Overall, the unrelated pairs had longer judged duration means than the repeated pairs. The most interesting result, among the duration judgement data, had to do with the group by pair-type interaction. The duration judgement means for the unrelated and repeated targets in the informed group were not significantly different. The form of the group by pair-type interaction, however, was not based on changes across groups in the repetition condition. The basis of the interaction was a difference between groups in the unrelated condition. Participation in the informed group led to shorter duration means for the unrelated pairs (2.05 for the uninformed group vs 1.81 for the informed group). Thus while the group by pair-type interaction was predicted, the data do not provide evidence that instructions change duration judgements for repeated targets.

It seems that a change in written and verbal instructions would affect identification accuracy to a greater extent than duration judgements, an inference supported by the present data. Subjects in the informed group were told that 50% of the targets were the same word as the priming word which was expected to give them an advantage in word identification for repetitions. The identification accuracy variable did show more significant changes than the duration judgement variable. The long duration continued to have significantly better identification accuracy than the short duration. Overall the difference in accuracy for the pair-type factor was nonsignificant; both the unrelated and repeated targets were correctly identified to the same extent.

The main effect of the group factor on accuracy was also nonsignificant with both the informed and uninformed groups on average having equal identification accuracy. This result suggests subjects in the informed group were achieving greater accuracy with repeated pairs at the expense of accuracy for unrelated pairs. The unrelated pairs had significantly better identification accuracy than the repeated pairs for the uninformed group at both the short and long durations. Thus, the uninformed group continued to display perceptual blindness as evidenced by shorter duration judgements and poorer identification for repeated targets. The informed group, on the other hand, were able to take advantage of the information about repeated targets to a certain extent. At the short duration, subjects in the informed group had significantly better identification accuracy for repeated targets. They expected repetitions and erred on the side of declaring too many repetitions. The change in instructions may have produced a response bias such that in an uncertain perception (16 ms duration) the informed group would assert that the target word was a repetition. For the long duration, the repeated pairs continued to show better identification accuracy but it was a nonsignificant difference.

As expected, a change in written instructions decreased perceptual blindness. Thus there is a modifiable component to perceptual blindness in which strategic factors can lead subjects to report a repeated target when ordinarily they would not. Their perception itself may not be altered but rather their willingness to report a repeated target may be increased. The end result is that duration judgements were not significantly different for the two pair types in the informed group yet the informed group did have significantly better word identification accuracy for repeated targets; results which had never previously occurred.

General Discussion

Processing time is an important factor to consider in the study of perceptual blindness. Experiment 1 clearly showed that a longer SOA effectively decreased perceptual blindness. The longer SOAs displayed nonsignificantly different duration judgements and word identification accuracy for the two pair types. While Experiment 1 demonstrated the importance of processing time, it was unable to rule out any of the competing theories to explain perceptual blindness. Increased processing time may allow the previously activated node to return to its resting level for reactivation (MacKay, 1987). Alternatively, with more time subjects may be able to individuate the repetition as a token of the same type as the priming word (Kanwisher, 1987).

Stategic factors also play a part in perceptual blindness. Both Experiments 2 and 3 elicited a change in subject strategy toward the consecutive repetition priming task. Experiment 2, for the identification accuracy variable, resulted in the proportion effect which in turn eliminated perceptual blindness for the high density group. Subjects successfully took advantage of the increased proportion of repetitions in that group. Thus the high density group evidenced no significant difference on the pair-type factor for identification accuracy. The effects of density on the duration judgement variable were not as clear cut. In the high density group nonsignificant pair-type differences were only noted in the 32 ms targets. Experiment 3 also displayed decreased perceptual blindness as subjects in the informed group strategically utilized their knowledge of repeated targets to achieve better word identification accuracy for repeated targets and a nonsignificant difference in the pair-type factor for duration judgements.

It should be noted that the changes in the duration judgement variable were not the same as the changes in the identification accuracy variable in all three experiments. Simultaneously in Experiment 1, the 750 ms SOA showed significantly longer duration judgements for the unrelated pairs and yet word identification accuracy was the same for repeated and unrelated pairs. In Experiment 2, the pair-type factor in the high density group was nonsignificant at both the short and long duration for the identification accuracy variable while for the duration judgement variable nonsignificance was only achieved at the 32 ms duration. In Experiment 3 similar results for the dependent variables occurred; identification accuracy was significantly better for the repeated targets in the informed group at the short duration while duration judgements showed a nonsignificant difference for the pair-type factor in the informed group. These differences of effects on identification accuracy and duration judgement may be reflective of the two components in perceptual blindness. Duration judgements are not as readily modifiable as they may be a part of the automatic aspect and identification accuracy is more easily modified because strategic factors are involved.

Another important result of the manipulations of Experiment 2 was that although there is a strategic component to perceptual blindness there still remains an automatic element in the process. Perceptual blindness was eliminated, but the proportion effect did not produce positive priming. The unrelated and repetition conditions differed nonsignificantly in the high density group because of decreased perceptual blindness, however there was no cost involved for the unrelated targets.

Perceptual blindness when it first occurred in our laboratory (Marohn & Hochhaus, 1988b), was a pardoxical phenomenon with very little prior documentation in the literature. Since that time, and even after the current series of experiments began, we have located several candidate explanations for perceptual blindness (Kanwisher, 1987; MacKay, 1987; Humphreys, Besner, & Quinlan, 1988). Kanwisher has developed the token individuation hypothesis to explain subjects' inhibition to perceive repeated targets. MacKay's node structure theory is very similar to the refractory period hypothesis which Kanwisher believes she has eliminated in her Experiment 3 (Kanwisher, 1987). Kanwisher found greater accuracy for repeated targets even at Lag 1 (the condition most analogous to consecutive repetition priming). Her results are in conflict with our prior work (Marohn & Hochhaus, 1988a, 1988b) and Experiments 1 (500 ms SOA condition), 2 (low and medium density groups) and 3 (the uninformed group) in the current paper. It is my contention that facilitation due to a repetition effect did not occur in Kanwisher's Experiment 3 but rather her Lag 1 repeated condition was confounded by possible subject errors. Kanwisher stated,

> When subjects err in this task, most of their errors consist of naming a word on the list, but it is usually the word preceding the target. This might suggest that it was difficult to determine which word occurred last, or that the next-to-last word was functionally last when the last word was imperceptible. (p. 130-131)

In Lag 1, how can Kanwisher determine whether repeated targets are actually being reported or whether simply the "next-to-last word identification" (the priming word itself) is occurring due to an inability to reprocess a repeated target because of the refractoriness of the nodes? It is my belief that Kanwisher eliminated the refractory period hypothesis too quickly.

Humphreys et al. (1988) suggested that "subjects need to treat primes and targets as discrete perceptual events in order to benefit from the repetition of the unmasked prime" (p. 57). The effects of the priming word on the target word is called "perceptual capture" where the targets are not perceived because of the prior immediate presentation of the priming word. Humphreys et al. successfully eliminated perceptual blindness by inserting a mask between the priming word and the target word. According to Humphreys et al., the mask allowed the target word to be perceived as a separate event. Perhaps the work of Humphreys et al. lends credence to Kanwisher's token individuation hypothesis. Insertion of the mask allowed the target word to be token individuated because it was perceived as a discrete perceptual event separate from the first presentation.

The current series of experiments further illuminates the phenomenon of perceptual blindness. With this additional information, future research needs to evolve such that the exact mechanism behind percetual blindness can be isolated. The use of evoked potentials and other physiological measurements during the consecutive repetition priming task would document any discernable changes in the subjects' evoked potential records as they respond to the task requirements.

The manipulation of word frequency is a potential test for the node structure theory. MacKay (1987) proposes that self-inhibition is longer for higher level nodes. This assumption would predict greater perceptual blindness for high frequency words which are higher on the perceptual hierarchy than are low frequency words. The Experiment 1 data of Humphreys et al. (1988) show a trend which would support this prediction. Word identification accuracy for low frequency words was greater than the accuracy for high frequency words in the immediate repeat condition. This trend is worth investigating in a consective repetition priming design which is free from tne interference of the other lag and mask conditions contained in Humphreys et al.

Future research could also involve the consecutive repetition paradigm followed by either a final, incidental recall task or a final, incidental recognition memory task. Humphreys et al. (1988) suggested that repetitions affect these differently; perhaps better recall for repeated targets and no difference on the recognition test. MacKay (1987) might predict better recall and recognition for unrepeated targets. Kanwisher

(1987) might predict better recall and recognition for repeated targets. Inferences concerning recall and recognition based on the MacKay and Kanwisher models, however, have not been made explicit by the authors.

To nail down the central component in perceptual blindness, experiments could be designed to show the null effects of various manipulations. Experiment 1 showed decreased perceptual blindness when the prime duration was decreased to 250 ms (in the 250 ms SOA condition). Further work with variations in prime duration and prime intensity would provide additional information on the effects of the priming word on the perception of the repeated targets.

As stated earlier, Humphreys et al. (1988) suggested that perceptual blindness occurs because the target word is not perceived as a distinct perceptual event. In the current methodology, the target word is two lines lower on the screen than the priming word; thus there is a degree of spatial separation. A parametric study of the effects of prime to target spatial separation may reveal whether perceptual blindness is simply due to physical proximity.

A final suggestion for future research is to separate the duration judgement and word identification tasks. Earlier pilot work had shown that there were no complications due to the dual task requirement. However, it is not clear which is fundamental or more primary to the other. As stated above, the two dependent variables were not equally affected by the various manipulations. They also may tap into different components of repetition priming.

The foregoing suggestions may appear disjointed. They are offered in the interest of broadening the data base for the perceptual blindness phenomenon. The candidate theories mentioned above cannot be ruled out until we know more about the circumstances surrounding perceptual blindness. The present experiments have advanced our knowledge and can be further used to continue documentation of perceptual blindness.

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Figure Captions

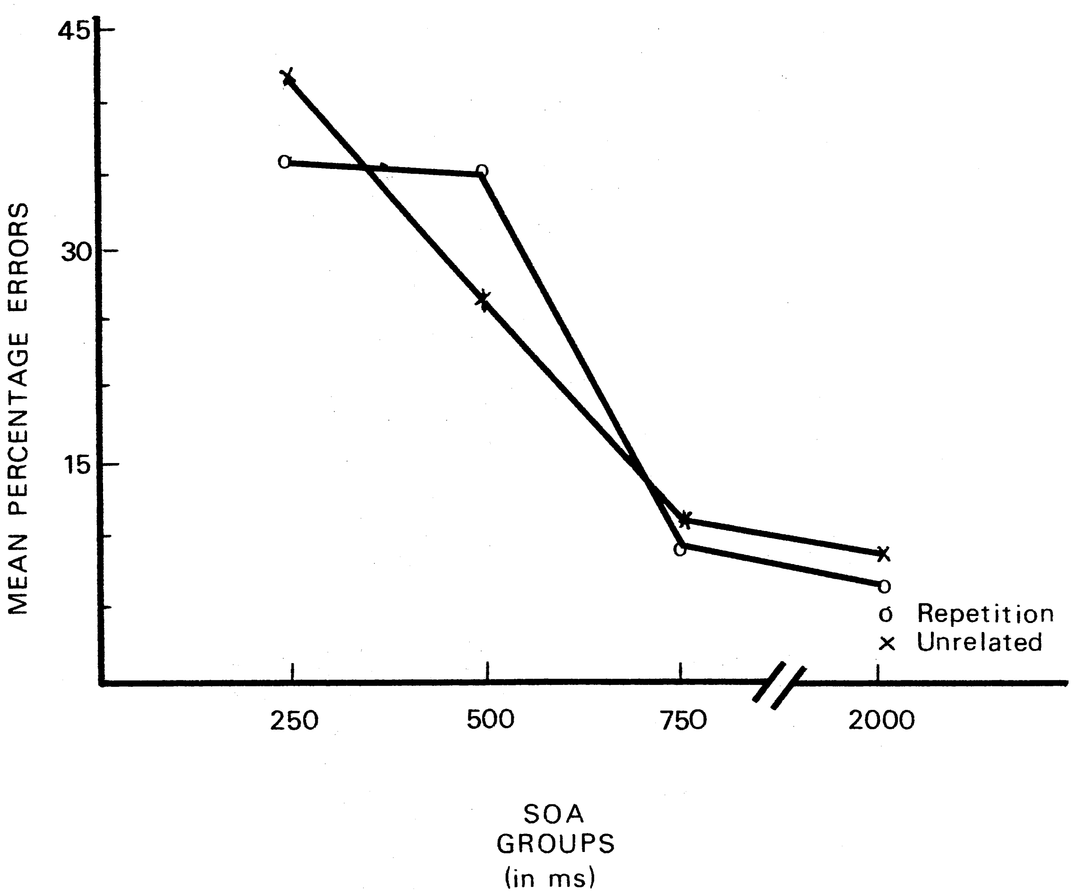
Figure 1. Mean percentage errors as a function of pair type and stimulus onset asynchrony (SOA) in Experiment 1.

Figure 2. Mean judgements of apparent duration as a function of pair type, duration, and density in Experiment 2.

Figure 3. Mean percentage errors as a function of pair type and density in Experiment 2.

Figure 4. Mean judgements of apparent duration as a function of pair type and group in Experiment 3.

Figure 5. Mean percentage errors as a function of pair type, duration, and group in Experiment 3.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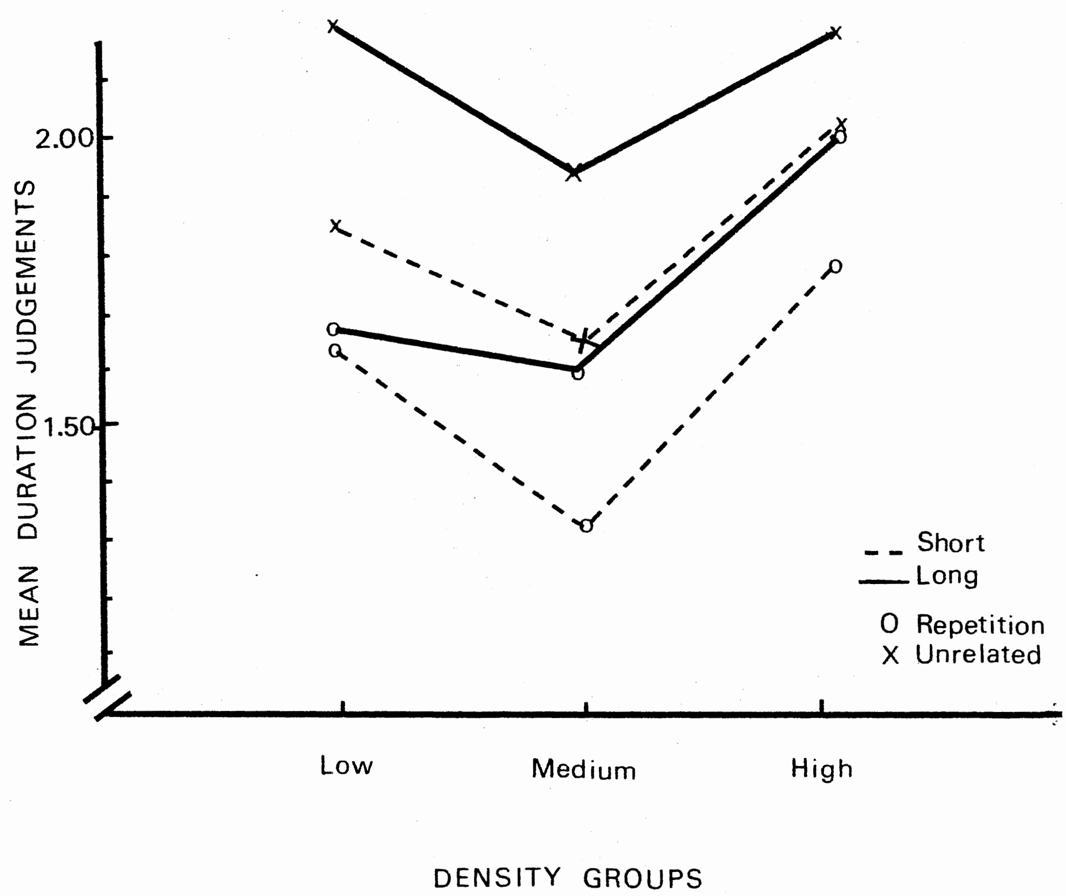
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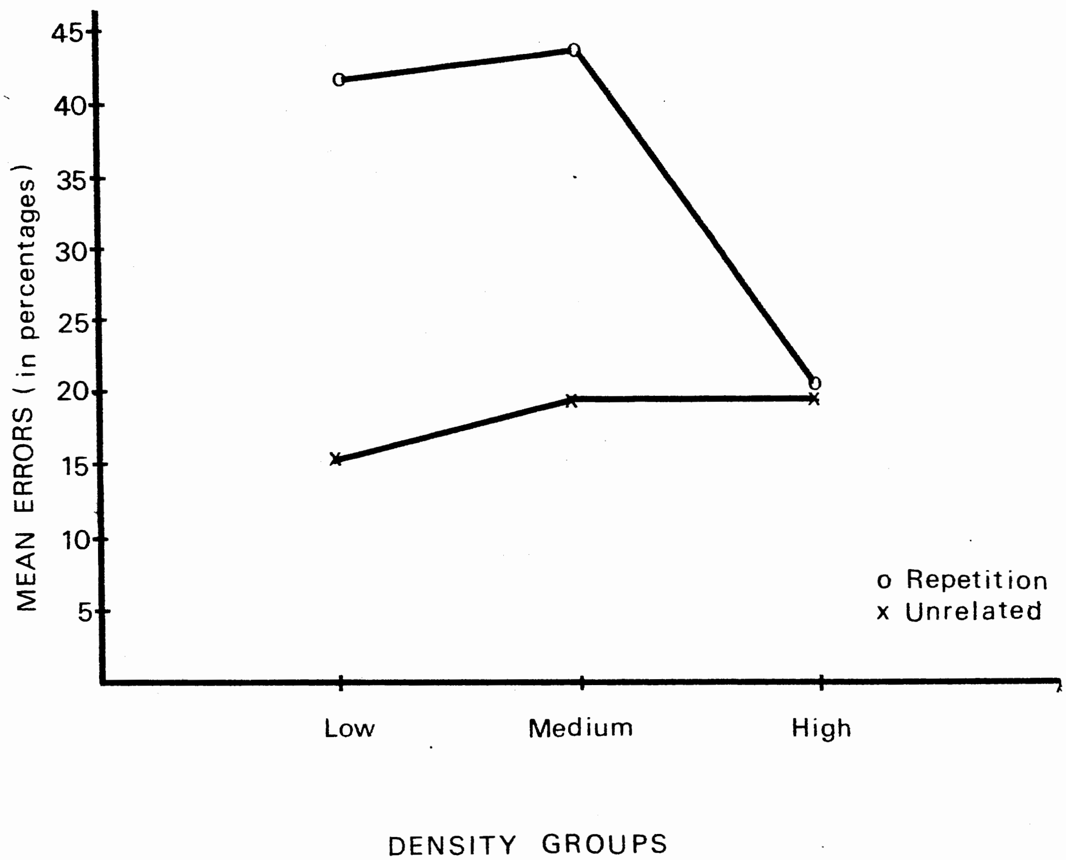
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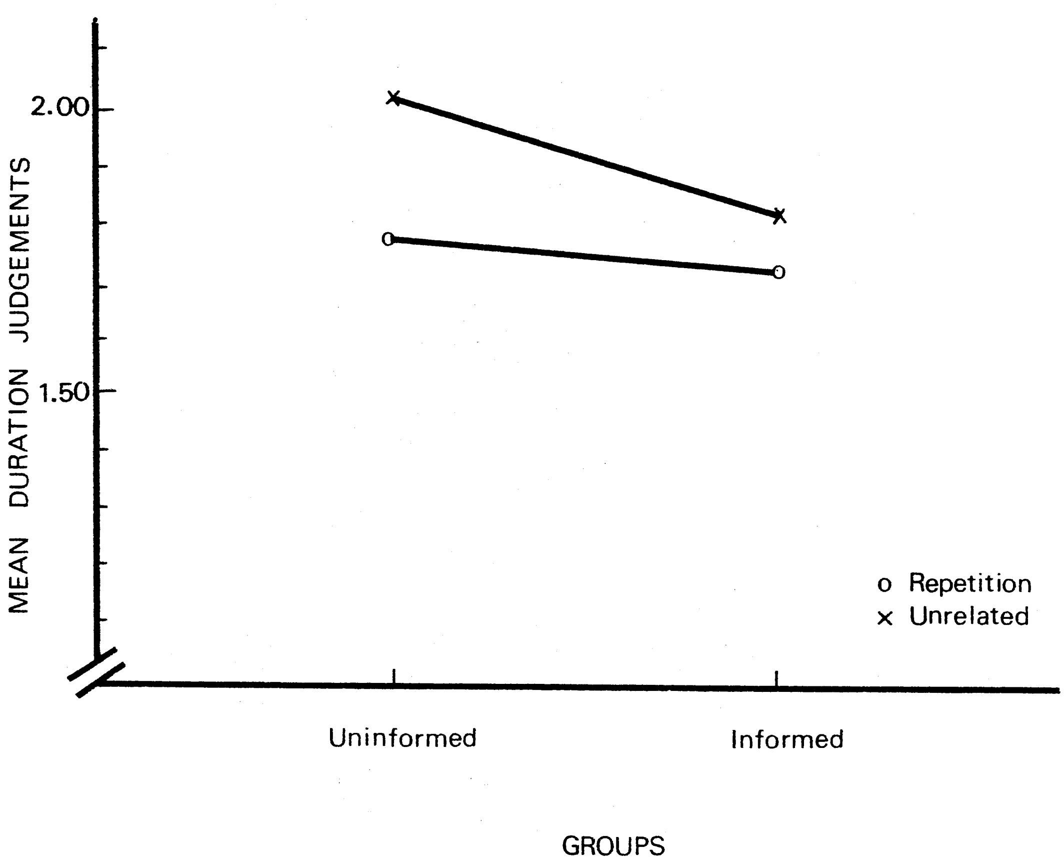
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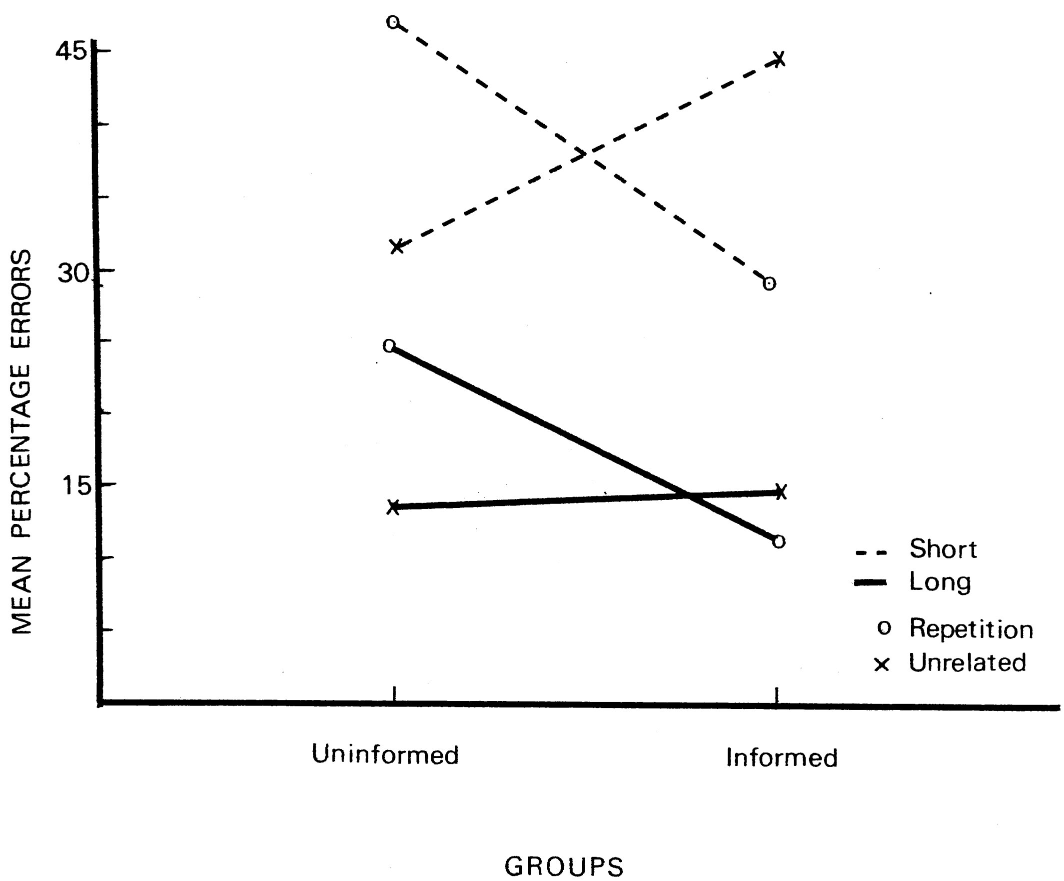
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VITA

Kathleen M. Marohn

Candidate for the Degree of

Doctor of Philosophy

Thesis: THE ROLES OF PROCESSING TIME AND STRATEGIC FACTORS IN PERCEPTUAL BLINDNESS

Major Field: Psychology

Biographical:

Personal Data: Born in Pueblo, Colorado, September 12, 1953, the daughter of James A. and Mary L. Eck.

Education: Graduated from Seton High School, Pueblo, Colorado, in May, 1971; received Bachelor of Arts Degree in Mathematics from the University of Arizona in May, 1975; attended University of Southern Colorado; received Master of Science Degree in Psychology from Oklahoma State University in December, 1986; completed requirements for the Doctor of Philosophy Degree at Oklahoma State University in May, 1989.

Professional Experience: Teaching Assistant, Fall, 1985; Project Assistant, Spring, 1986; Introductory Psychology Instructor, Fall, 1986 to Spring 1987; Experimental Psychology Lab Instructor, Fall, 1987 to Spring, 1988; Psychology of Women Instructor, Fall, 1988; Research Assistant and Experimental Psychology Lab Instructor, Spring, 1989; all of the above in the Department of Psychology, Oklahoma State University. Psychological Associate, Psychological Services Center, Oklahoma State University, August, 1986 to May, 1988.