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The effects of allocation of attention on negative priming

Stacy Lee Phelps

THE EFFECT OF ALLOCATION OF ATTENTION ON NEGATIVE PRIMING

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ABSTRACT

The phenomenon of negative priming occurs when a distractor object in the prime display becomes the target in the probe display. Reaction time is longer for a target that was a distractor in the preceding trial than for a target that was unrelated to the stimuli in the preceding trial. Negative priming is usually taken as an indicator of late selection theory. This experiment examines early versus late selection theories using the cueing paradigm and distance in an identity negative priming task. Early selection theory predicts that costs and benefits will be observed in the near and far conditions. Late selection theory predicts that costs and benefits will not occur in either the near or far conditions. Early selection theory predicts that negative priming will not occur following near or far valid trials; however negative priming should occur in near and far neutral and invalid trials. Late selection theory predicts that negative priming will occur following both near and far, valid, neutral, and invalid trials. The results showed significant costs and benefits. Also, negative priming was found for the near neutral and invalid trials. This experiment provided partial support for early selection theory of attention.

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INTRODUCTION

An abundance of research has been conducted on negative priming. Negative priming occurs when a distractor object in the prime display becomes the target in the probe display resulting in a longer reaction time (RT) than if the target in the probe display was unrelated to the stimuli in the prime display (e.g., DeSchepper, & Treisman, 1996; Fox, 1995b; May, Kane, & Hasher, 1995; Milliken, Tipper, & Weaver, 1994; Moore, 1996; Park & Kanwisher, 1994; Tipper, Weaver, & Milliken, 1995). It appears that as the length of time increases between the prime and probe displays, the effect of negative priming decreases (e.g., May et al., 1995; Neill & Valdes, 1992). The negative priming effect has occurred in a variety of research experiments using the Stroop paradigm (e.g., Gatti & Egeth, 1978; Neill, 1977), picture naming paradigm (e.g., Allport, Tipper, & Chmiel, 1985; Tipper, 1985), object identification (e.g., Moore,1996; Ruthruff & Miller, 1995; Fox, 1994; Fox 1995b; Neumann & DeSchepper, 1992), and object localization task (e.g., Park & Kanwisher, 1994). In the object identification task, the participant must either verbally name the object's identity or press a key on a keyboard that corresponds to that object. A commonly used object identification task is a flanker task (Eriksen & Eriksen, 1974) in which the target letter is in the middle of the computer screen and is flanked on both sides with distractor letters. In the object localization task, a participant must either move a joystick in the location of the target object or press a key on a keyboard that corresponds to that location (e.g., May et al., 1995; Milliken et al., 1994; Tipper et al., 1995). For example, the target object would be the letter X while the distractor object would be the letter O and the participant's task is to identify where X is located in the display.

It has been theorized that negative priming occurs because of inhibitory mechanisms working on the distractor object (e.g., May et al., 1995; Moore, 1996; Tipper et al., 1995). Tipper et al. (1995) has argued that activation of distracting mental representations is directly reduced via selective inhibition mechanisms. For example, if A is the target and B is the distractor, the mental representations for A and B would be activated. However, inhibitory mechanisms would reduce the amount of activation received by the mental representation of B, because it is the distractor. If B then becomes the target in the following display, negative priming will be observed as a result of the inhibitory mechanisms working on the mental representation of B.

Negative priming has usually been taken as evidence of the late selection theory of selective attention (Fox, 1995a). Late selection theories state that it is automatic to recognize and process familiar stimuli and this doesn't require attention (Fox, 1995a). In other words, attention is not necessary for all the stimuli in an environment to be processed to a semantic level (Fox, 1994). An interpretation of the negative priming paradigm under the late selection theory is that both the distractor and the target object would be identified to a semantic level. Thus, the distractor interferes with the target for control of resources.

Late selection theories were proposed in contrast to the early selection model which holds that objects are not recognized unless they receive attention because only basic physical features are extracted and represented in parallel (Fox, 1995a; Treisman & Gormican, 1988). However, because of the capacity limitation of the human cognitive system, focal attention is required to integrate features to form meaningful object images. In other words, attention can operate in parallel to perform preliminary analysis of the component feature of stimuli in the visual field. However, pattern recognition and object identification requires focal attention. This process is assumed to use scarce mental resources, which can not handle parallel processing of multiple stimuli. Spatial location, color, or orientation of the stimuli is presumed to be the bases for which stimuli receive attention (Yantis & Johnston, 1990).

Selective attention can be explained by using the spotlight metaphor. The spotlight theory of selective attention was developed by Posner (1980). According to the spotlight metaphor, within one's visual field one can focus his/her attention on various parts by moving one's attention. Processing of stimuli falling within the spotlight is facilitated. However, if a person wants to process information from another part of the visual field it takes time to move the spotlight (Eriksen & Yeh, 1987). Posner (1980) developed the cueing paradigm and costs and benefits analysis. In the cueing paradigm, there are three types of cues: valid, invalid, and neutral. A valid cue points to the target location. An invalid cue points to either the distractor location or an empty location. A neutral cue does not provide any information about the target location.

The cueing paradigm results in costs and benefits. According to Jonides and Mack (1984), cost-benefit analysis was developed to test for selective preparatory effects in which target processing maybe facilitated when a forewarning cue is presented resulting in the participant having some advanced preparation. Cost occurs when a participant's reaction time is longer following invalid cues than neutral cues. Benefit occurs when a participant's reaction time is shorter following valid cues than neutral cues. Estimates of the degree of costs and benefits can be obtained when the experiment included valid, invalid, and neutral cues. The cueing paradigm assumes that in order to accrue the consequences of a cue, time is necessary (Jonides & Mack, 1984).

According to Posner (1980), the attentional spotlight can fall under reflexive or voluntary control. The attentional spotlight has two sources of control: volitional or endogenous orienting and nonvolitional or exogenous orienting. Central cues fall under voluntary control while peripheral cues fall under involuntary processes (e.g., Jonides, 1981; Koshino, Warner, & Juola, 1992; Muller & Rabbit, 1989).

Yantis and Johnston (1990) performed a series of experiments on spatial attention, which manipulated the cueing paradigm and the distances between the target and distractor letters in a circular array of eight letters. On some of the trials, a response-compatible, response-incompatible, or task irrelevant letter (not a possible target letter) would appeared at one of the uncued distractor locations. For example, in the response-compatible condition A would be the cued target letter and a redundant A would appear at one of the other seven uncued locations, in the same display. In the response-incompatible condition, A would be the cued target letter and another possible target, such as X would appear at one of the uncued locations. In other words, the target and distractor have the same identity, A and A, in a response-compatible condition. Whereas, the identity of the target and distractor are different, A and X, in a response-incompatible condition. Interference occurs when the distractor object competes with the target object for the limited attentional resources in the prime display. Interference is measured by the difference in reaction time when the target and distractors had different identities (incompatible) from when they had the same identity (compatible). The results showed a minor increase in the degree of interference when the stimuli were presented close together (small circle). Also, the items adjacent to the cued location could entirely explain the interference effect. For circle with various circumferences, performance was only affected by incompatible items located adjacent to the cued location. In other words, if an incompatible item appeared directly on either side of the target item then interference would occur. Yantis and Johnston concluded that these results imply an early selection mechanism. Participants were unable to efficiently focus their attention when selected items appeared close together. Distractor items adjacent to the cued location produced small facilitory (from redundant targets) or interference effects (from distractors) when attentional selection is essentially complete. Overall, distractor items do not affect performance when attention is efficiently focused.

Kramer, Humphrey, Larish, Logan, and Strayer (1994) performed a series of experiments, which examined age differences in visual attention. The experimenters investigated, among other things, the extent to which precues could be used by young and old adults to reduce distractor interference in a negative priming experiment. In the prime display, they used precues which either appeared 0msec (simultaneous with the target and distractors), 100msec, or 200msec before the presentation of the target and distractors. Cue validity was 100%. In other words, the cue always pointed to the location of the target object. The displays contained response compatible and response incompatible distractors. The result showed that as the cue-target stimulus onset asynchrony (SOA) increased, both interference and negative priming decreased. In other words, the longer the cue appeared on the computer screen before the presentation of the target and distractor objects, the smaller the degree of interference and negative priming. Kramer et al. (1994) concluded that the participants were able to effectively prefocus their attention on the target location. It appears that as the duration of the cue increased, participants were able to focus their attention on the target location and process target information while not processing distractor information. These results support early selection theory.

Negative priming was also used by Fox (1994) to investigate theories of selective attention. Fox (1994), used various experimental manipulations in order to test whether there is a positive or negative relationship between interference and negative priming. The first experiment used a modified flanker task in which the target letter is identified by an adjacent bar marker. The distance between the target and distractor letters was manipulated in the prime display. In the near condition, the stimuli appeared .97° apart. In the medium condition, the stimuli appeared 1.7° apart. The stimuli appeared 2.6° apart in the far condition. In the probe display, the target and distractor always appeared .97° apart. The results showed significant interference in both the near and medium condition. The interference effect for the far condition was not significant. There was also an overall negative priming effect. Significant negative priming was observed following the near and medium prime trial, but not the far prime trial. Negative priming was significantly greater for the near condition than for the medium condition. These results support previous findings that when the distance between the target and distractor is small, the degree of interference is greater. Of particular interest is that as the distance between the target and distractor letters decreased, the degree of negative priming increased. These results provide support for early selection theory of attention because, negative priming was observed in the near and medium condition but not the far condition. It appears that in the far condition, the distractors might not have been identified because they did not receive attention. These results, on the other hand, do not support late selection theory, because according to late selection theory, negative priming would have to have been observed in the near, medium, and far condition.

In the second experiment, Fox (1994) manipulated interference by use of a cue. During the cued condition, an asterisk (cue) appeared at the target location 150msec before the target and distractor appeared. In the uncued condition, two asterisks appeared (one at the target location and one at the distractor location) 150msec before the presentation of the stimuli. The cue only appeared in the prime trial. Once again, interference was measured using compatible and incompatible trials. The results showed that the difference between compatible and incompatible trials were shorter for the cued condition compared to the uncued condition. Reaction times to response compatible conditions were shorter than reaction times to response incompatible targets. Again an overall negative priming effect was observed. Following the cued condition, the degree of negative priming was significantly greater than when it followed the uncued condition. However, forward masking may have confounded these results because the cues appeared at the same location as the stimuli.

Fox (1995b) modified the above cueing experiment by moving the cue in order to avoid forward masking. The experiment was the same except the cue (asterisk) appeared near the target location instead of on the target location. The results showed that when the target location was pre-cued interference did not occur, but when the target location was not cued, significant interference from incompatible distractors occurred. Negative priming was observed in both the pre-cued and uncued conditions. Moreover, greater degree of negative priming was observed in the cued compared to the uncued condition. These results provide partial support for early and partial support for late selection theories. Early selection theory was supported because, interference occurred in the uncued condition but not the pre-cued condition. On the other hand, late selection theory was supported because significant negative priming was observed in both the pre-cued and uncued condition.

Fox (1995b) replicated this same experiment except that all participants received in separate blocks of trials containing the cued and uncued conditions. The results of this second experiment showed that interference occurred in both the cued and uncued trials. There was less interference in the cued condition. Greater degree of negative priming was observed for the cued rather than for the uncued condition. In a third experiment, a cue (plus sign) appeared to the left or right of the prime target location 150msec before the presentation of the target and distractor in the cued condition. In the uncued condition, the central fixation point, an asterisk, was replaced by a plus sign for 150msec. Once again, interference was found for the uncued but not for the cued condition. Also, significant negative priming occurred for both the cued and uncued condition. In contrast to the first two experiments, the degree of negative priming was the same for both the cued and uncued conditions. This suggests that the interaction found in the Fox (1994) experiment was an artifact of forward masking. One may conclude from these results that interference and negative priming are unrelated. In other words, negative priming can occur without interference. Since negative priming occurred, one can infer that the distractor information was processed but did not interfere with the processing of the target information. There are two possible explanations for this. The first explanation is that the distractor information interfered with the processing of the target information, but the degree of interference did not reach statistical significance. The second explanation is that the distractor information was processed and successfully inhibited before it was able to produce interference. It appears that the target and distractor information are processed simultaneously which supports late selection theory.

The relationship between visual attention and perceptual grouping was investigated by Fox (1998). In particular, experiment 3A was conducted to determine in a flanker task if a greater degree of interference and negative priming would occur when the target and distractors were located in a near position (1.2°) or a far position (2.4°). Fox hypothesized that when the target and distractor objects were consistently presented in the same color, that more interference and negative priming would occur when the stimuli were in the near position. For far trials, participants showed shorter RT than for the near condition. Also, compatible conditions resulted in shorter RT. Furthermore, the near condition resulted in a significant degree of interference while the far condition was marginally significant. Overall negative priming was also observed. Probe trials following far prime trials had shorter RT than those following near prime trials. Negative priming was not found following far prime trials but, was found following near prime trials. Fox concluded that spatial proximity exerts a strong influence over both interference and negative priming when the target and distractor objects appear in the same color. In other words, spatial proximity can affect perceptual grouping based on the target and distractor objects being the same color. More response competition and more negative priming resulted when the target and distractors were located in the near position than when they were located in the far position. In other words, there was a positive relationship between response competition and negative priming. These results support early selection theory in that spatial proximity exerts a stronger influence of the identification of the stimuli than does perceptual grouping.

Neumann and DeSchepper (1992) theorized that unattended objects such as distractor objects in negative priming need to be actively inhibited by attentional resources. They also theorized that when a concept is arbitrarily affiliated with increasing number of facts, this will result in a fan effect (Neumann & DeSchepper, 1992). In other words, the activational energy required for an accurate memory trace for a particular concept is reduced with increasing distractors. Neumann and DeSchepper hypothesized that the fan effect should be easily detectable if the mechanism underlying the suppression effect observed in negative priming is spreading inhibition. In order to test this hypothesis they conducted two experiments. Participants engaged in an identification task in which they read aloud the red target letters from a group of letters. Each display contained one, two, or three distractor letters printed in a different color. The target and distractor letters were not superimposed in the first experiment but, were superimposed in the second experiment. Also in the second experiment, the participants were either given instructions that emphasized accuracy or speed of responses. The participants in the accuracy condition were instructed to make their responses as accurately as possible, whereas those in the speed condition were told to make their responses as quickly as possible.

The results from the first experiment showed that distractor repetition conditions (distractor in prime trial became the target in the probe trial) had longer RT compared to control conditions. Also, there was a significant interaction between the number of distractors and the stimulus type. They found that as the number of distractors increased, the amount of negative priming decreased. The results of the second experiment again showed a significant main effect for the number of distractors and stimulus type. Also, there was a three-way interaction between the type of instruction, stimulus type, and number of distractors. Negative priming was found for participants given accuracy instructions, whereas, participants in the speed instruction condition had slightly shorter RT for the distractor repetition condition than for the control condition. Neumann and DeSchepper concluded that these results support the activation-suppression model in which both distractor and target stimuli are activated in parallel. Furthermore, facilitation will result when the participant is encouraged to respond rapidly and the stimuli are presented rapidly because, the distractor letters are still active when the response to the probe display is required.

In the majority of negative priming experiments, the target and distractor objects fall within the focus of attention. Using Posner's spotlight metaphor, both the target and distractor will be processed when they appear in close spatial locations because, they probably fall within focal attention or the spotlight. According to Yantis and Johnston (1990), a poor test of early selection occurs when all the stimuli in a multielement display fall within 1° of central vision. In most negative priming experiments, the stimuli usually appear superimposed (e.g., Tipper, 1985) or in close spatial proximity (e.g., Fox, 1994; Fox,1995b; Fox, 1998). Negative priming has been found in both the cued and uncued conditions when the stimuli are presented in close proximity (e.g., Fox, 1994; Fox 1995b). In Fox (1998) experiment described above, negative priming occur when the stimuli were in the near location (1.2°) but not in the far location (2.4°). This result is inconsistent with late selection. Previous research on negative priming has provided partial support for both early (e.g., Fox, 1994; Fox, 1998; Kramer et al., 1994) and late selection (e.g., Fox, 1995b; Neumann & DeSchepper, 1992) theories of attention.

The purpose of the present study was to investigate if negative priming really was indicative of late selection theory of visual attention. Unlike previous studies, this experiment specifically manipulated distance so that the target and distractor objects did not always fall within the visual spotlight of attention. The cueing paradigm was utilized to direct the participants focus of attention to a particular area of the display. This allowed the experimenter to investigate if negative priming was indicative of early or late selection theory of attention.

In the prime display, the cue validity and the distance between the target and distractor objects were manipulated. The target and distractor objects appeared either close together (near) or far apart (far). A central cue either pointed to the target (valid), pointed towards the distractor (invalid), or a pound sign appeared at the central fixation point (neutral). The probe display contained either control (probe target was unrelated to the stimuli in the prime display) or distractor target (DT) trials (prime distractor became probe target).

Early and late selection theories predict different results for the above experiment. Basically, the cueing paradigm should not affect the degree of negative priming according to late selection theory because, focal attention is not required to process distractor information. In other words, regardless of cue validity (valid, neutral, or invalid), the RT for the DT (here after RT (DT)) condition should be longer than the RT for the control (here after RT (control)) condition and this difference should be the same for both near and far locations. In addition, late selection theory predicts an absence of the cost and benefit when the stimuli are presented in both the near and far locations. In other words, the RT for the invalid (here after RT (invalid)) trials should not be significantly longer than RTs for the neutral trials (here after RT (neutral)). Also, the RT should not be significantly shorter for valid trials (here after RT (valid)) compared to neutral trials. In contrast to late selection theory, the early selection theory predicts that the degree of negative priming should differ depending on cue validity and distance. According to early selection theory, the RT for the DT condition should be the same as the RT for the control condition during the near and far valid trials because, only the target will appear within focal attention. Hence, the distractor object should not be processed nor should it produce negative priming. In other words, for the near and far valid conditions the RTs for distractor target conditions should not be significantly longer then those for the control conditions. However, the RT for the DT condition should be significantly longer then the RT for the control condition during the near and far neutral and invalid trials. In these conditions, the distractor object will appear within the focal attention and will be processed to a semantic level resulting in negative priming. Early selection theory also predicts that the RTs should be significantly longer following invalid compared to neutral cued conditions and it should be shorter following valid compared to neutral cued conditions at both near and far locations.

To summarize, according to the late selection theory the following hypothesis should be confirmed:

H1: Negative priming (RT (DT) > RT (control)) should occur for all cue validity conditions (valid, neutral, and invalid) at both the near and far locations.

H2: Costs (RT (invalid) > RT (neutral)) and benefits (RT (valid) < RT (neutral)) should not occur at either the near or far conditions.

On the other hand, according to the early selection theory, the following hypothesis should be confirmed:

H3a: Negative priming (RT (DT) > RT (control)) should not occur in either the near or far valid conditions.

H3b: Negative priming (RT (DT) > RT (control)) should occur in both the near and far locations for both the neutral and invalid conditions.

H4: Costs (RT (invalid) > RT (neutral)) and benefits (RT (valid) < RT (neutral)) should occur at both the near and far locations.

METHODS

PARTICIPANTS

Twenty-one undergraduate students with normal or corrected to normal vision from California State University, San Bernardino participated in this experiment. The participants showed normal color vision. They received extra course credit for participating in this experiment. One participant was eliminated from the sample due to age[1]. Nineteen of the remaining participants were female and one was male. The average age of the participants was 28.8 years old (SD = 9.01).

DESIGN

A 3 X 2 X 2 within subjects factorial design was used. The independent variables were 1) cue validity, 2) distance, and 3) priming condition. "Cue validity" and "distance" were varied in the prime display and "priming condition" was varied in the probe display. The first independent variable (cue validity) was a qualitative variable. The three levels were valid, invalid, and neutral. In the valid condition, the cue pointed to a target letter. In the invalid condition, the cue pointed to a distractor letter. In the neutral condition, the central fixation point became a pound

1 The participant eliminated from the experiment was 62 years old. Consistent with Connelley and Hasher's (1993) previous findings, this participant did not show the negative priming effect on any of the conditions due to her age.

sign (#); therefore no information about the possible target location was given. The cue was valid on 60 percent of the trials, invalid 20 percent, and neutral 20 percent. A valid cue was presented on a majority of the trials so that the participants would consistently use the cue. The second independent variable (distance) was a quantitative variable. Distance between the target and distractor was either near (2cm) or far (8cm). From the viewing distance of approximately 60cm, the two stimuli were separated 1.43° of visual angle for the near condition and 6.3° of visual angle for the far condition. The third independent variable (priming condition) was qualitative. The two levels were DT (the prime distractor became the probe target) and control (no relationship between the stimuli in the prime and probe display). The main dependent variable was RT. As mentioned above, for the prime trials, benefits were measured by the RT difference between neutral and valid trials. Costs were measured by the RT difference between neutral and invalid trials. For the probe trials, negative priming was measured by the difference in RT between DT and control probe trials. In addition to RT, participants' error rates were also measured. In this study the correlation coefficient between RT and error rates were used to test for speed-accuracy trade-off.

MATERIALS

Stimulus presentation and data collection were controlled by a MEL2 program (Schneider, 1988) on a pentium computer with a fifteen inch SVGA monitor. The task was a character recognition task. In each trial, two stimulus letters appeared (a target letter and a distractor letter). A target letter was indicated by light green and a distractor letter was light blue. Stimulus letters were I, O, S, and X. In different trials, these letters served as either targets or distractors. From the viewing distance of about 60cm, the height and width of each letter was .5cm (.48°) and .5cm (.48°), respectively.

PROCEDURES

The participants were given verbal instructions and practice trials before the main experiment. At the beginning of the prime display, a central fixation point "+" and two placeholders appeared on the computer screen for 300msec. This was followed by a blank screen for 200msec. Then a central cue appeared next to the fixation point (.5cm) for 150msec. The cue was a solid arrow, which pointed to either the right or left side of the computer screen. If an arrow did not appear then the central fixation point was replaced by the pound sign (#). The participant was asked to shift his or her attention in the direction the arrow was pointing because, on a majority of the trials the target object would appear on that side of the computer screen. Next, two letters (one green and one blue) appeared on the computer screen. The stimuli are I, O, S, and X. The key assignment for the letters was d, f, j, and k, respectively. The participant was instructed to identify the green letter (target) and press the corresponding key on the keyboard. For example, if the participant saw a green I, then he or she pressed the d key on the keyboard. If the participant made an error the computer made a beep sound. The stimuli appeared on the computer screen for 2000msec or until the participant responded. The computer recorded the participant's RT for each response. After the participant responded, there was a 500msec inter trial interval (ITI) followed by the probe display. The probe display included the following: the central fixation point and two placeholders, which appeared on the screen for 300msec. This was followed by a blank screen for 200msec. Then the probe stimuli (one green and one blue letter) appeared in the near position for either 2000msec or until the participant responded. Again, the participant's RT was recorded. There was another ITI for 1500msec followed by the next set of trials. Sets of prime-probe trials were presented randomly. The participant was instructed, at the beginning of the experiment, to respond as quickly and as accurately as possible. The participant was also instructed to try and keep their error rate below 5 percent, which was four errors per block of trials. The entire experiment took approximately one hour to complete. Figure 1 shows the trial sequence for the prime display and Figure 2 shows the trial sequence for the probe display.

There were a total of 800 trials. Four hundred trials in the prime display and 400 trials in the probe display. There were 240 trials for the valid conditions and 80 trials each for the neutral and invalid conditions. Half of the valid (120), neutral (40), and invalid (40) trials were for the near condition and the other half for the far condition. The same was true for the DT and control conditions.

RESULTS

PRIME ANALYSIS

Trials from the prime display were not used in the analysis if they contained errors or if the reaction time was less than 200msec or greater than 1200msec. The overall error rate was three percent. Mean reaction times and error rates for the prime trials are shown in Table 1. The data met the homogeneity of within-group variance and independence of error component assumptions of analysis of variance. The assumption of independence of error component was met through the design of the experiment. The computer randomly selected the order of the presentation of the stimuli for each participant and only one participant went through the experiment at one time. The assumption of normality of sampling distribution was partially met. There were equal sample sizes; however the degrees of freedom of error for the distance condition, which was 19, was less than the minimum recommendation of 20. The assumption of homogeneity of covariance or sphericity was violated. The Geisser-Greenhouse correction to the F critical value was applied. The assumption of additivity can not be directly tested; usually a significant condition by subject interaction results in a large error term and very little power.

The remaining data from the prime trials were submitted to a 3 (cue validity: valid, neutral, and invalid) X 2 (distance: near and far) repeated measures ANOVA. The main effect for distance was significant, $F(1,19) = 17.52$, $p < .05$, $\eta^2 = .48$. The RTs were significantly longer for the far condition than the near condition. There was also a significant main effect for cue validity, $F(2,38) = 13.64$, $p < .05$, $\eta^2 = .418$. The RT for the valid condition was shorter than the RT for the neutral condition, which in turn, was shorter than the RT for the invalid condition. The interaction between cue validity and distance was not significant. For each of the cue validity conditions, RTs for the far conditions were longer than RTs for the near condition. Figure 3 shows the mean RTs in milliseconds for the valid, neutral, and invalid conditions at the near and far locations.

Using a Dunnett adjustment, post hoc comparisons were performed to test for costs and benefits. There was a significant difference between the neutral and valid conditions. The RT for the valid condition (M = 544, SD = 26) was shorter than the RT for the neutral condition (M = 568, SD = 25). There was also a significant difference between the neutral and invalid conditions. The RT for the neutral condition (M = 568, SD = 25) was shorter than the RT for the invalid condition (M = 590, SD = 12). Table 2 shows the mean cost and benefit for the near and far locations in milliseconds. As can be seen from this table, significant benefits (RT (valid) < RT (neutral)) and significant costs (RT (invalid) > RT (neutral)) were observed in both the near and far locations. These results disconfirmed Hypothesis 2 and confirmed Hypothesis 4. The early selection theory was supported.

A bivariate correlation for RT and error rate resulted in an r of .41 ($p > .05$). This indicates that speed-accuracy trade-off did not occur.

PROBE ANALYSIS

In the probe data analysis, RT data containing errors on either the prime or probe trials were excluded. The overall error rate was three percent. RTs that were less than 200msec or greater than 1200msec were also excluded from the data analysis. The mean RT and error data are shown in Table 3. The assumptions of homogeneity of within-group variance and independence of error component were met. The independence of error component was met through the experimental design. The assumption of normality of sampling distribution was partially met. The sample sizes were equal, but the degrees of freedom for error for the distance, priming condition, and distance by priming condition were 19. The assumption of homogeneity of covariance (sphericity) was violated and the F critical value was adjusted using the Geisser-Greenhouse correction. The assumption of additivity could not be tested.

The remaining data was submitted to a 3 (cue validity: valid, neutral, and invalid) X 2 (distance: near and far) X 2 (priming condition: control and distractor target) repeated measures ANOVA. The main effect for priming condition was significant, $F\ (1,19) = 5.293$, $p < .05$, $\eta^2 = .218$. The RT for the DT condition was longer than the RT for the control condition. Also, the interaction between the distance and priming condition was significant, $F\ (1,19) = 14.961$, $p < .05$, $\eta^2 = .441$. In the near condition, the RT for the DT was longer than the RT for the control condition, whereas, the RTs were the same for DT and control conditions in the far condition. Figure 4 shows mean RT for the DT and control conditions at the near and far locations.

Planned comparisons were performed on the negative priming data, the difference in RT between the DT and control conditions, in order to test Hypothesis 1, 3a, and 3b. Hypothesis 1 (proposed in accordance with late selection theory) states that negative priming (RT (DT) > RT (control)) should occur for all cue validity conditions (valid, neutral, and invalid) at both the near and far locations. Hypothesis 3a and 3b (proposed in accordance with early selection theory) state that negative priming (priming (RT (DT) > RT (control)) should not occur in either the near or far valid conditions (3a), while it should occur in both neutral and invalid conditions at the near and far locations(3b). Bonferroni method was used to determine if the negative priming for each condition (valid near, valid far, neutral near, neutral far, invalid near, or invalid far) was significantly different from zero. The probability level was set at .01 to avoid familywise error. A Significant negative priming effect was found for the neutral near condition, $t\ (19) = 5.45$, $p < .01$, and invalid near condition, $t\ (19) = 4.37$, $p < .01$. The negative priming effect was not significant for the following conditions: valid near, $t\ (19) = 1.94$, valid far, $t\ (19) = 0.86$, neutral far, $t\ (19) = 1.86$, and invalid far, $t\ (19) = 1.17$. These results confirmed Hypothesis 3a, partially confirmed Hypothesis 3b, and disconfirm Hypothesis 1. The early selection theory was partially supported.

A bivariate correlation was performed on the probe RT and error rates resulting in an r of -.04 ($p > .05$). This suggests that speed-accuracy trade-off did not occur.

DISCUSSION

PRIME DATA

The results from the prime data showed significant cueing effects of costs and benefits. These results confirm Hypothesis 4 proposed by early selection theory, in which costs and benefits should occur for both the near and far locations. On the other hand, these results disconfirm Hypothesis 2 predicted by late selection theory, in which costs and benefits should not occur at either the near and far locations. These results suggest, in congruence with previous research, participants were able to shift their attention according to the central cues (e.g., Posner, 1980). In other words, when the cue appeared in the display, participants were able to effectively move their spotlight of attention in the direction the arrow was pointing, so that the stimuli in that location appeared within their focal attention. For example, when a valid cue appeared, the participant moved his or her attention in the direction it was pointing and then the target appeared within his or her focal attention. Early selection theory was supported by the prime data.

One result which was not predicted by early or late selection theory was the RTs for the near condition were consistently shorter than the RTs for the far condition at each level of cue validity. One possible explanation for this is that participants were still in the process of shifting their attention when the stimuli appeared. For example, in the valid condition the target letter appeared before the participant had finished moving their focal attention to the target location. Another possibility is a confound between the size of the target and distractor letters and distance. The letters were the same size in both the near and far conditions. Size of the stimuli affects the visual angle or retinal asymmetry. If the participants did not move their eyes, the stimuli in the far condition would fall onto their peripheral vision making it more difficult to identify the target. This in turn would incur time; hence the RT difference between the near and far conditions.

PROBE DATA

Negative priming, as measured by the difference in RT between the control and DT conditions, was significant for the neutral near and invalid near conditions but not the valid near, valid far, neutral far, or invalid far conditions. These results confirm Hypothesis 3a (negative priming would not occur during the near or far valid condition) and partially confirmed Hypothesis 3b (negative priming would occur in the near and far neutral and invalid trials). These results disconfirmed Hypothesis 1, which predicted that negative priming would occur in all cue validity conditions (valid, neutral, and invalid) at both the near and far locations. This pattern of negative priming does not support late selection theory; however, it partially supports early selection theory.

It appears that two conditions need to be satisfied for negative priming to occur. First, the stimuli need to be in close spatial proximity to one another. Second, the target and distractor objects need to have equal weight of attention competing for attentional resources. In the far valid conditions, the focal attention was weighted at the target location so that the distractor object did not compete for attentional resources. Since the distractor object was not competing for attentional resources it was not inhibited; therefore negative priming did not occur. In the far neutral condition, the participant may have been in a diffused mode of attention, in which the participant selected to focus his or her attention onto the target object based on color. This assumes that color is processed preattentively. In this case, only the target object received the weight of focal attention and the distractor object did not compete for attentional resources. Since the distractor object was not inhibited, negative priming did not occur. In the far invalid condition the participant may have processed the distractor item then shifted attention to the other side of the display to process the target item. This shifting of the weight of attention may have override the processing of the distractor information. Therefore, processing of the distractor object might have inhibited, but the inhibition was not carried over to the following trial. Hence, negative priming did not occur. In the near valid condition, the focal attention was weighted at the target location so that the distractor object did not compete for attentional resources. Since the distractor object was not competing for attentional resources it was not inhibited; therefore negative priming did not occur. In the near neutral condition, both the target and distractor object may have had equal weight of focal attention competing for resources. In this case, the identity of the distractor object was inhibited. This in turn resulted in negative priming. In the near invalid condition, the distance between the target and distractor objects may not have been great enough to override the processing of the distractor object when participants shifted their focus of attention. Even though the participants shifted their focal attention from the distractor to the target location, the distractor object may still have been within the spotlight of attention competing for attentional resources. In this case, the identity of the distractor object would be inhibited resulting in negative priming.

There is one note of caution in interpreting the cueing data. This data may be limited be a potential confound between valid condition and practice. Since the valid condition occurred sixty percent of the time while the neutral and invalid condition each occurred only twenty percent of the time, the participant had three times more practice with the valid condition. Practice effects and not the allocation of attention maybe why the RT to the valid condition is shorter than the RTs for the neutral and invalid conditions.

Future research may want to investigate the effect of allocating attention using the cueing paradigm in an identity negative priming task where the target letter is identified by a bar marker. This may help minimize the differences in RT observed between the near and far location in the prime display, because with the bar marker the participant could not preattentively choose the target object based on color. Also, it would be interesting to see if the effect of allocating attention is same in spatial and identity negative priming tasks.

APPENDIX A

INFORMED CONSENT

You are being asked to participate in a study in visual attention. This study is being conducted by Stacy Phelps under the supervision of Dr. Hideya Koshino, assistant professor of Psychology. This research project has been approved by the Human Subjects Review Board, Department of Psychology, California State University, San Bernardino. The university requires that you give your consent before participating.

This experiment is concerned with the role of selective attention in letter recognition. At the beginning of each trial, you will see a plus sign at the center of the display. Please gaze upon the plus sign and avoid moving your eyes from it. Next either the plus sign will be replaced by a pound sign (#) or an arrow will appear. The arrow will point to either the right or left side of the display. Please keep your eyes on the center plus sign while shifting your attention to the direction the arrow is pointing. Next, two letters will appear on the screen. One letter will be green, the other letter will be blue. Your task is to identify the green letter and press the corresponding key on the keyboard as quickly and as accurately as possible. The possible letters are I, O, S, and X. This study will take approximately one hour of your time.

Please be assured that any information you provide will be held in strict confidence by the researchers. At no time will your name be reported along with your responses. All data will be reported in group form only. At the conclusion of this study, you may receive a report of the results by contacting Dr. Hideya Koshino at (909) 880-5435.

Please understand that your participation in this research is totally voluntary and you are free to withdraw at any time during this study without penalty, and to remove your data at any time during this study.

There are no risks involved in this study. Any questions about this study or your participation in this research should be directed to Dr. Koshino at (909) 880-5435. If you have questions about research subjects' rights or in the event of a research-related injury, contact the university's Institutional Review Board at (909)880-5027.

By placing a mark in the space provided below I acknowledge that I am at least 18 years of age.

Place a check mark here:________________

Today's date:____________

APPENDIX B

CLASSIFICATION INFORMATION

Please provide the following information for classification.

Sex: Male Female

Date of Birth___________________________

APPENDIX C

DEBRIEFING STATEMENT

The purpose of this experiment is to examine if early selection or late selection theory is indicate of negative priming. Early selection theory states that objects are not recognized unless they receive attention. Late selection theory states that it is automatic to recognize and process familiar stimuli and this does not require attention. The phenomena of negative priming occurs when a distractor object in the prime display becomes the target in the probe display resulting in a longer reaction time than if the target in the probe display was unrelated to the stimuli in the prime display. In other words, in the first display if the distractor object was O and then in the second display O became the target object it would take you longer to recognize O then if the target had been some other letter.

The cueing paradigm and distance were manipulated in this experiment. In the cueing paradigm, there are three types of cues: valid, invalid, and neutral. In this experiment, the cue was valid if it pointed to the green letter, invalid if it pointed to the blue letter, and the neutral cue occurred when the plus sign became the pound sign (#). Cost and benefits result from using a cue. Cost occurs when the reaction time is longer following invalid cues than neutral cues. Benefit occurs when the reaction time is faster following valid cues than neutral cues. The stimuli either appeared close together or far apart. Late selection theory predicts that regardless of the distance between the target and distractor, the cost and benefits effect of the cueing paradigm will not be observed.

However, the cueing paradigm should not affect the degree of negative priming because, focal attention is not required to process distractor information. Early selection theory predicts that the cost and benefits effect will not be observed when the stimuli are presented in the near location but, will be observed when they are presented in the far location. Furthermore, negative priming should occur during invalid trials. Since, the distractor object will appear within the focal of attention and will be processed resulting in negative prime. Negative priming should not occur on valid trials because, only the target appears within focal attention. Hence, the distractor object should not be processed nor should it produce negative priming.

APPENDIX D

TABLES AND FIGURES

TABLE 1

MEAN RT (IN MILLISECONDS)
AND MEAN ERROR RATES (%) FOR PRIME DATA

		Type of Cue Validity					
		Valid		Neutral		Invalid	
Distance		RT	Error	RT	Error	RT	Error
Near	*M*	525	1.9	550	2.6	581	4.4
	SD	81	3.1	92	3.0	93	5.2
Far	*M*	562	4.5	586	2.9	598	2.2
	SD	89	2.5	102	5.4	111	2.7

TABLE 2
COSTS AND BENEFITS (IN MILLISECONDS)

	Distance			
	Near		Far	
	Benefit	Cost	Benefit	Cost
M	25	31	24	13
SD	34	77	44	48

TABLE 3

MEAN RT (IN MILLISECONDS) AND
MEAN ERROR RATES (%) FOR PROBE DATA

		Type of Cue Validity					
		Valid Control		Neutral Control		Invalid Control	
Distance		RT	Error	RT	Error	RT	Error
Near	M	536	3.1	521	4.4	529	2.4
	SD	87	2.7	103	5.0	101	3.1
Far	M	553	2.9	550	4.2	547	2.6
	SD	79	3.1	84	7.0	105	3.6
		Distractor Target		Distractor Target		Distractor Target	
Near	M	RT	Error	RT	Error	RT	Error
	SD	548	3.3	554	3.6	555	3.8
		80	3.6	95	4.4	91	5.3
Far	M	548	2.4	540	2.5	554	2.7
	SD	91	2.8	101	3.6	91	4.0

FIGURE 1

TRIAL SEQUENCE FOR PRIME DISPLAY

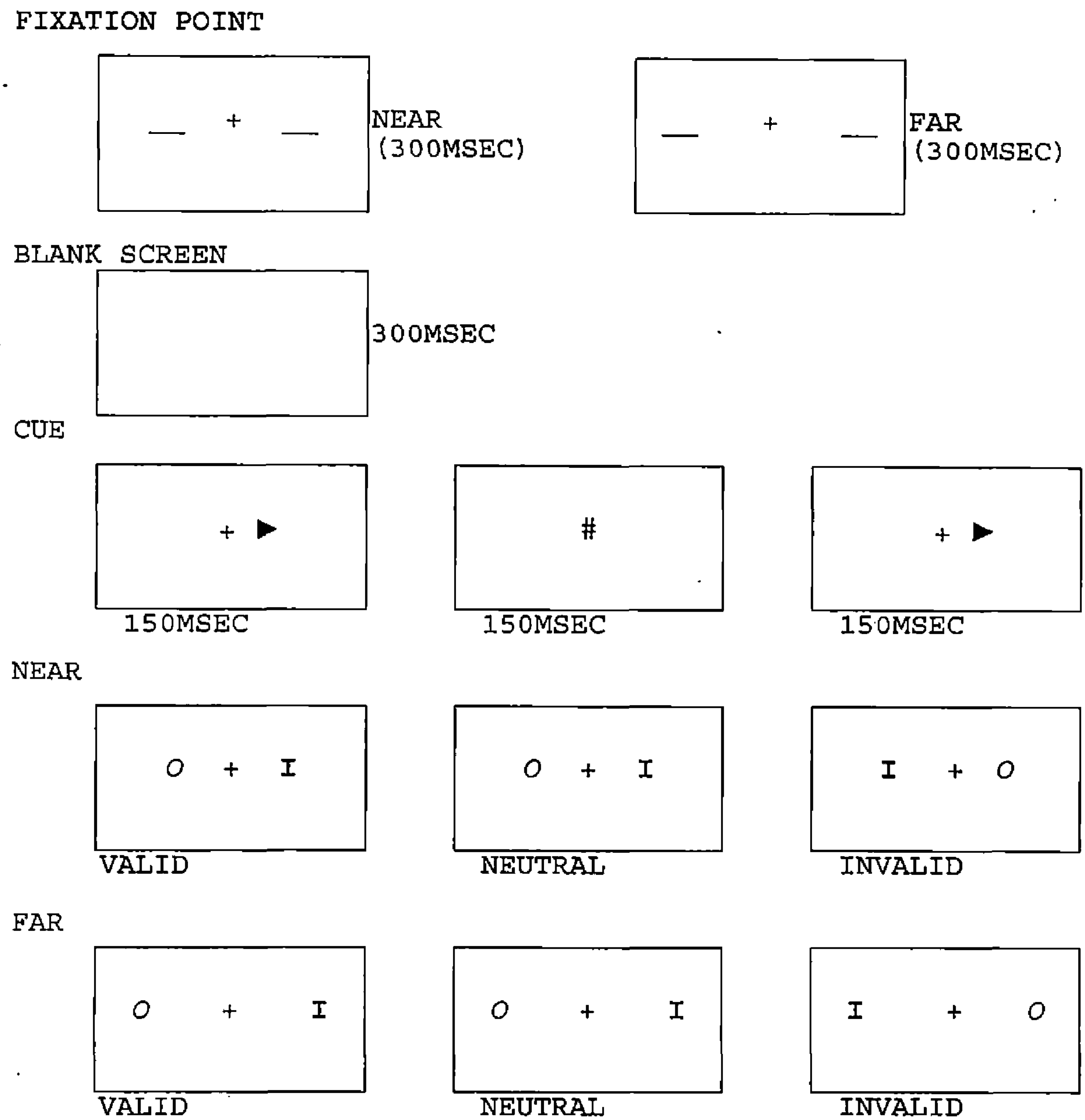


FIGURE 2

TRIAL SEQUENCE FOR PROBE DISPLAY

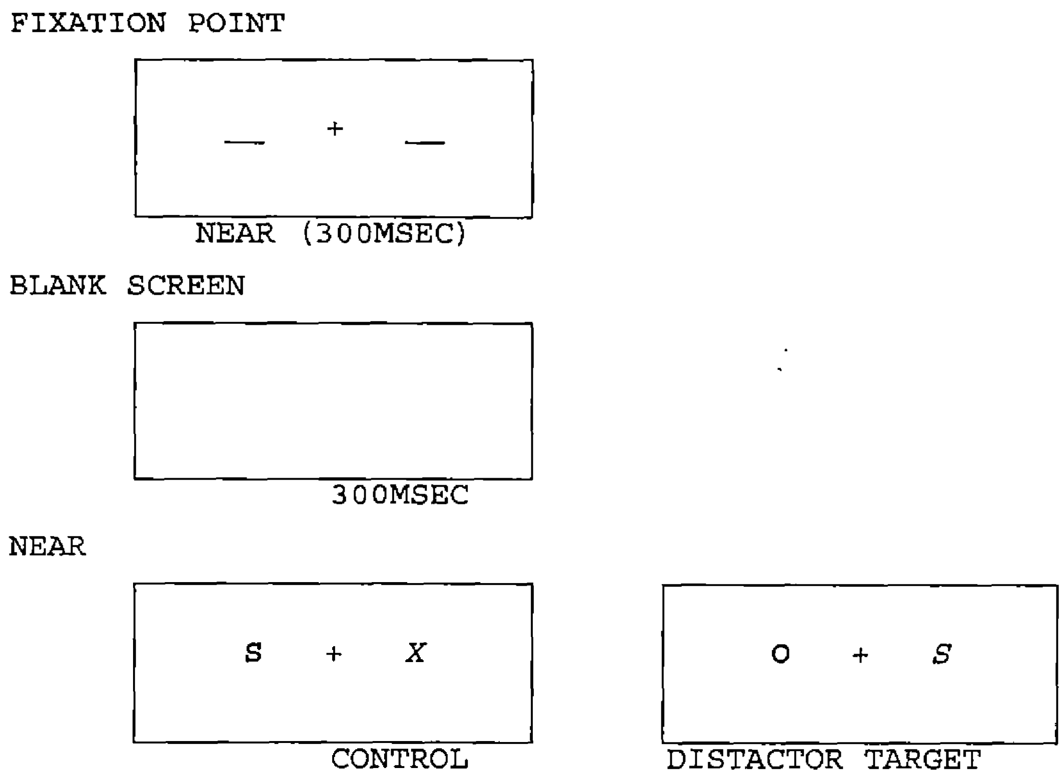


FIGURE 3

MEAN RT (IN MILLISECONDS) FOR VALID, NEUTRAL, AND INVALID CONDITIONS AT NEAR AND FAR LOCATIONS

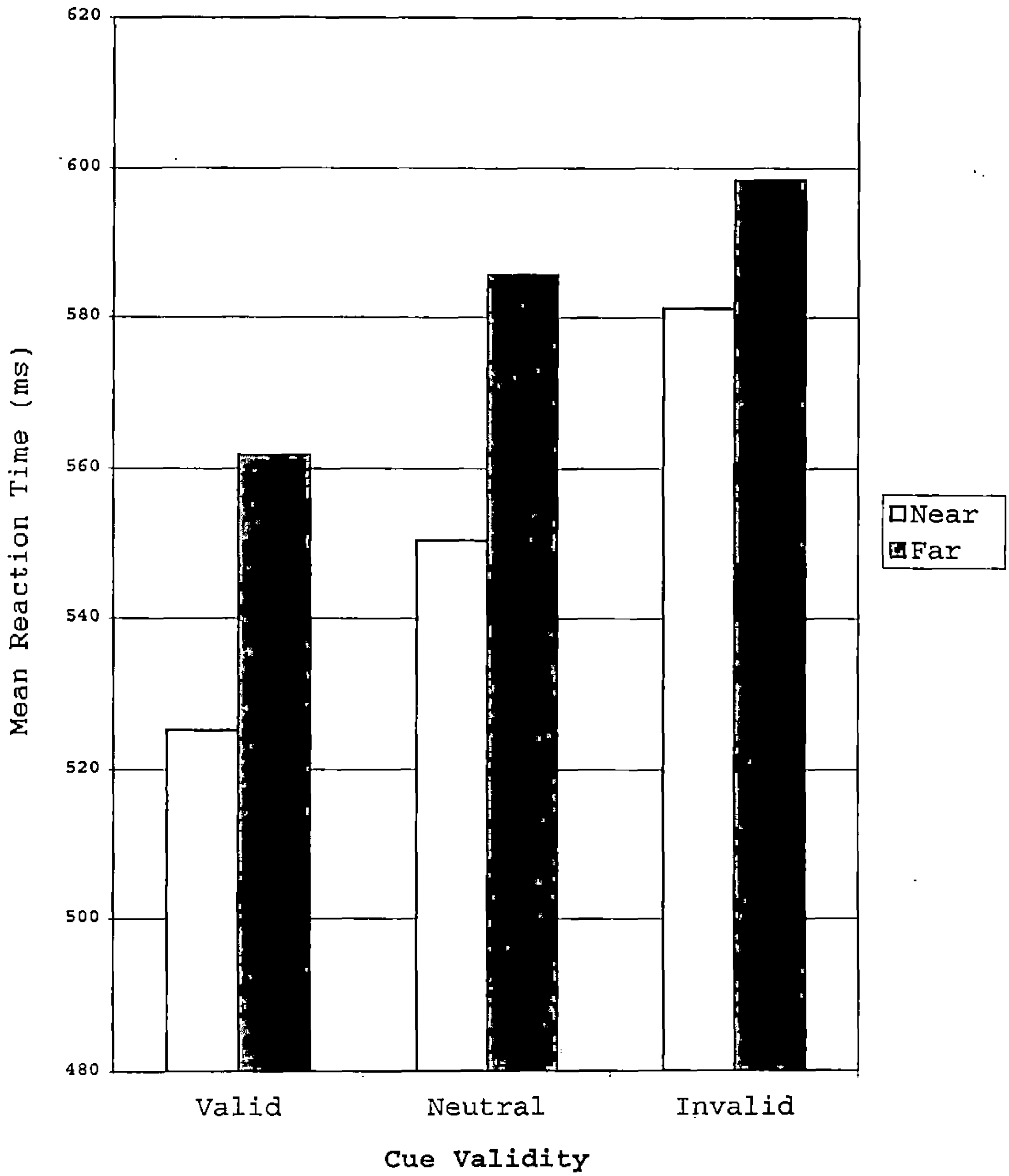


FIGURE 4
MEAN RT (IN MILLISECONDS) FOR CONTROL AND DISTRACTOR TARGET CONDITIONS AT NEAR AND FAR LOCATIONS

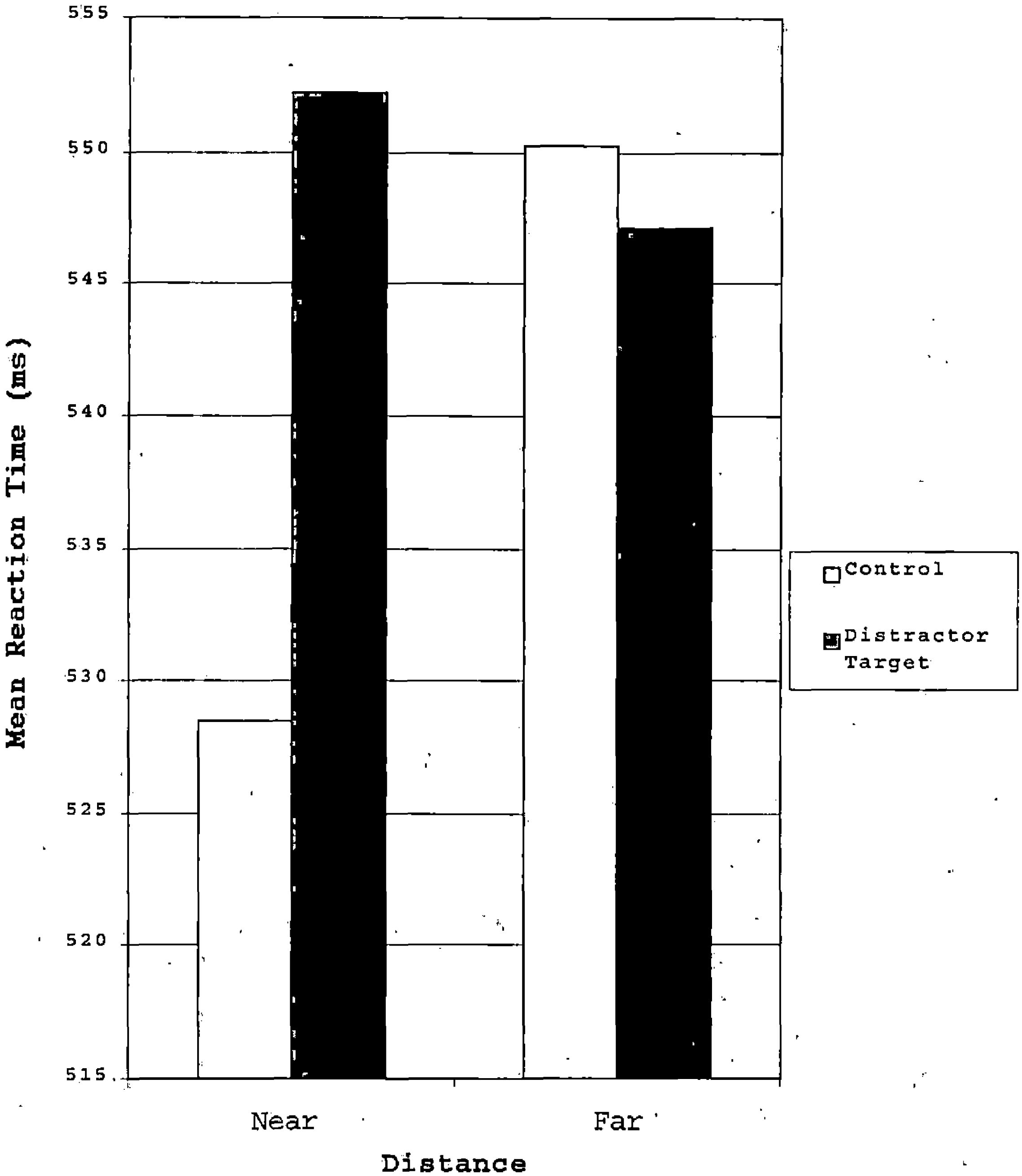
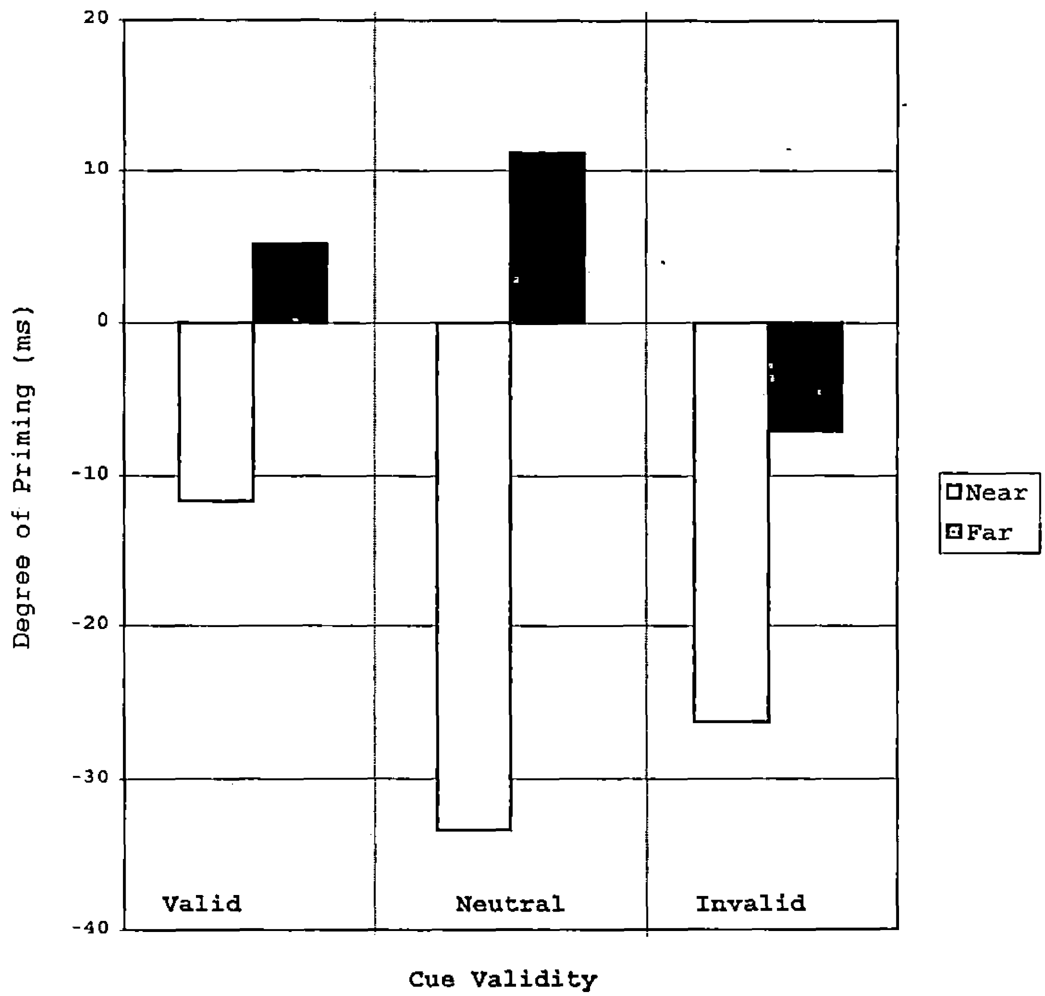


FIGURE 5
DEGREE OF PRIMING (IN MILLISECONDS) FOR VALID, NEUTRAL, AND INVALID CONDITIONS AT NEAR AND FAR LOCATIONS



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