Object-Based Perceptual Grouping Affects Negative Priming

Luis J. Fuentes
Universidad de Almería

Glyn W. Humphreys
University of Birmingham

Inmaculada F. Agis and Encarna Carmona
Universidad de Almería

Andrés Catena
Universidad de Granada

In 5 experiments the authors examine the role of object-based grouping on negative priming. The experiments used a letter-matching task with multiple letters presented in temporally separated prime and probe displays. On mismatch trials, distractor letters in primes were repeated as targets in probes, or distractor and target letters were completely different. Negative priming was shown by slowed responses when distractors were repeated as targets relative to when the stimuli differed. This occurred both when only letters were presented (Experiments 1 and 4) and when letters were surrounded by boxes (Experiment 5). Experiments 2, 3, and 4 showed that negative priming was affected by the grouping of target and distractor letters in prime displays. Negative priming was reduced when 1 of the distractor letters was placed in the target box and 1 was left outside the box; facilitatory priming was observed when both distractor letters appeared in the target box. The data were accounted for in terms of there being (a) object-based competition for visual selection, (b) inhibition of distractor objects that compete for selection with target objects, and (c) activation or inhibition of the identities of all component elements within target or distractor objects.

The visual world usually contains many objects, only some of which can be acted upon at a time; hence, there is a need for selection mechanisms in vision that enable actions to be addressed to behaviorally relevant objects. For coherent behavior to occur, close relations should exist between object coding and selection. In this article, we will present new evidence on the relations between object coding and visual selection and in particular on the relations between object coding and the excitatory and inhibitory processes that mediate the selection of target objects from displays containing multiple stimuli. The experimental procedure we used was negative priming (Tipper, 1985). In this procedure, participants can be presented with displays containing multiple stimuli. Only the target is responded to on a given trial, the other stimuli are distractors. Responses to stimuli that were distractors on a previous trial are slowed when the stimuli are subsequently presented as targets. Such negative priming effects may be taken as evidence for the involvement of inhibitory processes in selecting targets from

distractors (Tipper, 1985). In the following experiments, we examined how such inhibitory processes and any excitatory processes applied to targets to facilitate their selection are influenced by factors affecting the parsing of displays into perceptual objects. We asked whether excitatory and inhibitory mechanisms of selection are influenced by object parsing even when the spatial relations between selected (target) and rejected (distractor) stimuli are kept constant.

Since the time of the Gestalt psychologists (e.g., Koffka, 1935/1963; Köhler, 1929/1947), it has been known that visual elements group into perceptual objects on the basis of various visual properties, including proximity, similarity, closure, colinearity, and common fate (see Bruce & Green, 1991, for a current review). More recently, other properties have been added to this list, such as connectedness (Palmer & Rock, 1994). Thus, although there is a general propensity for spatially proximal elements to group (e.g., Treisman, 1982), grouping by proximity can be overruled if nonproximal elements share other properties, such as their color (similarity) or their movement direction (common fate). The efficiency of selection in vision seems to vary as a function of the grouping between display elements. For example, numerous experiments have used the flanker letter interference paradigm, in which responses are slowed when flanking target and distractor letters have incompatible responses, and have shown that interference is related to the spatial proximity of targets and distractors. Interference is greater when stimuli are close relative to when they are distant (e.g., B. A. Eriksen & C. W. Eriksen, 1974; C. W. Eriksen & Hoffman, 1972). This paradigm suggests that it may be more difficult to select targets from distractors if the stimuli group by proximity. However, interference can be greater between nonadjacent stimuli than between adjacent stimuli if nonadjacent targets and distractors have a common movement

pattern not shared by targets and adjacent distractors (Driver & Baylis, 1989). Similarly, the selection of bracket-like targets (e.g., [) can be influenced by whether they group by closure, by symmetry, or by both with other elements in displays (e.g., []). Grouping can either help (e.g., Donnelly, Humphreys, & Riddoch, 1991) or hinder selection (e.g., Pomerantz, 1981; Pomerantz & Schwaitzberg, 1975), depending on whether the grouped stimuli can be mapped onto a task-appropriate response. Similarity of shape and color can also determine grouping even when these features conflict with spatial proximity (Grabowecky, Robertson, & Treisman, 1993).

These results, demonstrating that selection in vision is determined by grouping relations between display elements over and above effects of spatial proximity, impinge on accounts of whether selection is solely spatially mediated or object-based (see Humphreys & Bruce, 1989, for a review). Many current accounts of selection in vision propose that selection is achieved by the allocation of attention to the spatial area surrounding targets, consistent with attention operating as either some form of spotlight (e.g., Posner, 1980) or zoom lens (C. W. Eriksen & St. James, 1986; C. W. Eriksen & Yeh, 1985). Within the spotlight or zoom lens, stimuli are activated, whereas outside the spotlight or zoom lens, stimuli may be inhibited (cf. Johnston & Dark, 1986; Moran & Desimone, 1985; Treisman & Gormican, 1988). Selection is achieved by differential activation of target representations over those of distractors. However, evidence for effects of grouping by common movement and closure or symmetry (see above) suggests that, at the very least, selection is influenced by factors additional to spatial location. For example, spatial selection (e.g., through an attentional spotlight) may be coupled to top-down activation of display elements from an object-recognition system sensitive to a variety of stimulus properties, including similarity, closure, and so forth (see Farah, 1990; Humphreys & Riddoch, 1993). Top-down, object-based activation of display elements may in turn lead to bottom-up activation of the spatial selection system so that the beam of the spotlight is narrowed or widened according to whether display elements cohere into perceptual groups irrespective of whether groups are defined by low-level physical features (Farah, Wallace, & Vecera, 1993) or by more abstract properties (e.g., lexicality) (Brunn & Farah, 1991; LaBerge, 1983; Sieroff, Pollatsek, & Posner, 1988). This notion of independent but coupled space- and object-based selection systems fits with neurophysiological evidence that distinguishes between visual pathways concerned with coding where and what stimuli are (Ungerleider & Mishkin, 1982).

For models in which selection is thought to be either purely spatial or achieved by the coupling of space- and object-based systems, selection is achieved by respectively exciting and inhibiting elements at target and distractor locations. One consequence of selection may be that stimuli are more available for response on subsequent trials if they are presented for a first time than if they have been rejected previously as distractors and therefore have been subject to inhibition. The phenomenon of slowed responses to stimuli that were previously distractors is known as negative

priming (e.g., Tipper, 1985). Negative priming has been shown to be tied to the locations of distractors. For example, responses to a target are slowed if the target is presented at the same location as a previous distractor (Tipper, Brehaut, & Driver, 1990; see also Park & Kanwisher, 1994). However, negative priming can also be observed on more abstract representations that do not seem tied to distractor location. For instance, negative priming is observed when distractors move through space and apparently disappear behind an occluding surface, suggesting that inhibition operates on object-centered representations, that is, inhibition seems to move with the ignored object (Tipper et al., 1990). Negative priming is also influenced by the semantic relations between distractors on trial n and targets on trial $n + 1$, and it transfers between pictures and words (Tipper & Driver, 1988). This last result suggests that inhibition is applied to semantic representations, irrespective of the original form of the stimulus and its spatial location. Indeed, negative priming can occur with spatially overlapping targets and distractors (Allport, Tipper, & Chmiel, 1985) when selection cannot involve selective inhibition of distractor locations. Such findings suggest that forms of selection in vision other than those based on location-coded representations may exist.

In the present study, we sought to show how the ability of the visual system to group stimuli into perceptual objects can modulate the inhibitory processing of distractor stimuli that compete for selection with target stimuli, despite the fact that target–distractor eccentricity is kept constant. Grouping involved stimuli without preexisting stored representations as a perceptual group, and so any effects could not have been based on inhibition of semantic representations. We used a sequential physical-matching task in which participants matched target letters presented at fixation on the basis of whether they were physically the same or different. The targets were flanked by two distractor letters printed in a different color to that of the target. The first display was termed the prime, and the second display was termed the probe. In the negative priming condition, or the ignored repetition (IR) condition, the distractor in the prime was repeated as the target in the probe display. In the control condition, or the unrelated (UR) condition, letters in the prime display were different from target and distractor letters in the probe display. Priming effects were measured by subtracting (respectively) the mean latencies and errors in the IR condition from those in the UR condition.

Figure 1 illustrates the displays we used in the experiments. In experiment 1, we simply used colored letters. In Experiment 2, the central target letter in the prime display was placed in a box with one of the two distractor letters. In Experiment 3, all the letters in the prime display were placed within a single box. In Experiment 4, we replicated the same conditions of Experiments 1 and 3 in a within-subject design, and in Experiment 5, all the letters in the prime display were placed in individual boxes. Placing letters together within a box can lead to their being encoded as parts of a single perceptual group. For instance, Treisman, Kahneman, and Burkell (1983) found that when participants had to name a word and then report the location of a small gap in a

Conditions

	AR	IR	UR
Experiments 1&4			
Primes	B A B	B A B	B A B
Probes	C A C	C B C	C D C
Experiment 2			
Primes	B A|B	B A|B	B A|B
Probes	C A C	C B C	C D C
Experiments 3&4			
Primes	B A B	B A B	B A B
Probes	C A C	C B C	C D C
Experiment 5			
Primes	B|A|B	B|A|B	B|A|B
Probes	C A C	C B C	C D C

Figure 1. Prime display configurations used in Experiments 1–5. AR = attended repetition condition; IR = ignored repetition condition; and UR = unrelated condition.

box presented simultaneously with the word, performance was better when the word was presented inside the box than when it was presented on the opposite side of fixation. This result occurred even when the distance between the word and the gap in the box was equal in the two cases. Fuentes, Agis, Carreño, and Ortells (1989) replicated this result when a lexical-decision task was used and when different attentional strategies were induced when participants performed the dual task. Such results indicate that letters presented simultaneously within a box are perceived as parts of the same object by the visual system. Therefore, in the present experiments, we manipulated whether target and distractor letters in prime displays were coded as parts of a single object or whether they were coded as separate objects. We assessed the role of object-coding on negative priming from distractor onto target letters even when interletter distances between targets and distractors were kept constant.

General Method

Apparatus and Stimuli

Stimuli were presented (by use of a VGA card) on the color monitor of an IBM-compatible computer. The computer controlled all stimulus events and timing operations. Keypress responses were made on the computer keyboard.

All the letters from the Spanish alphabet were used as stimuli. In 40-column text mode, letters averaged 5 mm high and 4 mm wide, and at a distance of 60 cm, they subtended an average of 0.48 × 0.38 degree of visual angle.

Design and Procedure

Participants performed a physical-matching task involving prime and probe displays containing three letters. The central letter was the target and was printed in red. Targets in both prime and probe displays were flanked by two letters (the distractors) that were printed in green and had the same identity. The conditions were as follows: On *same* trials, the target letter in the prime display was repeated as the target letter in the probe display, or the attended repetition (AR) condition (e.g., B A B → C A C). On *different* trials, there were two conditions: (a) the IR condition, in which the distractor in the prime display became the target in the probe display (e.g., B A B → C B C) and (b) the UR condition, in which the distractors differed in prime and probe displays (e.g., B A B → C D C).

Participants were presented sequentially with prime and then probe displays. Distractors were displaced 1 cm (0.96°) from fixation, and the target fell at fixation.

Each trial started with a fixation point (*) lasting 500 ms, followed by the prime display. Primes were exposed for 60 ms and were followed by a blank display lasting 740 ms. Subsequently, the probe display was presented until the response was made. The intertrial interval was 1,000 ms.

Participants were told to respond *same* by pressing a key with their dominant hand if the targets in both the prime and the probe displays were the same letter. *Different* responses were made with the nondominant hand and were required if targets were different letters. Instructions stressed speed, accuracy, and the benefit of ignoring distractors.

Participants were given three blocks of trials. The first block was a practice block. The experimental blocks contained 72 trials, 36 in which the prime target was repeated in the probe display (the AR condition) and 36 in which the target in the probe display was different from that in the prime display. Within the second set of 36 trials, there were 18 trials in which the distractor in the prime display became the target in the probe display (the IR condition) and 18 trials in which distractors in the prime display differed from those in the probe display (the UR condition). The practice block contained 48 trials: 24 for *same* trials (the AR condition) and 24 for *different* trials (12 for the IR condition and 12 for the UR condition).

Experiment 1

In experiment 1, we sought to establish negative priming by using the procedure described in the General Method section. Fuentes and Humphreys (1996) found negative priming by using both a name-matching task and a physical-matching task similar to the one we used. Experiment 1 replicates the physical-matching task in their study.

Method

Twenty-four undergraduates from the University of Almería were tested. The students received course credits for their participation, and all of them had normal or corrected-to-normal vision. The display configurations we used in Experiment 1 are shown in Figure 1.

Results

Data from one participant were dropped because of a very high error rate. The mean of median reaction times (RTs) and the percentage of error per condition are shown in Table 1.

A one-way analysis of variance (ANOVA) was performed on correct RTs, with condition (IR and UR) as a within-subjects factor. The results showed a reliable difference between the IR and UR conditions, $F(1, 22) = 7.88, MSE = 602, p < 0.025$. The difference between the conditions was not reliable for errors, $F(1, 22) = 3.54, p > 0.05$. Errors, however, followed the same pattern as RTs.

Discussion

Experiment 1 showed that negative priming occurred in a letter-matching task, replicating the effect observed in previous work (Fuentes & Humphreys, 1996). This result was consistent with inhibition being applied to distractor letters in the prime display so that participants could select the target letter. However, the results from Experiment 1 do not allow one to differentiate the contribution of spatial and object factors on negative priming, and both space-based and object-based theories can accommodate the present results.

As noted earlier in this paper, spatial accounts of selection propose that visual attention acts as a spotlight, with competition for selection existing between stimuli that appear within the spotlight (B. A. Eriksen & C. W. Eriksen, 1974). As a consequence, distractors close to targets may be subject to inhibition to prevent their being selected over targets.

In contrast to the spatial account, an object-based account

can be developed that assumes that competition for selection operates between perceptual groups (objects), which are not determined solely by the relative spatial locations of group members. Inhibition (producing negative priming) is applied to distractor objects that compete for selection with targets in prime displays. With the configurations we used in Experiment 1, distractor letters may group together on the basis of similarity because distractor letters were identical and differed in color from target letters. This group may compete for selection with the target letter in prime displays and hence may be inhibited to enable the target to be selected. A consequence of inhibiting the distractor group may be that the identities of its members, the distractor letters, may be inhibited, slowing responses in the IR condition when the target letter in the probe display is the same as the previously rejected distractor.

These space-based and object-based accounts of negative priming make different predictions about how performance might be affected by introducing a box into the prime display to alter the grouping between target and distractor letters. The space-based view holds that competition for selection should be the same, providing that the spatial locations of target and distractor letters are kept constant in prime displays. The object-based account holds that inhibition should only be applied when targets and distractors are encoded as separate perceptual groups. If the distractor is encoded as a member of the same group as the target, it may even be true that distractor identities are excited if inhibition of competing distractor objects is coupled with excitation of target objects to initially select the target. In Experiment 2, the displays matched those we used in Experiment 1 except that a box was drawn around the target and one of the distractor letters in prime displays. Letters within the box may group together (Fuentes et al., 1989; Treisman et al., 1983). Consequently, the distractor letter within the box may be activated along with the target letter, and there may be inhibition of the second distractor letter, which forms a separate group from the target–distractor group. The net result might be that the activation of the identity of the distractor remains around baseline level, in which case negative priming may be eliminated.

Experiment 2

Method

Twenty-four undergraduates from the University of Almería were tested. The students received course credits for their participation, and all of them had normal or corrected-to-normal vision. None of the participants had participated in Experiment 1.

The prime display configuration we used in Experiment 2 is shown in Figure 1. For one block of trials, the target in the prime display and the left distractor were located inside a box, and for another block, the target and the right distractor were placed together in the box. The order of each block was balanced across participants. The design and procedure were as mentioned in the General Method section.

Table 1
Mean of Median Reaction Times (RTs) and Error Percentage (Er) as a Function of Condition

Measure	Condition		
	AR	IR	UR
Experiment 1			
RT	473	534	514
Er	3.4	5.1	3.5
Experiment 2			
RT	436	484	482
Er	3.4	4.4	2.5
Experiment 3			
RT	455	490	501
Er	4.7	4.7	4.7
Experiment 4			
Box			
RT	513	544	561
Er	4.6	3.8	2.6
Nonbox			
RT	502	557	541
Er	4.1	4.9	3.2
Experiment 5			
RT	478	527	514
Er	3.0	5.0	3.4

Note. AR = attended repetition; IR = ignored repetition; UR = unrelated.

Results

Table 1 shows the mean of median RTs and error percentage for this experiment. Analysis of correct RTs showed no reliable differences between the IR and UR conditions, $F(1, 23) < 1$. However, there was an effect on errors, $F(1, 23) = 10.50$, $MSE = 4$, $p < .01$. The IR condition produced more errors than the UR condition.

An additional two-way mixed ANOVA was conducted with data from Experiments 1 and 2. The analysis of RTs showed no main effect of experiment. However, both the main effect of condition and the Experiment × Condition interaction were reliable, $F(1, 45) = 6.54$, $MSE = 447$, $p < .025$, and $F(1, 45) = 4.23$, $MSE = 447$, $p < .05$, respectively. The Experiment × Condition interaction occurred because there was a reliable inhibition effect in the IR condition compared with the UR condition in Experiment 1 but not in Experiment 2. The analysis of errors showed a main effect of condition, $F(1, 45) = 11.67$, $MSE = 5.9$, $p < .01$. The IR condition produced more errors than the UR condition across experiments. No other reliable effects were observed.

Discussion

The magnitude of negative priming on RTs was decreased in Experiment 2 relative to Experiment 1, though some effects on errors remained (note that the effects on errors did not interact with experiment as a variable). Taking both the speed and accuracy of performance into account, we found a reduction in negative priming on RTs, a finding that is consistent with an object-based account of competition for selection in vision. In Experiment 2, one of the distractors in the prime display was placed within a box with the target. This procedure may have led to competition for selection between the single distractor (outside the box) and the target object (the box and its elements) and to inhibition of the competing distractor (to allow the target to be selected). At the same time, excitation of the target object could have produced activation of the distractor in the target box, counteracting any inhibition of the distractor letter's identity. The net result is reduced negative priming relative to that found in Experiment 1, where distractors were subject solely to inhibition.

Although the data are consistent with this object-based account of competition for selection, we accept that they do not constitute strong evidence; although negative priming on RTs was reduced here, an effect on errors remained. Stronger evidence for an object-based account of selection would surface if negative priming in the IR condition could be reversed to generate a positive priming effect under particular circumstances. The object-based account predicts such a reversal if distractors are (at least initially) selected as belonging to the same object as the target. For instance, if distractors are placed within a box with the target, their internal representations may be activated along with the representation of the target because all the letters within the box may be selected together. Facilitatory priming may

result in the IR condition relative to the UR condition. We examined this hypothesis in Experiment 3.

Experiment 3

In Experiment 3, we assessed the object-based account of selection by placing target and distractors within a single box. The prediction was that facilitatory instead of inhibitory priming should be observed in the IR condition (relative to the UR baseline) because of the target and the distractors being perceived as belonging to a single object.

This experiment also enabled us to test another account of the slowed RTs in the IR condition compared with the UR condition (in Experiment 1). One possible reason for the slowed RTs is that in the IR condition (but not in the UR condition), there is a match between the identities of the distractors and the identity of the target. This match may bias a *same* response and lead to slowing of the final *different* response that is required in this condition; this result should be the case if the response involves a form of random walk to a decision criterion and if evidence for a *same* response shifts the walk processes away from the boundary for different responses (Ratcliff, 1985). If such biasing effects produce the slowing of RTs in the IR condition, then slowing of RTs should occur under all circumstances and should not be affected by whether a box surrounds the target and the distractors.

Method

Twenty-two undergraduates from the University of Almería participated for course credits. None of the participants had participated in the previous experiments. All had either normal or corrected-to-normal vision.

The configuration of the prime display is shown in Figure 1. All letters in prime displays were located inside a single box. The design and procedure were as indicated in the General Method section.

Results

Table 1 shows the mean of median RTs and error percentage. Analysis of correct RTs showed reliable differences between the IR and UR conditions, $F(1, 21) = 4.54$, $MSE = 333$, $p < .05$. Latencies in the IR condition were shorter than in the UR condition. There were no effects on errors, $F(1, 21) < 1$.

Data from Experiments 1 and 3 were entered into a two-way mixed ANOVA. The analysis showed that only the Experiment × Condition interaction was reliable, $F(1, 43) = 12.26$, $MSE = 471$, $p < .01$. RTs were slower in the IR condition than in the UR condition in Experiment 1 but were faster in Experiment 3. Error analysis did not produce any reliable difference. The differences in RTs across the experiments were not produced by a speed–accuracy trade off.

In order to reinforce the conclusions raised through the comparison of Experiments 1 and 3, we replicated the conditions of these two experiments in Experiment 4. In Experiment 4, participants were presented with mixed trials in which the three letters in the prime display could appear

either within a single box (as in Experiment 3) or without any box at all (as in Experiment 1). If the facilitation observed in Experiment 3 was due to grouping, an interaction between condition and prime configuration should be observed, with inhibition (negative priming) in the nonbox configuration, and facilitation (positive priming) in the box configuration.

Experiment 4

Method

Twenty-four undergraduates from the University of Almería participated for course credits. None of the students had participated in the previous experiments. All had either normal or corrected-to-normal vision.

The configuration of the prime display was similar to that of Experiments 1 and 3. Half of the trials presented all letters in prime displays inside a single box, and half of the trials presented them without any box. Trials of both types were randomly presented within each block of trials. The rest of the procedure was as indicated in the General Method section.

Results

Table 1 shows the mean of median RTs and error percentages. The only reliable result was the Condition × Configuration interaction, $F(1, 23) = 13.60$, $MSE = 502.3$, $p < .01$. In the box configuration, RTs were shorter in the IR condition than in the UR condition (positive priming), $F(1, 23) = 4.97$, $MSE = 726.6$, $p < .05$, but they were longer in the IR condition than in the UR condition in the nonbox configuration (negative priming), $F(1, 23) = 6.78$, $MSE = 475.8$, $p < .025$.

Error analysis showed only a main effect of prime configuration in *different* trials (IR and UR conditions). Error rate was higher when primes appeared inside the box, $F(1, 23) = 5.20$, $MSE = 3.5$, $p < 0.05$. No other effects were reliable.

Discussion of Experiments 3 and 4

In contrast to Experiments 1 and 2, a reliable facilitatory priming effect occurred when distractor letters in prime displays were repeated as targets in probe displays (in the IR condition relative to the unrelated baseline, the UR condition). This effect was found when only box trials were run (Experiment 3) and when they were randomly mixed with nonbox trials (Experiment 4). The letter identities and interletter spacing were the same as in Experiment 1, the only difference being that all the letters in prime displays were surrounded by a box. We suggest that the identities of all letters within the box (in the prime display) were activated. When the target in the probe display was a letter from the prime display, RTs to the target were then facilitated because the target's lexical identity had been preactivated (relative to when letters in prime and probe displays were unrelated). This result is important because it indicates that negative priming is not just due to the suppression of distractor letter identities; rather, it reflects

inhibition applied to objects that compete for selection with targets. When this competition for selection is removed, by arranging displays so that distractors and targets are parsed into a common object description, facilitatory rather than inhibitory priming emerges. The evidence of facilitatory priming in Experiments 3 and 4 also overrules an account of the slowed RTs in the IR condition being due to priming of a *same* response and moving evidence away from a *different* response (Ratcliff, 1985). Because letter identities were the same here as in Experiment 1, the same results should have occurred; clearly, they did not.

Also, nonbox trials in Experiment 4 produced similar effects to those in Experiment 1. When no box was presented, negative priming was then observed, indicating that distractors and target were perceived as separate groups.

Experiment 5

We ran Experiment 5 to test the possibility that the differences in negative priming between (a) Experiment 1 and the nonbox configuration of Experiment 4 and (b) Experiments 2, 3, and the box configuration of Experiment 4 were due to the box itself affecting the processing of the distractor. For instance, if the box masked the distractor letters, then it may have been less necessary for the distractors to be inhibited in order for the target to be selected; this situation might have particularly been the case when the distractor letters fell just on the inside of the box (in Experiments 3 and 4). This account does not explain why facilitation rather than inhibition was observed, but it may provide an account of why negative priming decreased when the box was present. To examine this idea, in Experiment 5 each letter was surrounded by an individual box. If the boxes reduced negative priming per se, negative priming should again be reduced in Experiment 5 relative to Experiment 1. However, on an object-based account, distractor and target letters presented in separate boxes should compete for attention, as in Experiment 1; negative priming should be observed because of the need to inhibit distractor objects that compete with targets.

Method

Twenty-four undergraduates from the University of Almería participated in this experiment. The students received course credits for their participation. None of the students had participated in the previous experiments, and all had either normal or corrected-to-normal vision.

The configuration for prime displays is shown in Figure 1. Each letter in the prime display was located within a single box. The design and procedure were as indicated in the General Method section.

Results

Table 1 shows the mean of median RTs and error percentages. There were reliable differences between the IR and UR conditions for both RTs and errors, $F(1, 23) = 6.95$, $MSE = 303$, $p < .025$, and $F(1, 23) = 5.55$, $MSE = 5.68$, $p < .05$, respectively. As in Experiment 1, latencies in the

IR condition were longer than in the UR condition, and the error rate was greater for the former condition than for the latter.

Analysis of data from Experiments 1 and 4 showed a main effect of condition for both RTs and errors, $F(1, 45) = 14.59$, $MSE = 449$, $p < .001$, and $F(1, 45) = 8.78$, $MSE = 6.81$, $p < .01$, respectively. No other differences were reliable.

Discussion

Experiment 5 replicated Experiment 1. There was a reliable negative priming effect (slower RTs and more errors in the IR condition relative to the UR condition), even though boxes were present in prime displays. The difference between the boxes in Experiment 5 and those in Experiments 2, 3, and 4 was that in Experiment 5, the boxes separated the target from the distractor letters, whereas in the earlier experiments, at least one distractor was grouped with the target. Clearly, the presence of boxes per se was unimportant; what was important was whether distractor and target letters formed separate perceptual objects that competed for selection. Only when distractor and target letters competed for selection was inhibition applied to distractors, generating negative priming.

General Discussion

Experiment 1 showed that the present matching task was susceptible to negative priming; RTs were slower when distractors in prime displays were repeated as targets in probe displays relative to when new targets were presented (in the IR condition relative to the UR condition). Experiment 5 replicated this result when the letters in prime displays were each surrounded by individual boxes. Experiments 2 and 4 showed that the magnitude of negative priming varied as a function of whether the boxes in prime displays grouped target and distractor letters together. In Experiment 2, the box grouped one distractor letter with the target and left one separate from the target. Negative priming was reduced relative to when there were no boxes present (Experiment 1). We suggest that this reduction occurred because the lexical representation of the distractor was activated by being part of the same object as the target and that this activation counteracted the inhibition applied to the same representation to reduce competition with the target from the separated distractor. In Experiment 3, both distractor letters were placed in the target box. Under these circumstances, RTs were facilitated when distractors in primes were repeated as targets in probe displays. This effect was replicated when box trials were randomly mixed with nonbox trials, producing facilitation in the former condition and inhibition in the latter condition (Experiment 4). We propose that lexical representations of distractors were activated along with those of the target when participants attended to the object containing the target. The data in our study are consistent with participants' initially selecting both the target and distractors when they fall in the same box. Nevertheless, participants eventually have to respond to the target and ignore the distractor. How is this accomplished?

We propose that there are two stages of selection, perhaps occurring in a hierarchical fashion. Larger objects or objects that include more local elements would be selected first, whereas local elements would be selected later on a second stage (cf. Navon, 1977).

When the box surrounds the target, the box is selected in the first stage, and its constituents are activated (target and distractors alike). Stimuli not selected are inhibited below their resting level, leading to negative priming relative to the unrelated baseline condition. At the second stage, the target within the box is selected again by activation of its representation and inhibition of competitor representations. This enables the target to be selected because its representation is relatively more activated than the representation of the distractor, even though the distractor is selected along with the target at the first stage. Note, however, that even if the representation of the distractor is inhibited at the second stage, the representation may still be activated above resting level because of the initial activation at the first stage. Responses should still be facilitated when distractors are repeated as targets (in the IR condition) relative to when new targets appear (in the UR condition).

Nevertheless, this facilitatory effect contrasts with results observed in Stroop tasks where participants name the color and ignore the meaning of colored words. In this task, color and name are attributes of a single object, that is, a word. Now, if the ignored name of a previous word becomes the name of color that participants are to respond to, negative instead of positive priming is then observed (Dalrymple–Alford & Budayr, 1966; Neill, 1977). In other words, contrary to our proposal that grouping of targets and distractors in a single object produces facilitation when the previous distractor becomes the next target (Experiment 3), Stroop tasks show that the response to the ignored attribute of a single object is suppressed, producing negative priming.

However, the Stroop tasks differ from our procedure in a crucial point. In our experiments, participants had to match elements from the probe display with elements previously presented in the prime display. This task required maintained activation of selected elements until the probe display was presented. In contrast, in the Stroop procedure, representations are not maintained across trials but rather are inhibited to enable the response to be made on the next trial without danger of perseveration. Hence, in the Stroop tasks, representations may be inhibited, whereas in ours, selected elements were activated and led to positive priming. What was important in our case was whether the elements that maintained activation were influenced by grouping between targets and distractors and whether elements that were suppressed (being irrelevant to the subsequent response) were also affected by whether they grouped or segmented from the target.

The present results also demonstrate that negative priming is not due simply to the suppression of lexical identities for distractors or to inhibition to reduce spatial competition for selection between proximal targets and distractors. The identities of targets and distractors were maintained across the experiments, as was the interletter spacing, yet qualitatively different patterns of performance emerged according

to the grouping relations between targets and distractors. The findings also go against recent accounts of negative priming that claim that slowed RTs to previously ignored stimuli do not reflect inhibition to stimulus representations. One alternative account is that negative priming reflects perceptual mismatches between stimuli on prime and probe displays (e.g., Park & Kanwisher, 1994). For example, in the present paradigm, RTs may be slowed in the IR condition because there is a mismatch in both the locations and color of target letters in probes when they have previously appeared as distractors in primes. However, on the basis of a perceptual match account, it is difficult to see why performance was facilitated in the IR condition when distractor letters appeared in a box with the target; note that there are still differences in the location and color of the letters repeated in probes from primes. This account can only hold for the present data if the perceptual matches involve coding at relatively abstract levels so that there is a match between distractors in primes and targets in probes if they occur within the same box, irrespective of color and location differences between the letters. Such a proposal contradicts one of the tenets of the perceptual match account as voiced by Park and Kanwisher that matching involves a perceptual code bound to a location. We have shown that location-based coding of letters can be overridden by varying the strength of target–distractor grouping. We do not deny that location-based perceptual matching may play a role in at least some negative priming effects. However, we propose that it was not crucial in our study.

A second account of negative priming was advanced by Neill and colleagues (Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992) based on Logan's instance theory of automatization (Logan, 1988). This account assumes that the presentation of a stimulus automatically evokes the retrieval of the most recent episode involving that stimulus, in which information about the response (or nonresponse) made to it is also included. When a previous distractor becomes the current target, an episode containing tags such as "ignore it" or "do not respond" is automatically retrieved. These tags conflict with the current task demand of responding to the target, and the response is delayed until the conflict has been resolved. This episodic retrieval explanation could account for some of the priming effects observed here. For instance, in Experiment 1 prime and probe displays looked similar so that the probe display could facilitate retrieval of the prime display, favoring negative priming to be observed. In Experiment 3, both displays looked quite different, and negative priming was not observed. Against this account are the results of Experiment 5. In this experiment, prime and probe displays looked different, as they did in Experiment 3 (see Figure 1); however, negative priming was observed.

Instead, the results may be accounted for in a parsimonious way by the suggestion that negative priming can reflect inhibition of distractor representations when there is competition for selection between target and distractor objects. This account explains why negative priming was reduced when one of two distractor letters in primes was incorporated into the target object, leaving only one separate distractor to compete for selection. It can also account for

why performance was facilitated when both distractor letters in primes were incorporated into the target object if there was activation of the target object along with inhibition of competing objects.

Given our proposal that the facilitation and inhibition effects reflect (respectively) activation and inhibition of separate target and distractor objects, our research illustrates two additional points. One is that when objects are attended or ignored, there is, respectively, activation or inhibition of all components of the object. When distractors were part of the target object, their identities were activated along with that of the target, generating a facilitation effect in the IR condition in Experiments 3 and 4. This view of some form of linkage between the parts of attended or ignored objects matches recent proposals emerging from studies of visual neuroscience (Duncan, 1996; Humphreys, Romani, Olson, Riddoch, & Duncan, 1994). For example, object properties coded and selected in separate neural areas (color, form, etc.) are nevertheless linked together to enable behavior to be addressed to all the properties once they are selected. In this paper, we propose that by attending to the box containing the target, there is linked activation of all letter identities represented within.

The second additional point is that the letters within the box seem to be grouped on the basis of a property such as "being enclosed by a common area." Note that the target and distractor stimuli themselves do not group on the basis of closure, similarity, or other principles proposed by the Gestalt psychologists, as evidenced by the results from Experiment 1. Their grouping is produced by being enclosed together but not by the relations between the letters themselves. This grouping by common enclosure is not shown by prior studies that have demonstrated grouping by using box stimuli (Fuentes et al., 1989; Treisman et al., 1983) because those studies showed grouping between the box and the enclosed elements (e.g., a word within the box) rather than grouping between elements within the box (as we have shown). There remains the issue of what limitations exist on grouping of this sort. In work with normal participants, Van Selst and Jolicoeur (1995) have shown that it is difficult to compute relationships between internal elements with random, complex polygons. Whether their finding is due to display complexity, familiarity, or to some other factor and whether their finding would hold if one used the present paradigm awaits future research. Irrespective of the answers to such questions, our results show that negative priming is bound to object-based coding of stimulus properties.

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