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Processing of distractors inside and outside the attentional focus in a priming procedure

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A priming procedure was used to study the processing of distractors located either inside (between the location of two targets) or outside (peripherally to the locations of the targets) the focus of attention. The stimuli were five-letter arrays, and participants had to decide whether two marked target letters were the same or different. In Experiments 1 and 2, positive priming was obtained both when targets and in-distractors in primes repeated as targets in probes; negative priming was found when out-distractor primes repeated as targets in probes. In Experiment 3, we also manipulated the match in letter case from primes to probes. In-distractors produced reliable positive priming, irrespective of whether the letters matched in case. In contrast out-distractors produced negative priming but only when the letters had the same case in primes and probes. These results are attributed to a spatial attention process operating (in this case) on low-level visual features, and an object-based selection process that enables more abstract information to be processed for selected stimuli.

Over the last two decades, the spotlight metaphor has been influential in interpreting data on visuospatial attention (Cave & Bichot, 1999). According to this metaphor, attention can be oriented intentionally to locations in space just as a spotlight can be moved to illuminate individual objects in a room. The processing of a visual stimulus is assumed to depend on its location with respect to the spotlight (LaBerge, 1983). Stimuli located inside the focus are fully

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processed, while those outside the focus are ignored (Cave & Bichot, 1999; Eriksen & Eriksen, 1974; Hahn & Kramer, 1998; Johnston & Dark, 1985). Thus, the spotlight facilitates the processing of objects located in the selected region of the visual field. This property of the spotlight metaphor holds whether the focus has a fixed (Posner, Snyder, & Davidson, 1980) or a variable size (Eriksen & St. James, 1986; Eriksen & Yeh, 1985; Laberge, 1983). For variable size models, facilitation of processing of objects inside the focus is an inverse function of the size of the focus. For example, a zoom lens model assumes that the greater the power of the ''lens'', the smaller the region of space covered by the focus and the greater the resolution of processing (Eriksen & Murphy, 1987; Maringelli & Umiltà, 1998). The notion that stimulus processing is facilitated for objects within a selected region of the visual field is also central to both abrupt-edge and gradient spotlight models, which assume that attention is centred on the target and falls off as the distance to the centre of the focus grows (Downing & Pinker, 1985; LaBerge & Brown, 1989).

However, the spotlight metaphor has been criticized by proponents of object-based accounts of selective attention (Driver & Baylis, 1989; Duncan, 1984). According to these views, attention is allocated to objects, rather than to space, and the amount of interference produced by nontarget objects is greater when they belong to the same object as the target (Pomerantz & Pristach, 1989) or can be easily grouped with the target (Baylis & Driver, 1992). However, recently, Goldsmith and Yeari (2003) demonstrated that the extent of the spatial focus of attention modulates the emergence of object-based effects. Object-based attention can be prevented by inducing a narrow spatial focus, whereas it can be elicited in conditions where it would not commonly appear simply by inducing subjects to spread their attention across the display (Goldsmith & Yeari, 2003; see also Lamy & Egeth, 2002). Therefore, it seems that the emergence of object-based selection is contingent on a spatial selection mechanism (see, for example, Vecera, Flevaris, & Filapek, 2004).

Although there is a wide agreement among variants of spotlight models that there is processing of relevant stimuli inside the focus, much less is known about the processing of irrelevant distractors within the focus. One of the reasons for this dearth of knowledge may be the difficulty of establishing whether attention can be deployed simultaneously to more than one position in space.

In an early study on this issue, Egly and Homa (1984; see also Juola, Bouwhuis, Cooper, & Warner, 1991) displayed two letters to subjects, one at the centre of the visual field and the other located in one of three concentric rings. The task was to localize the peripheral letter after naming the central letter. On half of trials the ring containing the displaced letter was cued verbally at the start of the trial. Generally speaking, valid cues produced a benefit in localization of the peripheral letter, while invalid cues produced costs in location. Importantly, when the middle ring was cued, equivalent costs were observed when the miscued target letter was in the inner ring and when the miscued target letter was in the outer ring. Assuming that the attentional focus expands spatially from the centre outwards to the cued middle ring, then a benefit should occur for targets in the inner ring while a cost should occur for targets in the outer ring. Similar results were obtained by Juola et al. (1991; see also Linnell & Humphreys, 2004). These results suggest that the attentional focus can be split, or perhaps that it can be adjusted to a ring-like region. In any case, if attention functions like a spotlight, then the target letter on the outer ring should have been outside the focus, and therefore a cost rather than a benefit should have been observed.

Whereas the above studies examined the processing of targets inside and outside the attentional focus, other studies have examined the processing of nontargets. Following Kahneman and Henik (1981), Fuentes and Ortells (1993) demonstrated that Stroop interference was higher the shorter the distance between a target colour patch and distractor incongruent colour words. In a similar vein, Johnston and Dark (1985) reported a study in which semantic priming effects from related primes at attended locations depended on the prime's duration, whereas no semantic priming at all was produced by primes at unattended locations despite exposure durations of up to 500 ms. Although repetition priming for unattended primes was obtained, this occurred only with long exposure durations. These results suggest that distractors located outside the attentional focus are not fully processed, and that even processing of their low-level physical features can be impaired.

In this paper we asked whether distractors located between two attended targets (hereafter, in-distractors) are processed in a qualitatively similar manner to those located outside the spatial region that encompasses two targets (hereafter, out-distractors). According to unitary focus accounts, when subjects have to attend to two simultaneous noncontiguous targets, the region between the two targets is also attended. Consequently, in-distractors should be processed fully, whereas out-distractors ought to be ignored. On the other hand, if the attentional focus can be split, then in-distractors and out-distractors may be equally ignored.

Only a few studies have examined the processing of nontargets displayed between two attended regions. In one important study, Heinze, Luck, Münte, Gös, Mangun, and Hillyard (1994) examined this issue using event-related potentials (ERPs). Subjects had to indicate whether two arbitrary figures matched. These figures were presented either at adjacent locations or separated by a distractor. Following the display that contained the target figures, a white vertical bar (the probe) was presented which subjects were asked to ignore. The component of ERP P1 to probes was enhanced both when probes were displayed in the locations of the previous targets, and also, although to a lesser extent, when they appeared between the targets. The P1 component is thought to reflect low-level processing of stimuli. Heinze et al. concluded that the region between the two targets could not be ignored, which is consistent with the notion of a unitary attentional focus.

However, other authors have argued that under certain conditions attention can be deployed to two noncontiguous spatial locations and that subjects can split their attentional focus. Castiello and Umiltà (1992) used a simple detection task to demonstrate that the attentional focus can be divided, and the region between two attended stimuli ignored, when those stimuli appear in opposite hemifields. Following this idea, Kramer and Hahn (1995) presented two target letters in different visual hemifields, each target precued by a rectangle. Two distractors were located between the two targets. The task was to determine whether the target letters were the same or different. Pairs of distractors were selected either to prime or not to prime the response to targets. Thus, for targets that required either a same or different response, the distractors could also be either same or different. The predictions were straightforward. If subjects cannot ignore the distractors, longer reaction times should be observed when the response to the targets is incompatible with the response primed by the distractors. This result was observed when targets and distractors appeared abruptly. However, no such interaction was found when the stimuli appeared after a set of premasks, so that their onset was not abrupt. Kramer and Hahn (see also Hahn & Kramer, 1998) reasoned that subjects might divide the focus between two noncontiguous targets, but that the abrupt onset of distractors between the targets automatically captured attention. This capture of attention may then unify the focus and facilitate the processing of intervening distractors. Using a similar procedure, Hahn and Kramer have shown that the attentional focus can also be divided when targets are displayed within the same hemifield.

However, abrupt-onsets cannot be the only factor that determines the unity of the attentional focus. Bichot, Cave, and Pashler (1999) failed to find accurate differences between searching for serially presented targets and searching for simultaneously presented targets. Subjects were presented with a brief series of frames containing either one (serial condition) or two targets (simultaneous condition) and a vertical array of three intervening distractors. The task was to indicate the largest target digit. If a single continuous region were selected, more errors ought to occur in the simultaneous than in the serial condition, as the time for processing targets in the simultaneous condition was double that in the serial condition (Bichot et al., 1999). In their sixth experiment, Bichot et al. presented a circular array of eight letters centred at fixation with a radius of 6.1°. The subjects' primary task was to indicate whether two differently coloured target shapes were the same or different. The secondary task was to recognize the letters displayed on same trials. The recognition of letters at noncued locations was lower than that for letters at distractor locations, regardless of whether the distractor locations were adjacent to or far from target locations. The authors concluded that the focus of attention can be divided and that distractors can be successfully ignored. In a very similar cueing study, Awh and Pashler (2000) demonstrated that rates of correct report of uncued in-distractors identities were lower than those of targets, but higher than those of out-distractors. These effects appeared mainly when other nonrelevant stimuli (noise) were presented in the same display than targets and distractors. Following Cepeda, Cave, Bichot, and Kim (1998), Bichot et al. assumed that multiple targets could be selected without intervening distractors being selected due to inhibition or suppression (Awh & Pashler, 2000) of noncued locations. Unfortunately, the recollection task (recognition) used makes it unclear whether distractors were not selected, or whether they were selected but forgotten.

Thus, the studies described above suggest that the attentional focus can be divided (Cave & Bichot, 1999) in four circumstances: When target and distractors are easily discriminable (for example, by colour, as in Bichot et al., 1999), when there is a lot of noise at irrelevant locations (Awh & Pashler, 2000), when onset of stimuli is not abrupt (Hahn & Kramer, 1998; Kramer & Hahn, 1995), and when stimuli appear in opposite hemifields (Castiello & Umiltà, 1992). The assumptions that underlie inferences about dividing the attentional focus are consistent across the studies. In particular, if the attentional focus can be split, then distractors between two attended locations ought to be successfully ignored irrespective of their position relative to targets (Awh & Pashler, 2000; Cepeda et al., 1998); that is, the same processing should occur for distractors located between two attended targets (in-distractors) as for distractors located outside a unitary region that contains two attended targets (out-distractors). On the other hand, if the attentional focus cannot be divided, processing of in- and out-distractors should differ, as far as they are located at the same distance from the attended locations (see Awh & Pashler, 2000). Specifically, it would be expected suppression of out-, but not of in-distractors.

A potential drawback here is that the assumptions are silent on the possibility that in- and out-distractors may be processed to different levels. In this paper we asked whether in- and out-distractors reach the same level of processing. The processing received by distractors was measured using a priming procedure. Interference procedures, not priming, have been the most common way to measure the level of processing reached by nonattended stimuli. However, there is actually a wide agreement that priming procedure may provide a more sensitive measure of processing than interference (Catena, Fuentes, & Tudela, 2002; Driver & Tipper, 1989; Fox, 1995). Therefore one important difference between the approach here and that of previous studies is the greater sensitivity of our measure to the processing reached by visual stimuli. We presented letter arrays both in the prime and probe display. Simultaneous presentation of the complete array should promote a unitary attentional focus centred on the middle of the array. The targets were located either at positions 2 and 4 (Experiments 1 and 2), or at positions 1 and 5 (Experiment 3) in the array. With targets at positions 2 and 4, the letter in position 3 was an in-distractor while the letters in positions 1 and 5 were out-distractors. In contrast, for targets at positions 1 and 5, there were only in-distractors located at positions 2–3–4. A split focus account would predict that both in- and out-distractors should be ignored effectively and therefore that they should produce equivalent priming effects (e.g., no priming if they are simply ignored, or negative priming if they are suppressed). In contrast, a unitary focus account would predict that attention should be allocated to positions between the targets in the array, but not to positions outside a unitary region that contains both targets. Thus, an in-distractor should not be ignored—for instance, it may facilitate response to a matching target in a following probe display. In contrast, out-distractors should be ignored more effectively: There may either be no priming (due to successful filtering) or negative priming (due to distractor suppression) (see Tipper, 2001, for a review). If indeed in-distractors produce positive priming and out-distractors produce negative priming, relative to a neutral prime condition, this qualitative difference in priming would be particularly strong evidence against the view that distractors are processed in the same way inside and outside the focus of attention.

EXPERIMENT 1

In this experiment, a letter matching task was combined with a priming procedure to ascertain whether processing of in- and out-distractors is similar. Sequentially presented prime and probe displays each contained a five-letter array, with two of the letters marked by arrows. Subjects were to decide whether the two letters marked with an arrow matched or not. Target letters were separated by one distractor letter (in-distractor) and were flanked by two identical letters (out-distractors).

According to unitary focus accounts, if in-distractors are fully processed, then positive priming should be observed when both the target and the in-distractors are repeated in the primes and probes. In contrast, there may be negative priming when the out-distractors letters are repeated in the probes. However, if there is a nonunitary focus, negative priming may be expected for both kinds of distractors, (in- and out- of the foci), while positive priming should occur only when targets in primes are repeated as targets in probes.

Method

Participants. Thirty-five (20 females, 29 right-handed) Psychology undergraduates from the University of Granada volunteered for course credit. All participants had normal or corrected-to-normal vision. They were between 18 and 25 years old.

Apparatus and stimuli. The stimuli were displayed on an SVGA monitor controlled by a 133 Pentium-based PC computer. The letters were white Sans Serif uppercase printed on a black background and subtended a visual angle of 0.57 degrees (about 3 degrees for the complete array). The stimuli were randomly selected from the alphabet, with the exception of Q and I, to avoid confusion with other letters or numbers. The letters in each display were arranged in a five-element array. We refer to the letters according to their position, numbered from left to right in the array. According to this scheme, target letters were located in positions 2 and 4, and were signalled by an arrow located above each letter. Distractors located in positions 1 and 5 (out-distractors) were identical, and differed from the distractor located in position 3 (the in-distractor).

Procedure. The instructions emphasized that subjects should attend to the target letters and avoid allocating attention to the distractors. Each trial began with a 500 ms central fixation asterisk immediately followed by a five-letter array (the prime display) centred at fixation. The task was to decide as quickly and accurately as possible whether the two target letters were the same or different. Subjects responded by pressing one key when target letters were the same and another key when they were different. Key assignment was counterbalanced across subjects. Following each response, the letter array was cleared and there was a 500 ms blank interval, then a 500 ms presentation of the central fixation asterisk, and then another five-letter array (the probe display), which remained on until subjects responded. Again, subjects were to press one key when letters 2 and 4 were the same and another key when they differed. Following the response to the probe display, there was a blank intertrial interval of 1000 ms.

There were four conditions of interest according to the prime–probe relations (see Figure 1): *In-distractor repetition* (IDR; the in-distractor in primes were repeated as targets in probes); *out-distractor repetition* (ODR; the out-distractors in primes were repeated as targets in probes); *target repetition* (TR; the targets in primes were repeated as targets in probes); and *nonrepetition* (NR; the letters in primes were not repeated in probes).

In all of these conditions, the two target letters in both the prime and probe displays were the same; that is, same responses were required to both the prime and probe. To ensure that participants were performing the same/different matching task, three conditions that required different responses were included. One of these conditions required a same response to the prime and a different response to the probe, another required a different response to the prime and a same response to the probe, and a third required a different response to both prime and probe. The repetition relation between the letters in the prime and probe displays in these three additional conditions was not manipulated.

The experimental session began with a practice block of 70 trials, followed by three experimental blocks of 140 trials each. Each experimental block was composed of 20 trials from each of the seven conditions. Following each block of trials subjects were required to rest for at least 1 min.

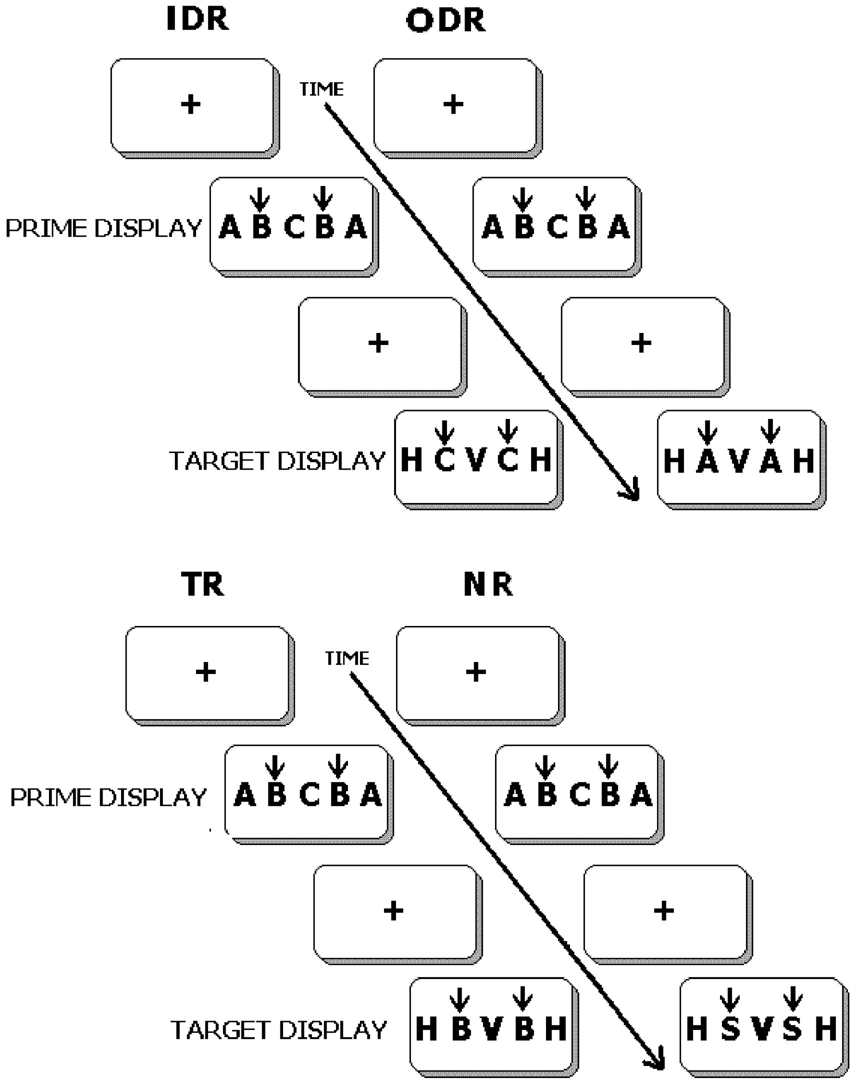

Figure 1. Experimental conditions of Experiment 1. IDR: In-distractor repetition condition, ODR: Out-distractor repetition condition, TR: Targets repetition condition, NR: Nonrepeated condition.

Results and discussion

Responses times (RTs) that were less than 200 ms or greater than 1500 ms were excluded from the analysis (0.6% of the data). RTs for correct responses were then used to compute mean RTs for each experimental condition, separately for

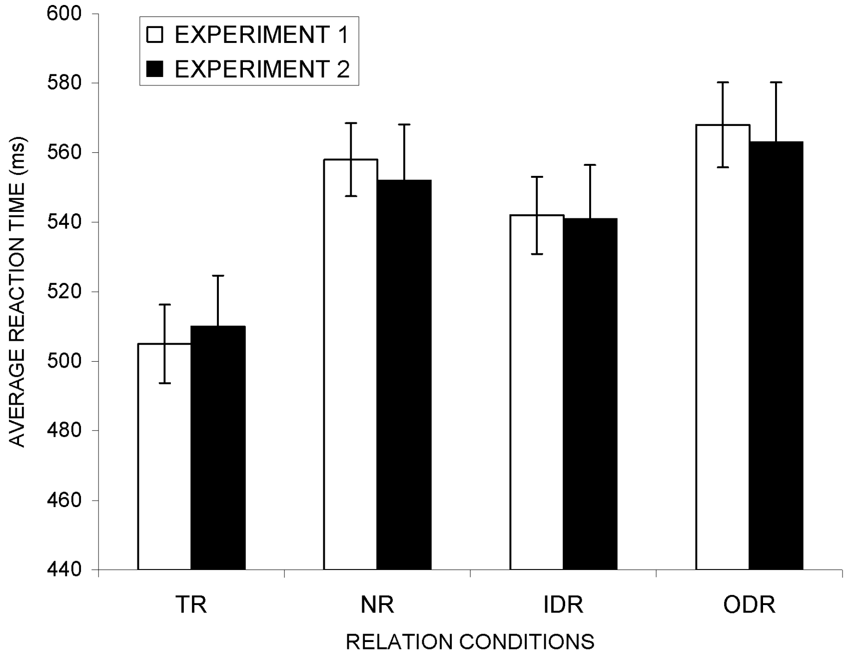

Figure 2. Means of reaction times (and standard errors of mean) for each prime–probe repeated relation in Experiments 1 and 2.

each subject. These means were then submitted to a one-way within-subject analysis of variance with prime–target relation as the only factor. The mean RTs in each experimental condition collapsed across subjects are displayed in Figure 2. The percentages of error were 1.80, 3.24, 2.77, and 3.57, respectively for conditions TR, NR, IDR, and ODR. Note that the pattern of errors is similar to that for reaction times. In all the experiments reported here *p*-level was fixed at .05.

The means in Figure 2 suggest that priming effects produced by distractors depended on prime location. This observation was supported by the analysis of variance, which revealed a significant effect of prime–target relation, $F(3, 102) = 110.87$, $MSE = 237$, $p < .001$. A posteriori LSD comparisons indicated that responses in the TR condition were faster than those in the other three conditions ($p < .05$). Also, responses in the NR condition were slower than those in the IDR condition ($p < .05$), and faster than those in the ODR condition ($p < .05$). The analysis of error percentages revealed a main effect of prime–target relation, $F(3, 102) = 3.08$, $MSE = 6.99$, $p = .03$. Post-hoc LSD tests indicated that there were more errors in both the ODR (3.57%) and NR (3.24%) conditions than in the TR condition (1.80%).

These results demonstrate that the location of distractors is an important factor in determining the processing they receive. More importantly, the results demonstrate that the direction of priming can be qualitatively different for in-distractors and out-distractors: In-distractors produced positive priming, whereas out-distractors produced negative priming. This results rule out any spatial attention model based on the idea that distractors are filtered or that they do not activate their internal representations.

However, the differences between in- and out-distractors might have been due to the locations they occupied either with respect to the attentional focus or with respect to the visual field (in-distractors were always at fixation, whereas out-distractors were always far from fixation). Differences in retinal acuity might at least contribute to the differences in priming shown by the two kinds of distractors. In addition, the differences in priming from both in- and out-distractors might be due to there being two out-distractors but only one in-distractor. It is possible that one in-distractor is not enough to produce negative priming (Yee, 1991). Experiment 2 was designed to address the issues of the differential number and visual field locations of in- and out-distractors.

EXPERIMENT 2

In this experiment we replicated the conditions of Experiment 1 but used displays containing only one in- and one out-distractor, each located at the same distance from the fixation point. We have the following predictions. If the different pattern of priming in Experiment 1 depended on the number of distractors, using the same number of in-and out-distractors should make those differences disappear.

To control for visual field location we presented letter arrays containing four letters. One target letter was presented at fixation (the fixated target). This randomly occupied either position 2 or 3 of the array, with the other target occupying either position 4 or 1, respectively. Now, the in-distractor could be presented either to the right or left of the fixated target (position 3 for targets at positions 2 and 4, or position 2 for targets at positions 1 and 3). The out-distractor would then fall at position 1 or position 4, respectively. If priming in Experiment 1 depended on attention focus, then we should replicate the same pattern of results observed in Experiment 1. In contrast, any differences between in- and out-distractors in Experiment 1 that were due to differential number or acuity should be eliminated since both distractors were now at the same distance from fixation.

Method

Participants. Nineteen Psychology undergraduates from the University of Granada volunteered for course credit. All participants had normal or corrected-to-normal vision.

Procedure. In this experiment we used the same experimental conditions as in Experiment 1 except for three important changes. First, the letter arrays contained only four letters, two targets, one in-distractor, and one out-distractor. Second, one of the targets, randomly selected, was presented at fixation (the fixated target). Third, to prevent that the in-distractor falling at the fovea due to eye movements being made between the two targets, we shortened the exposure duration of the displays to 180 ms.

The experimental session began with a practice block of 70 trials, followed by two experimental blocks of 182 trials each (26 trials per experimental condition). Following each block of trials subjects were required to rest for at least 1 min.

Results and discussion

Response times (RTs) that were less than 200 ms or greater than 1500 ms were excluded from analysis (0.5% of the data). The mean correct RTs for each experimental condition were then computed separately for each subject. These means were submitted to a one-way within-subject analysis of variance with prime–target relation as the only factor. Mean RTs in each experimental condition collapsed across subjects are displayed in Figure 1. The percentages of error were 9.8, 6.4, 9.6, and 14.6, respectively for TR, NR, IDR, and ODR. If we compare these results with those of Experiment 1 we see that RTs followed the same pattern and differences between the conditions were similar in size in both experiments. The error percentages were higher in this experiment presumably due to the short exposition duration of the displays and the uncertainty of the target's location (1 and 3 or 2 and 4).

As in Experiment 1 we found a significant effect of prime–target relation, $F(3, 54) = 29.52$, $MSE = 338.8$, $p < .001$. We conducted three planned comparisons to address the above predictions. One-tailed *t*-tests showed reliable differences between NR and both TR, $t(18) = 7.61$, IDR, $t(18) = 2.083$, and ODR, $t(18) = -1.72$; $p = .05$. Therefore, as in Experiment 1, responses in the NR condition were slower than those in IDR and faster than those in the ODR condition.

The analysis of the error percentages revealed a main effect of prime–target relation, $F(3, 54) = 3.86$, $MSE = 57.01$, $p = .02$. The paired *t*-test comparisons indicated that there were more errors in the ODR than in all other conditions, $t(18) = 3.33$, $t(18) = 2.22$, and $t(18) = 2.09$, respectively for NR, IDR, and TR.

The qualitative difference between the priming effects observed in conditions ODR and IDR is inconsistent with a divided focus account, as a divided focus ought to produce priming effects that are the same sign for in- and out-distractors. The present results might be explained in two other ways. One possibility is that subjects shift a single focus of attention from one target to the other, and in doing so attention is also allocated to the distractor between the targets. In this case, out-distractors would be ignored, while the level of processing reached by the in-distractor might approach that of the targets. Although the smaller positive priming effect for the IDR condition than for the TR condition appears inconsistent with this view, this difference may have occurred because two prime letters contributed to performance in the TR condition, while only one prime item contributed to performance in the IDR condition. However, there is a wide agreement that the minimum time to detect a first object at one location followed by a second object at a second location is greater than 200 ms (Duncan, Ward, & Shapiro, 1994). Therefore, this ''shifting'' focus account of the present results is unlikely. A second possibility is that the attentional focus expanded to cover the three central letters (a static focus), but that the in-distractor was not processed to the same level as the targets, and thus produced a smaller priming effect. For example, if targets are processed both at a level of physical features and at higher levels (e.g., abstract letter identities), while in-distractors are processed only at the level of physical features, then a smaller priming effect may be expected from in-distractors. We pursued this issue in the next experiment.

EXPERIMENT 3

The aim of this experiment was twofold. First, we wanted to explore further the hypothesis that in-distractors cannot be ignored. Second, we were interested in whether the level of processing differed for in- and out-distractors. With respect to the first issue, it was suggested that the different size of positive priming for conditions TR and IDR in Experiment 1 could be related to the number of primes involved (two for the TR condition and one for the IDR condition). If so, then the results from Experiment 1 do not necessarily imply that targets and in-distractors are processed differently. To address this issue, we included a condition in Experiment 3 in which targets appeared at locations 1–5, and three identical distractors appeared at positions 2–3–4. Then, we can check whether the number of in-distractors determines the sign of any priming (e.g., does a single distractor produce positive priming while two or more distractors produce negative priming?). Moreover, the shifting focus account described above would predict similar positive priming effects from these in-distractors and from the targets (or at least, a smaller difference in priming effects than the differences between conditions TR and IDR observed in Experiments 1 and 2).

With respect to the second issue, to examine whether positive priming for condition IDR in Experiment 1 depends on the level of processing reached by the in-distractor, we manipulated the congruency of the letter-cases in primes and probes. It is possible that only the physical features of in-distractors are processed. If this is the case, then positive priming would be expected only when the critical letters in primes and probes match in case.

Method

Participants. Twenty University of Granada Psychology undergraduates volunteered for course credit. All participants had normal or corrected-to-normal vision.

Procedure. In this experiment we used a 2 × 2 × 3 factorial within-subjects design. The prime letter case (upper vs. lower) and the distractor letter location (positions 2–3–4 for the in-distractor condition, and positions 1–5 for the out-distractor condition) were blocked, whereas the prime–probe relation was randomized within blocks (target repeated, no letters repeated, and distractor repeated). There were four blocks in the experimental session. The prime letters were upper case (U) for two blocks and lower case (L) for two blocks, while the probe letters were always upper case. This variable was factorially combined with the distractor letter location, so that distractor locations were 1–5 (out-distractors repetition condition, ODR; targets occupied positions 2–4) for two blocks, and 2–3–4 (in-distractors repetition condition, IDR, targets occupied positions 1–5) for two blocks. For each trial all distractor letters were the same. Note that when we refer to out-distractors in condition ODR, there is also a distractor letter located at the central position of the five-letter array. Nevertheless, as will be shown later, negative priming for this condition was very similar to that for the ODR condition in Experiment 1. As such, the four blocks of experimental trials are given the labels U-IDR, U-ODR, L-IDR, and L-ODR, the first part referring to letter case (upper vs. lower case), and the second to the kind of distractor (in- vs. out-distractors). Block order was randomized for each subject.

The three levels of prime–probe repetition relations were mixed within blocks: In the NR condition, none of the prime letters matched any of the probe letters; in the TR condition, the prime target letters were the same as the probe target letters; in the DR conditions, the prime distractor letters were the same as the probe target letters. In all of these conditions, the two target letters in both the prime and probe displays were the same; that is, same responses were required for both the prime and probe. As in Experiment 1, to ensure that subjects were performing the required same/different discrimination, three additional conditions that required different responses were included. One of these conditions required a same response for the prime and a different response for the probe, a second required a different response for the prime and a same response for the probe, and a third required a different response for both prime and probe. No letter was repeated from prime to probe in these response control conditions. In all conditions, the three distractors were the same letter. Subjects completed a practice block of 60 trials (10 trials for each of the six conditions) before completing the four experimental blocks of 120 trials (20 trials for each of six conditions). All others procedural details were the same as in Experiment 1.

Results and discussion

RTs that were less than 200 ms or greater than 1500 ms were excluded from analysis (0.64% of the data). The mean correct RTs were submitted to a 2 (prime case) × 2 (distractor location) × 3 (prime–probe repetition relation) within-subjects ANOVA. The mean RTs and error percentages in each experimental condition collapsed across subjects are listed in Table 1. No reliable effects were observed in the error percentages (all *F*s < 1.5)

The results in Table 1 show that the direction and size of the priming effects produced by distractors depended on both the location and the case of distractors in prime displays. Negative priming was observed only with out-distractors (ODR condition), while positive priming was observed with in-distractors (IDR condition). Furthermore, these negative and positive priming effects for the distractor repetition conditions (DR condition) occurred only when letter case matched from prime to probe.

These observations were supported by the results of the ANOVA. The analysis revealed a significant three-way interaction between prime letter case, distractor location, and prime–probe repetition relation, $F(2, 38) = 8.56$, $MSE = 362.68$, $p < .05$. This interaction was examined further by conducting separate analyses for upper case and lower case primes.

In the analysis of upper-case primes, the interaction between distractor location and prime–probe repetition relation was significant, $F(2, 38) = 11.29$, $MSE = 382.24$, $p < .05$. Further analysis revealed that there was a significant effect of prime–probe repetition relation for both out- (ODR) and in- (IDR)

TABLE 1
Means of reaction times and percentages of errors (between parentheses) according to relation conditions in Experiment 3

	Prime–probe repetition relation			*Size of priming*	
	TR	*NR*	*DR*	*NR–TR*	*NR–DR*
U–ODR	538 (0.70	572 0.95	591 0.70)	34	–19
U–IDR	548 (1.15	617 1.90	599 1.15)	61	18
L–ODR	545 (0.55	582 1.25	575 0.45)	37	5
L–IDR	548 (1.05	590 1.20	596 0.90)	42	–6

TR: Prime targets related to probe targets, DR: Prime distractors related to probe target, NR: No letters repeated from prime to target, U: Uppercase prime letters, L: Lowercase prime letters, ODR: Out-distractors in primes (positions 1–5) repeated as targets in probes (positions 2–4); IDR: In-distractors in primes (positions 2–3–4) repeated as targets in probes (positions 1–5).

distractors, $F(2, 38) = 23.94$, $MSE = 604.92$, $p < .05$, and $F(2, 38) = 37.37$, $MSE = 688.15$, $p < .05$, respectively. Post-hoc LSD tests indicated a significant positive priming effect for TR trials in both ODR and IDR conditions. In contrast, priming effects were opposite in sign for DR trials in the ODR and IDR conditions; positive priming for repeated in-distractors, and negative priming for repeated out-distractors.

With lower-case primes, only the main effect of prime–probe repetition was significant, $F(2, 38) = 26.77$, $MSE = 759.191$, $p < .05$. Post-hoc LSD tests indicated that responses were faster for TR trials than for both NR and DR trials, but that RTs for NR and DR trials did not differ significantly.

There were several other significant effects in the overall analysis that were of less theoretical interest. There was a significant main effect of distractor letter location, $F(1, 19) = 4.38$, $MSE = 3388.71$, $p = .05$, indicating that responses were faster when distractors fell in peripheral locations relative to when they fell at central locations. There was also a significant main effect of prime–probe relationship, $F(2, 38) = 54.85$, $MSE = 1004.66$, $p < .05$, indicating that responses were faster in the TR condition than in both the DR and NR conditions. Finally, there was a significant interaction between distractor letter location and prime–probe relationship, $F(2, 38) = 3.58$, $MSE = 560.95$, $p < .05$, indicating that priming effects were generally more positive for the TR and DR conditions in the in-distractor condition. No effects were reliable on errors.

As in previous experiments, the priming effects from distractors depended on their location in the prime display. Out-distractors located peripheral to targets (U-ODR) produced negative priming, whereas in-distractors located between two targets (U-IDR) produced positive priming. Note that in the ODR condition there was a central distractor and two peripheral distractors. It appears that the priming effects for this condition depended more on the peripheral distractors than on the central distractor. More research is needed to explore the impact of the central distractor on priming in this condition. This result is similar to prior data using this matching procedure (see, for example, Neill & Valdes, 1992). Once again, this result is consistent with the view that the attentional focus was not divided in this task, with the result that distractors inside the attentional focus are processed differently from distractors outside the focus. However, the smaller size of the positive priming effect for in-distractors (U-IDR) than for targets (TR) is inconsistent with the view that all items within the attentional focus are processed identically. Recall that a similar result in Experiment 1 could have been attributed to there being one central in-distractor and two targets; two items perhaps ought to produce a larger priming effect than one item. However, in the present experiment, there were three central in-distractors and two targets, yet the results were much the same (compare the 18 ms priming effect for the U-IDR condition of this experiment with the 16 ms priming effect for the IDR condition in Experiment 1). As such, although distractors within the attentional focus appear to be processed differently than distractors outside the attentional focus, there are also differences in the processing of targets and distractors within the focus.

As noted earlier, one way of explaining these results is by reference to a dynamic attentional focus that shifts between the two targets but fails to exclude entirely the central distractors. According to this view, the central distractors would receive the same type of processing as the targets, but a smaller quantity. However, this fails to explain why priming effects for distractors occurred when the letters primes were in the same case as letters in the probe, but absent when the letter cases differed.

Our preferred interpretation is that the processing of in-distractors and targets differs qualitatively, rather than just quantitatively. We presume that both the low-level physical features and more abstract information is processed from targets, in contrast, distractors are processed only in terms of low-level physical features. According to this view, the opposite priming effects observed for in- and out-distractors in both Experiments 1 and 2 would be attributed to differences in how low-level physical features are processed within versus outside the attentional focus. One possibility is that the processing of low-level features is inhibited outside the focus and amplified within the focus (Neill, 1977; Tipper, 1985), but there are other accounts of negative priming that would apply equally well (e.g., Neill, 1997; Neill, Valdes, Terry, & Gorfein, 1992). The important point to note is that priming effects for distractors both within and outside the spatial focus of attention are presumed to reflect the processing of low-level physical features. In contrast, priming effects for targets are presumed to reflect the processing of both low-level physical features and higher level stimulus attributes such as letter identity. With this assumption in place, the priming effects for repeated targets can be thought of as the sum of two processing components, only one of which is shared with distractors located inside the attentional focus.

GENERAL DISCUSSION

In this study we examined the processing of nonattended stimuli located inside and outside the putative attentional focus using a priming procedure. The procedure was designed to distinguish between in- and out-distractors; that is, distractors that were either inside or outside a unitary region that encompassed the two attended targets. One critical result concerned priming effects for nonattended letters. Positive priming was observed for in-distractors and negative priming was observed for out-distractors in all three experiments. This result demonstrates that processing was qualitatively different for distractors inside and outside the attentional focus, independently of the retinal location of the distractors (Experiment 2), and it is consistent with the view that a unitary attentional focus was adopted in this task. If the focus had been divided, then all distractors would have had the status of out-distractors, and similar (negative) priming effects would have been observed for those located between the targets and for those located at peripheral positions.

The second important result concerned the level of processing reached by prime stimuli. The results of Experiment 3 are consistent with the view that target letters were processed up to an abstract, letter identity, level, but that distractors were processed only in terms of low-level physical features. This conclusion stems from the finding that the small but reliable priming effects observed for distractors depended on a match in letter case across the prime and probe displays. In this vein, more recently, Castillo (2001) displayed primes with different case, one target in upper the other in lower case. Castillo observed positive priming from targets, but no priming at all from distractors. The implication of our result is that, although items inside the attentional focus were processed differently from items outside the attentional focus (see above), distractors within the attentional focus were processed differently from targets within the attentional focus. It should be emphasized that we are not claiming that this particular difference in processing for targets and distractors inside the attentional focus always occurs. Rather, we claim only that this processing difference was characteristic of the performance of the participants in our study. Although this is not the strongest theoretical stance that the present results permit, there are many other studies that demonstrate that distractors can be processed to abstract, semantic levels (Tipper, 1985; see Tipper, 2001, for a more recent review). What is needed is an explanation for why distractors sometimes are and sometimes are not processed beyond their low-level physical features.

One possible explanation centres on recently demonstrated prime-task influences on priming effects. Generally speaking, recent studies suggest that the level of processing required by a task determines the level of processing reached by distractors (Besner & Stolz, 1999). In particular, Marí-Beffa, Fuentes, Catena, and Houghton (2000; see also Stolz & Besner, 1996) have shown that the direction of priming produced by distractors greatly depends on the congruency between the task applied to primes and probes. They reported a study in which negative priming occurred for distractors only when the level of processing required for the prime and probe tasks was the same; that is, when categorization was required for both prime and probe but not when a letter search was required for the prime and categorization was required for the probe (Marí-Beffa et al., 2000). Given that the task in our experiments required participants to make same/different decisions about letters that were physically identical, it follows that the low-level physical features of distractors were processed, which in turn produced the case-specific priming effects for distractors (see also Neill & Valdes, 1996, for a similar explanation).

Given the important role that task appears to play in modulating selective attention, we suggest that a unitary spatial attention focus is insufficient to explain all of the selective processing that occurs in this study. In particular, it seems necessary to distinguish between at least two types of selective process. First, the fact that in-distractors and out-distractors are processed differently could well be explained by reference to a spatial focus operating in visuospatial coordinates. At this level, we presume that attention can select only a cohesive region of space, and that features of all objects inside this region are activated, while features of objects outside are inhibited (see Fuentes, Humphreys, Agis, Carmona, & Catena, 1998, for a similar view) or coded as irrelevant (see Neill et al., 1992). However, recently, Müller, Malinowski, Gruber, and Hillyard (2003) have compared Steady State Visual Evoked Potentials (SSVEP, an electrophysiological activity of visual cortex in response to a flickering stimulus) for attended and unattended stimuli located between two nonadjacent attended targets. Müller et al. used a horizontal array of four flickering rectangles located at 4 and 9 degrees of visual angle to the left and to the right of fixation (numbered from left to right, locations would be 1, 2, 3, and 4). Subjects had to detect the simultaneous occurrence of a symbol at adjacent (1+2, 3+4) and nonadjacent (1+3, 2+4) locations. SSVEP amplitudes were higher for attended (location 2 in condition 2+4) than for unattended flickering locations (location 2 in condition 1+3). These authors assumed that the attentional focus could be split (see also, Müller & Hübner, 2002). Although this result appears to be compelling, there are several methodological questions that are necessary to solve in order to accept that the attentional focus can be divided at very early visual stage. First, Müller et al. did not control whether the subjects fixated in display plane, or at a point located closer or farther than the screen plane. This is important because the location of fixation may determine the stimulus projections to the retinas. In a recent experiment by Catena, Marí-Beffa, Valdés, Fuentes, and Houghton (2004), we used the same procedure as Müller et al. (2003), but we asked subjects about the strategy they adopted. All 14 subjects reported that they blurred the image in the display, by fixating in a different plane to that of the image; this could have generated differences in the SSVEP.

Recent evidence from neurophysiological studies on monkeys as well as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) studies in humans support our view on selection. One general view of selection is that it is based on competitive interactions between stimuli (Desimone & Duncan, 1995). For example, if two simultaneous stimuli are presented in the receptive field of a neuron, a ''winner-takes all'' competition takes place between the two stimuli, and the response of the neuron is controlled by the more salient stimulus. One of the consequences of this competitive interaction is that processing is suppressed for stimuli that lose the competition. Although bias in the competitive process can be introduced by bottom-up factors (e.g., differences in luminance between two stimuli), top-down attentional factors can also influence processing (Desimone, 2000). In particular, attention may bias competition in favour of target items so that they are less likely to suffer the suppressive effects of interactive competition (Kastner & Ungerleider, 2000).

Thus, if we assume that a unitary attention focus was centred on the array to cover the two noncontiguous targets in the present study, out-distractors but not in-distractors may suffer from the suppressive effects of competition. In this manner, processing of distractors would support low-level positive priming for in-distractors and low-level negative priming for out-distractors.

Nonspatial selection?

Although we have argued that attention seemed to operate in a unitary spatial manner here, other data suggest that a form of object-based selection occurred too. In particular, the fact that priming effects were observed for lower-case targets, but not for lower-case in-distractors, implicates that targets were selectively processed at a high level. This may reflect object-based selection of both targets, but not the intervening (in) distractor (cf. Egly & Homa, 1984; Linnel & Humphreys, 2004). Due to their selection as a single object, only targets are processed at the higher level.

Exactly how targets are selected without also selecting in-distractors requires further study. However, we speculate that the role of attention in this case is to block the higher level processing of items that are not relevant to the task at hand (Besner & Stolz, 1999); this blocking ultimately ensures that targets are processed more deeply than in-distractors.

In summary, the results from the present study suggest that, at a lower level of processing, attention may select a single contiguous region of space. The processing of features of objects inside this region is facilitated, while that for objects outside this region is suppressed. In contrast, at higher levels of processing, attention may differentiate between targets and distractors inside the attentional focus, producing benefits in processing only for the selected target objects. By this view, processing of distractors inside the attentional focus will be observed when the task requires analysis of low-level features, but not when it requires analysis of object identity.

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