Absence of Placeholders Abolishes Exogenous Attention Effect in a Peripheral Cueing Procedure

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Abstract   Most studies of exogenous visuospatial attention use placeholders indicating the regions where the stimuli appear on the screen. Preliminary results from our laboratory provided evidence that the attentional effect is more frequently observed when placeholders are used in these experimental procedures. Four experiments were carried out. Experiment 1 aimed at confirming the finding that the attentional effect of a spatially non-informative cue (S1) observed in the presence of placeholders disappears in their absence. The results confirmed this finding. Experiments 2, 3, and 4 examined several possible processes that could explain this finding. Experiment 2 investigated if the contribution of a faster disengagement of attention from the cued location or a stronger forward masking could explain the absence of attentional effect when no placeholders were used. Experiment 3 investigated if increased difficulty in discrimination of the target (S2) from S1 would favor the appearance of the attentional effect in the absence of placeholders. Experiment 4 investigated if an insufficient focusing of attention towards the cued location could explain the absence of attentional effect when no placeholders were used. The results of the three experiments indicated that placeholders act by reducing the discriminability of the S2. This would presumably lead to the adoption of an attentional set that favors the mobilization of attention by the S1.

Keywords   Spatial Attention, Exogenous Attention, Attentional Capture, Attentional Setting

1. Introduction

Several studies have shown that reaction time (RT) to a target stimulus (S2) appearing at the same location as a spatially non-informative peripheral cue (S1) is shorter than the RT to the S2 appearing at a different location than the S1 (e. g.[1],[2]). This effect is attributed to the exogenous mobilization of attention by the S1 and is greatest when the stimulus onset asynchrony (SOA) is of approximately 100 ms. Current research indicates that attention improves sensory processing at the cued location and reduces its efficiency at uncued locations ([3]).

If the S1 exogenously captures attention to its appearance location, one would expect the attentional effect (the positive difference between RT when the S1 and S2 appear in a different location and RT when they appear in the same location) to be a robust phenomenon. This is not, however, the case. In many experimental situations, the attentional effect is absent (e.g.[4], Experiments 1 and 2). In the last ten years, the necessary conditions for obtaining the attentional effect have been the subject of detailed studies (see[5], for a review of earlier studies).

It was shown that the kind of RT task being performed, previous experience of the individual, and the discriminability of the S2 must be considered. The attentional effect is more consistent in a task requiring identification of the S2 than in a task requiring only the detection of the S2 ([2],[6]). Previous experience with a detection task reduces the attentional effect in an identification task ([6]). Moreover, the attentional effect is observed when the S2 is difficult to discriminate but not when it can be easily discriminated. This holds both when a differentiation between two S2s is needed ([7]) and when a differentiation between the S2 and the S1 is needed (8-11]).

In this study, we investigated whether the presence of placeholders at the locations of stimulus appearance is related to the attentional effect observed in exogenous spatial cueing procedures. Since the majority of studies demonstrating this effect use placeholders on the screen, following the original procedure used by[1], it is possible that the attentional effect cannot be obtained or it is harder to obtain when no placeholders are used. Preliminary findings from our laboratory have suggested that the presence of placeholders is, indeed, critical for obtaining the attentional effect in several stimulatory conditions. Briefly, no attentional effect occurred when the stimuli (a gray ring as spatially uninformative S1, and a vertical line or cross as go S2s and a small ring as no-go S2) appeared on an empty screen ([12]), but a large attentional effect occurred when

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placeholders marked the location of the appearance of these same stimuli ([13]).

We conducted four experiments that are variations of Posner's peripheral spatial cueing procedure. In Experiment 1, we examined the consequences of eliminating the placeholders both in a short SOA and in two longer SOAs, in which inhibition of return (IOR) is expected, according to the original study. The attentional effect was observed in the presence of placeholders and disappeared when they were absent. In Experiment 2, we tested the hypotheses that the absence of placeholders abolished the attentional effect because of a larger forward masking by the S1 or because of a faster disengagement of attention from the cued location. We found no evidence supporting either of these hypotheses. In Experiment 3, we tested the hypothesis that the attentional effect was not observed in the absence of placeholders because the S2 is easier to discriminate when it appears on an empty screen. If that were the case, we would observe the attentional effect in the absence of placeholders by using other types of stimuli surrounding the S2. The results obtained in this experiment are in agreement with this hypothesis. In Experiment 4, we tested the hypothesis that the attentional effect is not observed in the absence of placeholders because of an insufficient focusing of attention at the cued location. The results did not support this hypothesis.

2. Experiment 1

In this experiment, we investigated the importance of placeholders for the occurrence of the attentional effect. One group of young adults was tested in a choice RT task with placeholders on the S1 and S2 appearance locations, and another group was tested in the same task, with the same S1 and S2, but without placeholders on the screen.

To examine whether the expected reduction or disappearance of the attentional effect in the absence of placeholders was related to the lack of significant cortical processing of the peripheral S1 signals, we also evaluated RT responses at longer SOAs. It is well known that at a SOA lasting several hundred milliseconds, a local inhibitory effect of an uninformative peripheral S1 usually occurs. This inhibitory effect is often attributed to the IOR process mobilized by the S1 (e.g.[14]). Since this process is mediated by cortical networks ([15],[16]), the finding of the inhibitory effect in the absence of placeholders would indicate that the S1 signals were processed to a significant extent at the cortical level.

We expected to observe the attentional effect in the placeholder condition and reduced or no attentional effect in the absence of placeholders.

2.1. Methods

2.1.1. Participants

Twenty-four young adults were selected. All presented normal or corrected-to-normal vision. None of them had previous experience with RT tasks or was aware of the purpose of the study.

All participants signed an informed consent form before performing the task. The Ethics Committee of the Biomedical Sciences Institute of São Paulo University approved this study.

2.1.2. Apparatus

The participants were tested in a dimly illuminated and sound-attenuated room. They sat down at a table with their head positioned in a chin-and-forehead rest. A 14-inch video monitor (CRT type; refresh rate, 60 Hz; screen resolution, 640 × 480 pixels) was mounted on a frame over the table. The center of the monitor's screen was 57 cm away at eye level. This screen was white and had a luminance of 15.2 cd/m². At its center, there was a black fixation point (<0.01 cd/m²). The participants responded to a visual target stimulus (S2) that would be presented on its left or right side by pressing left or right side keys mounted on the table. An IBM-compatible computer controlled by a protocol developed with the MEL Professional v. 2 software (Psychology Software Tools, USA) generated the stimuli and recorded the responses. The use of sensitive microswitches (Microsoft, USA) as response keys and the game port of a sound card (SoundBlaster, USA) input from the response keys to the computer provided time precision in the order of 1 ms for response latency measurements.

2.1.3. Procedure

The participants were divided into two groups, the control group (CG), with nine females and three males, and the experimental group (EG), with eleven females and one male. For the CG, two gray rings (3.40 cd/m², 1.50-degree diameter and 0.04-degree wide margin) centered 9 degrees away to the left and right side of the fixation point were used as placeholders. For the EG, no placeholders were used.

Each participant performed two testing sessions on separate days. The first session aimed at familiarizing the participants with the experimental conditions. It consisted of one block of 60 trials. Each trial began with the appearance of the fixation point. Between 1750 and 2250 ms later, a S1 occurred randomly, with equal probability, on the left or right side of the fixation point. The S1 stimulus was a dark gray ring (0.01 cd/m², 1.50-degree diameter and 0.04-degree wide margin) lasting 17 ms. Sixty-seven, 367, or 767 ms after the end of the S1 (SOAs were, thus, 100, 400, and 800 ms), a S2 occurred in the left or right hemifield. This stimulus was a black vertical line (<0.01 cd/m², 0.45-degree long and 0.04-degree wide), which lasted 34 ms. It appeared randomly, with equal probability, at the same location as the S1 or at the symmetric location on the opposite side of the fixation point (Figure 1). The participants were required to respond as fast as possible to the S2 with the hand corresponding to the side of S2 appearance. As soon as the response occurred or an interval of 600 ms had elapsed, the fixation point was replaced by a message lasting 400 ms.

This message consisted of the RT in milliseconds when the participant responded between 150 and 600 ms after S2 onset. The word "anticipated" was displayed when the participant responded less than 150 ms after the S2 onset. The word "slow" was displayed when the participant responded more than 600 ms after S2 onset. The word "incorrect" was displayed when the participant responded between 150 and 600 ms with the wrong hand. Then, the next trial began.
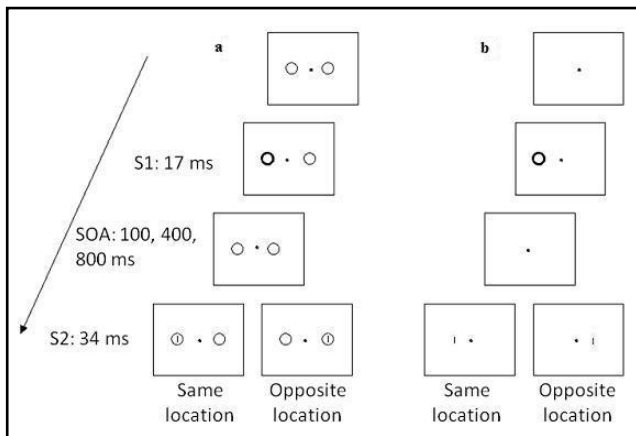

Figure 1. Schematic representation of the events sequence in a trial in the placeholders present condition (panel a) and the placeholders absent condition (panel b).S1, cue.SOA, stimulus onset asynchrony. S2, target stimulus

Error trials were repeated so that ten valid RT values were available for each of the six experimental conditions (three SOAs × two S2s relative to S1 location).

The second session was similar to the first. It consisted of four blocks, with 60 trials each. There was a resting interval between one block and the next, which was controlled by the participant (resting a minimum of 15 ms). A green asterisk was used instead of the RTs in the correct trials and a red asterisk was used instead of the written messages in the error trials.

2.1.4. Data Analysis

Second-session median RTs were calculated for each condition for each participant. Only the correct responses were submitted to the statistical analysis.

A mixed design analysis of variance (ANOVA) with repeated measures was performed on RT data. This ANOVA used group assignment (CG or EG) as between-subject factor and the SOA (100, 400, or 800 ms) and S2 location relative to S1 location (same or opposite) as within-subject factors. When appropriate, the data were further analyzed using the Newman-Keuls test.

2.2. Results and Discussion

The ANOVA revealed an interaction between group and SOA ($F_{5,66} = 9.59$, $p < 0.001$), group and S2 relative location ($F_{3,44} = 12.88$, $p = 0.002$), and SOA and S2 relative location ($F_{5,66} = 22.94$, $p < 0.001$) and a triple interaction ($F_{11,132} = 2.56$, $p = 0.089$) (Figure 2).

The post hoc analysis related to the triple interaction showed that, for the CG, the RT was shorter when the S1 and S2 appeared at the same location than when they appeared at opposite locations, for the 100-ms SOA ($p < 0.001$). It also showed that the RT was longer when the S1 and the S2 appeared at the same location than when they appeared at opposite locations, for the 800-ms SOA ($p = 0.030$). This group exhibited, then, an attentional effect at the 100-ms SOA and an IOR effect at the 800-ms SOA.
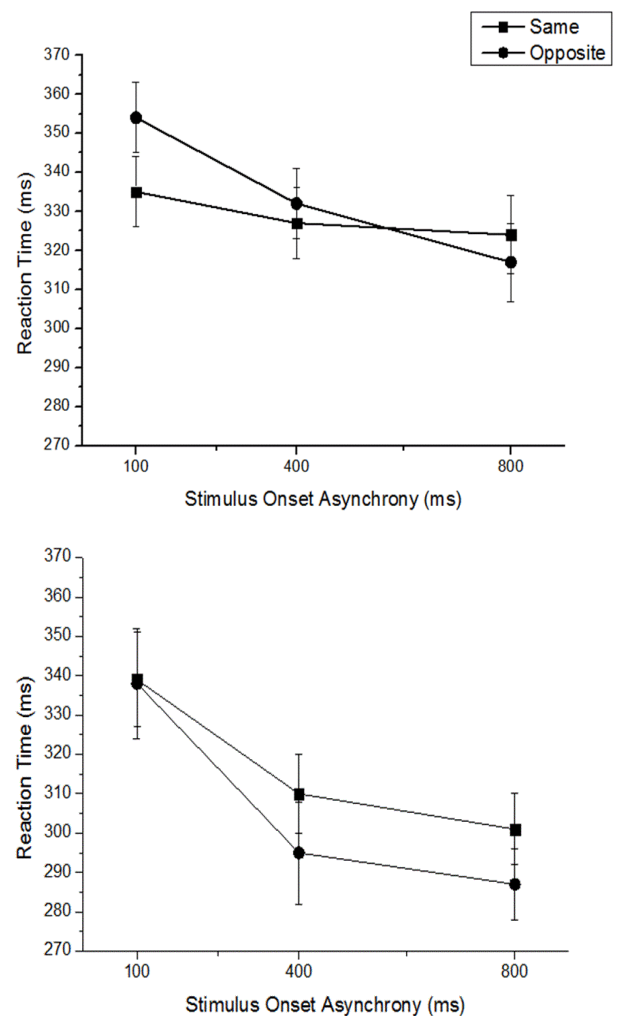

Figure 2. Mean (±SEM) reaction time to the target stimulus in the same location of cue appearance (filled squares) and in the opposite location of cue appearance (filled circles) in the placeholders present condition (above) and the placeholders absent condition (below)

For the EG, RT was longer when the S1 and the S2 appeared at the same location than when they appeared at the opposite locations, at both the 400- and 800-ms SOAs ($p < 0.001$ for both). This group exhibited, then, no attentional effect; it exhibited, however, an IOR effect at both the 400- and the 800-ms SOAs.

The attentional effect observed at the 100-ms SOA and the IOR effect observed at the 800-ms SOA in the presence of the placeholders (CG) is the expected pattern according to classical results reported in the literature (e.g.[1],[2]).

To our knowledge, the disappearance of the attentional effect in the absence of placeholders (EG) has not yet been reported in the literature. It is, however, in agreement with previous results from this laboratory (e.g.[12],[13]). This finding supports the hypothesis that placeholders might play an important role in the exogenous attentional effect observed in peripheral cueing procedures.

The occurrence of IOR in the absence of placeholders indicates that the S1 was significantly processed at the cortical level (e.g.[17],[15],[16]). This excludes the possibility that the lack of attentional effect in the absence of placeholders was because of insufficient cortical processing of the S1. The lack of the attentional effect and the IOR effect corroborates the hypothesis that different cortical mechanisms mediate the two phenomena (see[17], for a review on IOR hypothesis, and[23], for evidence challenging the biphasic pattern of early facilitation and late IOR following a peripheral cue).

The next three experiments examine possible explanations for the role of placeholders on this peripheral cueing procedure, in an attempt to shed light on the mechanisms of exogenous attentional capture by peripheral stimuli.

3. Experiment 2

Reference[19] attributed the absence of the attentional effect in several of his experiments to the early disengagement of attention from the uncued location. Placeholders could act as anchors for attention, delaying its disengagement and allowing it to influence the processing of the S2s. The lack of the attentional effect in the absence of placeholders in this task, in which a brief S1 is presented, could be explained by an early disengagement of attention from the cued location.

Another possibility is that placeholders would reduce forward masking of the S2 by the S1, since they diminish the luminance change characterizing the S1 (see[20], for a detailed description of the visual forward masking phenomenon). When the S1 is presented on an empty white screen, a greater change in luminance occurs, so that the S1 is a relatively more intense stimulus in the absence of placeholders. If that were the case, the S1 could forward mask the S2 to the point of neutralizing the influence of attention on RT responses.

Experiment 2 was intended to test the hypotheses that the attentional effect did not appear in the absence of placeholders in Experiment 1 because of an early disengagement of attention from the cued location and because of forward masking by the S1. Thus, the current experiment replicated Experiment 1, except for the use of only the placeholders absent conditions and for the use of the SOAs of 50, 100, 150, 200, and 250 ms. We assumed that there would not be enough time for attention to engage and disengage from the cued location at a SOA shorter than 50 ms. Indeed, the findings of[21] indicate that attention takes between 34 and 50 ms to be oriented. The appearance of the

attentional effect at this SOA, then, would support the early disengagement of attention hypothesis while the absence of the attentional effect would not support this hypothesis. The forward masking hypothesis would be supported if the attentional effect appeared at the 200- or 250-ms SOA, since at these intervals, forward masking should have decreased or even been absent (e.g.[22],[23]).

3.1. Methods

3.1.1. Participants

Twelve naïve males with the characteristics described in Experiment 1 were selected.

3.1.2. Procedure

Most of the procedure was similar to that described for Experiment 1. The differences were that only the placeholder-absent condition was tested, that the block sessions consisted of 72 trials, and that five SOAs were used: 50, 100, 150, 200, and 250 ms.

3.1.3. Data analysis

The same parameters were evaluated as in Experiment 1. An ANOVA with repeated measures was performed on RT data. This ANOVA had the SOA (50, 100, 150, 200, and 250 ms) and the S2 to S1 relative location (same or opposite) as factors. When appropriate, the data were further analyzed using the Newman-Keuls test.

3.2. Results and Discussion

The ANOVA revealed a main effect of SOA ($F_{4,55} = 96.44$, $p < 0.0001$), but no main effect of S2 to S1 relative location ($F_{1,22} = 0.27$, $p = 0.61$) or interaction between the two factors ($F_{9,110} = 0.65$, $p = 0.63$) (Figure 3).
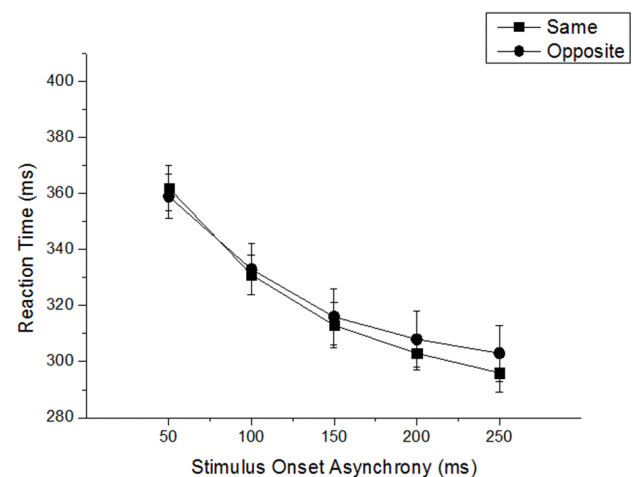

Figure 3. Mean (±SEM) reaction times to the target stimulus when it appears in the same location as the cue (filled squares) and in the opposite location as the cue (filled circles) in Experiment 2 (absent placeholders condition)

The absence of any attentional effect at the 50-ms SOA does not support the hypothesis that attention was oriented to the S1 and soon after disengaged from the cued location. It

was shown that attention takes between 34 and 50 ms to be fully mobilized by a S1 (e.g.[21], [24]). It is highly unlikely, therefore, that it could be oriented and then disengaged prior to the 50-ms SOA. In fact, to our knowledge, there is no evidence in the literature of such a short-lived attentional mobilization. As[14] stated, in the absence of such evidence, it is complicated to presume the occurrence of the phenomenon. Moreover, the absence of any attentional effect at the 250-ms SOA, when the inhibitory action of forward masking would have significantly diminished or even ceased ([22],[23]), suggests that forward masking cannot account for the disappearance of the attentional effect in the absence of placeholders.

Therefore, the authors concluded that neither a rapid disengagement of attention from the cued location nor a forward masking action of the S1 was responsible for the absence of the attentional effect in the placeholder-absent condition of Experiment 1 and in the current experiment.

4. Experiment 3

According to[7], the attentional effect is more difficult to observe when S2s are easily discriminated. In Experiment 1, the discriminability of the S2 was higher in the absence of placeholders than in their presence. This is indicated by the shorter RTs in the placeholder-absent condition and by the personal reports of subjects to the experimenter. It is possible, then, that the lack of attentional effect in the absence of placeholders is caused by the high discriminability of the S2 in this condition.

This hypothesis predicted that the attentional effect would be observed in the absence of placeholders, provided that the discriminability of the S2 was kept low enough, for instance, by distributing competitor stimuli across the screen.

To test this hypothesis, we used eight horizontal and eleven vertical black lines distributed along the whole screen, forming a square pattern with squares of 2.5-degree. We expected that the attentional effect would appear in this condition as it did in the presence of the peripheral gray rings used as placeholders in Experiment 1, since the discriminability of the S2 would be similarly reduced in both conditions.

4.1. Methods

4.1.1. Participants

Eight naïve females and four naïve males with the characteristics described in Experiment 1 were selected.

4.1.2. Procedure

The procedure was similar to that of the previous experiment with the exception that the background screen included, in addition to the fixation point, eleven equally spaced dark gray vertical lines and eight equally spaced dark gray horizontal lines. The thickness of these lines was 0.04 degree and their luminance was 3.4 cd/m². They formed a background square pattern along the whole screen, with squares of 2.5-degree.

4.1.3. Data analysis

The same parameters were evaluated, and the same analyses were performed as in Experiment 2.

4.2. Results and Discussion

The ANOVA revealed a main effect of SOA ($F_{4,55} = 68.05$, $p < 0.001$) and S2 to S1 relative location ($F_{1,22} = 6.62$, $p = 0.026$), but no interaction between the two factors ($F_{9,110} = 1.08$, $p = 0.377$) (Figure 4).
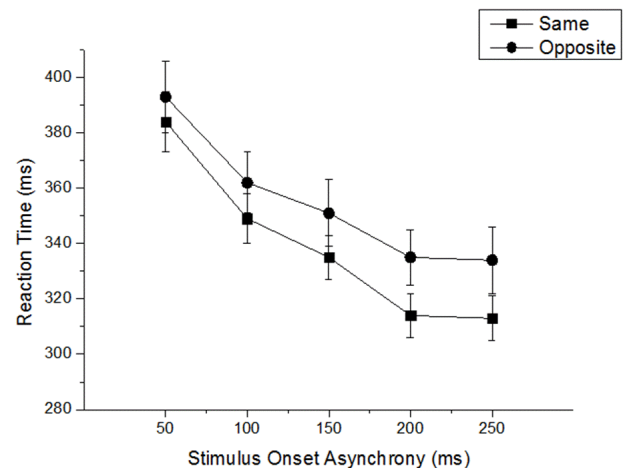

Figure 4. Mean (± SEM) reaction time to the target stimulus when it appears at the same location as the cue (filled squares) and when it appears at the uncued location (filled circles) in Experiment 3 (absent placeholders condition). In this experiment a grid formed by high contrast vertical and horizontal lines characterized the background screen

The appearance of the attentional effect despite the relatively high contrast of the S1 reinforces the conclusion that the disappearance of this effect in the absence of placeholders in the previous two experiments was not due to forward masking. In contrast, the finding constitutes strong evidence in favor of the hypothesis that the lack of attentional effect in the absence of placeholders was related to the high S2 discriminability. Before this hypothesis could be considered to account for our results, however, another explanation needed to be investigated. It was possible that the square pattern background acted by allowing the efficient focusing of attention at the cued location, as the placeholders could also have done, and not by interfering with the discriminability of the S2. We tested that possibility in Experiment 4.

5. Experiment 4

There is evidence that the size of the attentional focus can vary (e.g[25]). In experimental sets like the one used in the current study, the size of the attentional focus can basally encompass the entire screen or be restricted to the area around the fixation point. When the S1 lasts several tens of

milliseconds or there are placeholders on the screen, it is conceivable that attention has time to get focused exactly on the cued location. However, when the S1 is very brief, as is the case in this study, and there are no placeholders on the screen, attention might not have time to adjust its focus to the cued location but perhaps only to a larger area around it. In this case, its influence on S2 processing should be smaller, as suggested by the findings of [25]. A corresponding small attentional effect or even no attentional effect would be observed in this case.

The current experiment contrasted the "incomplete focusing of attention" hypothesis with the "high S2 discriminability" hypothesis as possible explanations for the lack of attentional effect in the absence of placeholders. A grid of lines similar to that used in Experiment 3 was used. The only difference was that the current experiment's lines had a low contrast. In this way, the lines did not significantly affect the S2 discriminability, although still allowing an efficient focusing of attention. If we observed an attentional effect, the "incomplete focusing of attention" hypothesis would be reinforced, while if we did not observe an attentional effect, the "high S2 discriminability" hypothesis would be reinforced.

5.1. Methods

5.1.1. Participants

Eight naïve females and four males with the characteristics described in Experiment 1 were selected.

5.1.2. Procedure

The procedure was similar to that of Experiment 3 with the exception that the light gray vertical and horizontal lines forming the background screen had now a luminance of 13.5 cd/m².

5.1.3. Data Analysis

The same parameters were evaluated and the same analyses were performed as in Experiment 2 and 3.

5.2. Results and Discussion

The ANOVA revealed a main effect of SOA ($F_{4,55}$ = 101.48, p < 0.001) but no main effect of S2 to S1 relative location ($F_{1,22}$ = 2.15, p = 0.17) or interaction between the two factors ($F_{9,110}$ = 0.66, p = 0.622) (Figure 5).

The absence of any attentional effect in this experiment despite the presence of clearly visible landmarks on the screen that could anchor attentional focusing does not favor the incomplete focusing of attention explanation for the lack of attentional effect in the absence of placeholders. It is, however, compatible with the high S2 discriminability influence on attentional capture explanation for the finding.

The result reinforces the conclusion that the lack of attentional effect in the absence of placeholders in Experiments 1 and 2 was not because of an early disengagement of attention from the cued location caused by

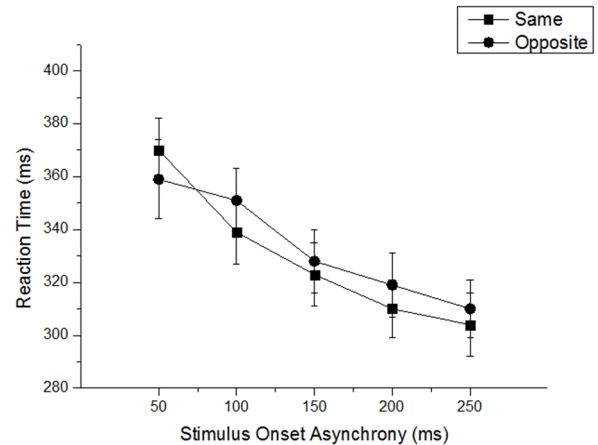the lack of sensorial stimuli to maintain attention engaged at the cued location.

Figure 5. Mean (± SEM) reaction time to the target stimulus when it appears at the same location as the cue (filled squares) and when it appears at the uncued location, in Experiment 4 (absent placeholders condition). In this experiment a grid formed by low contrast vertical and horizontal lines characterized the background. screen

6. General Discussion

In the present study, we investigated the influence of placeholders on the attentional effect often observed in variations of Posner's peripheral cueing procedure. We found that the attentional effect observed in the presence of placeholders disappeared when the placeholders were absent. This result, now observed using a location choice task, replicates a previous result from our laboratory that used a shape go/no-go task ([12],[13]). It indicates that placeholders are critical factors for the appearance of the attentional effect. This is probably the reason why these stimuli are so often used in studies of attention employing adaptations of Posner's peripheral cueing procedure (e.g.[1],[2],[11]).

Possible explanations for the critical role played by placeholders in this experimental procedure were examined in Experiments 2, 3, and 4. Placeholders were not used in any of these three experiments. The absence of the attentional effect at the 50-ms SOA, in Experiment 2, did not support the hypothesis that placeholders act as an anchoring point for attention, delaying its disengagement from the cued location when brief S1s are presented, since by this time, attention should be just completing its engagement ([21]). The absence of the attentional effect at the 250-ms SOA, in the same experiment, did not support the hypothesis that placeholders act by reducing the forward masking by the S1, which could antagonize the influence of attention on RT responses; by this time, forward masking should have receded to a low level or even ceased ([22],[23]). The appearance of the attentional effect when a high-contrast grid was used as a background screen, in Experiment 3, further argued against the forward masking hypothesis. Finally, the absence of the attentional effect when the low-contrast grid was used as background screen and could serve as a landmark for attentional focusing, in Experiment 4, did

considerably weaken the hypothesis that placeholders act by allowing a more efficient adjustment of the attentional focus.

The combined results of Experiments 3 and 4 are clearly in agreement with the hypothesis that placeholders act by reducing the discriminability of the S2. Indeed, the common factor to the high-contrast grid condition, which led to the appearance of the attentional effect in Experiment 3 and the placeholder-present condition in Experiment 1, was the low discriminability of the S2 indicated by the relatively long RTs of the observers in both conditions. Similarly, the common factor to the low-contrast grid condition in Experiment 4 and the placeholder-absent condition in Experiment 1 was the high discriminability of the S2, and in both conditions, the attentional effect was not observed. This explanation is also in agreement with previous findings from our laboratory ([7]) that the discriminability of the S2 influences the observation of the attentional effect.

Presumably, placeholders reduced the discriminability of the S2 by lateral inhibitory processes ([26],[4],[27]).

According to the hypothesis proposed by Folk and co-workers ([8-11]), the attentional set of an observer is adjusted to the characteristics of the task being performed. It is possible that when the S2 is less discriminable, the activity of the attentional mechanisms is maintained at a higher level to cope with the difficulty of the task. The S1 would generate stronger attentional signals, which would produce more facilitation of local sensory processing and more inhibition of sensory processing at other locations. Currently there is no physiological evidence supporting this hypothesis in the case of exogenous attention. However, such evidence is available for voluntary attention. The activity of visual neurons in the primary (V1) and secondary (V4) cortices is more influenced by this kind of attention in a difficult than in an easy discrimination task ([28],[29],[24]). Given the similarities between the mechanisms responsible for the two types of attention ([30],[31]), it seems reasonable to suppose that the same result would be obtained for exogenous attention.

7. Conclusions

In summary, the current study shows that placeholders are important for obtaining the attentional effects in Posner's peripheral cueing procedure. Taken together, our results suggest that placeholders act by reducing the discriminability of the S2. This presumably leads to the adoption of an attentional set characterized by high activity of the attentional mechanisms.

ACKNOWLEDGEMENTS

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