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Target Absent Trials in Configural Contextual Cueing

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Running Title: Target Absent Trials in Contextual Cueing

Abstract

In contextual cueing (CC), reaction times to find targets in repeated displays are faster than in displays that have never been seen before. This has been demonstrated using target-distractor configurations, global background colors, naturalistic scenes and the co-variation of target with distractors. The majority of CC studies have used displays where the target is always present. This paper investigates what happens when the target is sometimes absent. Experiment 1 shows that, although configural CC occurs in displays when the target is always present, there is no CC when the target is always absent. Experiment 2 shows that there is no CC when the same spatial layout can be both target present and target absent on different trials. The presence of distractors in locations that contain targets on other trials appears to interfere with CC and even disrupts the expression of previously learned contexts (Experiments 3-5). The results show that it is the target-distractor associations that are important in producing CC and, consistent with a response selection account, changing the response type from an orientation task to a detection task removes the CC effect.

Introduction

Going about our daily routine we often have to visually search the world to achieve our goals. Any given scene contains an abundance of visual information that needs to be attended, filtered and analysed in order to help us find what we are looking for. Take the example of searching for a friend in a crowd. If you were to attempt to pay attention to all the people in the crowd at once, your visual system would be overwhelmed. In order to search effectively, the visual system has developed several attentional mechanisms that enable us to limit our processing to one object or, perhaps, to a small set of objects at any one time.

In the laboratory, the real world task is typically simplified by having participants search for a target among a variable number of distractor items and recording the reaction time (RT) taken to find that target. A number of factors have been found to influence RT during these search tasks. For example, if a target is defined by an abrupt onset (Yantis & Jonides, 1984) or possesses a uniquely salient feature (Theeuwes, 1992; Treisman & Gelade, 1980) then attention is deployed to it rapidly. Likewise top-down attentional sets can guide attention to stimuli that possess target features (e.g. Duncan & Humphreys, 1989; Egeth et al., 1984; Wolfe, Cave & Franzel, 1989). More pertinent to the research in this paper, the presence of a meaningful global context or scene can affect search performance (e.g. Biederman, 1972; Reber, 1989).

Chun and Jiang (1998) showed that a familiar spatial context can speed search even if the context is meaningless and even if the observer does not know explicitly that the context is familiar (see Chun, 2000, for a review). In their experiments, Chun and Jiang had participants search for a rotated T among rotated letter Ls. Unbeknownst to the participants, some of the displays were repeated over time, maintaining their exact target-distractor configuration. The results showed that RTs were faster in repeated displays where the unique target location was correlated with display configuration than in non-repeated displays, where the configuration was unrelated to the location of the target. The authors concluded that the repeated spatial context of the displays cued the location of the target, leading to faster search. Further studies have shown that this knowledge was implicit. Participants often failed to explicitly recognize repeated displays (Chun & Jiang, 1998) or correctly identify where in the display the target had appeared (Chun & Jiang, 2003, although see Smyth & Shanks, 2008, who suggest that participants may have some explicit awareness). It has also been shown that the 'contextual cueing' (CC) benefit develops rapidly and decays slowly. Participants showed faster RTs after only five repetitions of a display (Chun & Jiang, 1998) and still showed a contextual cueing effect after a week (Chun & Jiang, 2003).

There have been several theories proposed to explain why contextual cueing occurs. Initially the CC effect was attributed to improving the deployment of attention within a scene (Chun & Jiang, 1998). It was thought that information within a repeated context would be able to 'guide' your attention to the target so that you find it faster. Although a context may facilitate guidance of attention, especially when participants have more time with a repeated display prior to response (Kunar et al., 2008a; see also Johnson et al., 2007), we have also proposed a second theory suggesting that contextual cueing might speed the response process (Kunar et al., 2007; Schankin & Schubö, 2009). In particular, the threshold needed to commit to a response in a repeated display may be reduced if the participant expects to see the target in a particular location within that context.

Regardless of the mechanism behind CC it is important to note that it is robust and an easily replicated effect. Repeating the context reliably facilitates target present responses (e.g., Chun, 2000; Chun & Jiang, 1998; Chun & Jiang, 1999; Chun & Jiang, 2003: Endo & Takeda, 2004; Hoffmann & Sebald, 2005; Jiang & Chun, 2001; Jiang & Leung, 2005; Jiang, Song & Rigas, 2005; Jiang & Wagner, 2004; Kunar et al., 2006; Kunar et al., 2007; Lleras & Von Mühlenen, 2004; Olson & Chun, 2002; Tseng & Li, 2004). Participants are certainly learning *something* about repeated displays. What is it that they are learning? Recent work has suggested that, when the configuration of the repeated stimuli is invariant ('configural CC') it is the relationship between the target and its surrounding distractors. We know that learning the absolute positions of the target items alone is not enough (see Chun & Jiang, 1998). Therefore, it must be the pattern of distractors or the stable relationship of the target to distractors that drives the CC benefit.

In a further investigation of this point, Olson and Chun (2002) manipulated repeated target displays by having the repeated context occupy one side of the display while the other side of the display was free to randomly change from trial to trial. In these studies Olson and Chun (2002) found that a CC effect could still be obtained as long as the relationship between the target with its immediately surrounding distractor items (e.g. in the invariant half of the display) was preserved. Similarly, Jiang & Wagner (2004) found that when they recombined two old displays (e.g. display A and B, which both predicted the target to be in the same location) to produce a 'new' display, a full CC effect was found as long as some of the target-distractor associations were maintained (i.e., half of the distractors were taken from display A and half from display B). Finally, Brady and Chun (2007) found that a CC effect still emerged if distractors in only one quadrant of the display cued the target's location (i.e., only two near-by distractors out of eleven distractors were predictive). The results showed that the CC effect observed in this 'Quadrant-Predictive' condition was the same as that observed in a condition where *all* the distractors predicted the target location (providing that the quadrant did not move position around the screen). In essence, it seems that the benefit obtained from repeatedly seeing a context is derived from the relationship between the target and its immediately surrounding distractors.

Notice that within these studies the relationship between the target and distracters was the variable that was manipulated. What happens when the context tells the observer that the target is not present? On first glance, one might predict that people could use this contextual knowledge to facilitate a response when the target is absent. Imagine, searching for a student in a crowded lecture theatre. From previous experience you know that this particular student always sits in the front row – three spaces left of the aisle. When the student is there you use this contextual knowledge to help find her. Intuitively, you would think that the same knowledge could speed your conclusion that she is absent from that lecture. If she is not sitting in that particular seat, chances are that she is not there at all. In fact, this pattern of data has been witnessed in the Repeated Search literature, where participants search the same display again and again (Wolfe et al., 2000, see also Kunar et al., 2008 and Oliva et al., 2004). Although search slopes, in these experiments do not become more efficient, RTs become faster over time in both target present and target absent displays (Wolfe et al., 2000, see also Kunar et al., 2007, for similar evidence in contextual cueing displays).

However, if it is the target-distractor associations that are important in configural CC, it may not necessarily be the case that a predictive context facilitates RTs in target absent trials. If there is no target-distractor association to be learnt, in the absence of a target, then perhaps, counter to the analogy above, there will be no contextual cueing. This paper investigates what happens when the target is sometimes absent from the display. To anticipate out results, we find that CC is largely confined to target present trials in displays where the configuration acts as the context.

In Experiment 1, we investigate whether a contextual cueing effect is observed when, in half the displays, the target is absent and in the other half of the displays the target is present. Here, for example, in a display with Configuration A, the target will always be present at location (x,y), while in a display with Configuration B, the target will always be absent. The results suggest that a CC effect only occurs in target-present displays. Experiment 2 investigates whether people can make use of the context when the *same* display predicts both target present and target absent responses (i.e., do people learn that in Display A, if the target is not at location (x,y), it is not there at all)? In this case, when the same context can accompany both target present and target absent trials, no CC benefit is observed on either present or absent trials. In Experiments 3 and 4 the target is always present but can appear in multiple possible target locations. In Experiment 3, distractors appear in any of the possible target locations that do not happen to contain the target, while in Experiment 4 distractors never appear in those target locations. The results suggest that it is the appearance of a distractor in a previously designated target location that disrupts contextual cueing. Experiment 5 shows that having a distractor appear in a target location disrupts the expression of CC, for both present and absent displays, even when the context has been successfully learned previously. In this case, changing the response dimension from an orientation task to a present/absent task removes the CC effect. We discuss the results in relation to the attentional guidance and response selection account of CC in the General Discussion.

Experiment 1

Previous experiments investigating CC have tended to use paradigms where the target is always present (e.g. participants have to respond to whether a target T is facing to the left or the right, Chun & Jiang, 1998; Kunar et al., 2007). We investigate if a CC effect occurs when participants have to respond to the presence or absence of a target. In this experiment, one set of displays *always* contains a target while in the other set of displays a target is *never* there.

Method

Participants:

Thirteen naïve observers served as participants. All participants were recruited on the basis that they fell within the age range of 18-55 and had normal or corrected to normal vision. All participants gave informed consent and were paid for their time.

Apparatus and Stimuli:

The experiment was conducted on a Macintosh computer using Matlab Software with the PsychToolbox (Brainard, 1997; Pelli, 1997). The distractor items were white L shapes presented randomly in one of four orientations (0, 90, 180 or 270 degrees). The target item (if present) was a white T shape rotated 90 degrees either to the left or to the right with equal probability. Each L contained a small offset (approximately 0.1 degree) at the line junction to make search more difficult (see Figure 1). All stimuli subtended 1.2° x 1.2° at a viewing distance of 57.4 cm and were presented in an invisible 8 x 12 matrix that subtended 34.6° x 25.6°. The background was a uniform grey.

Procedure:

The experiment consisted of six epochs, in turn made up of five blocks each containing 24 trials. Within a block, twelve displays were repeated displays in which the target and distractor locations remained the same throughout the experiment. These configurations were repeated once in each block throughout the experiment. The configurations of the other half of the trials were never repeated ('unrepeated' displays). In a CC experiment, it is important to assure that participants are learning the context of the display and not merely learning likely target locations. Accordingly, on the unrepeated trials, targets were restricted to twelve locations (see Chun & Jiang, 1998). However, in these trials, the relationship of targets to distractors was not preserved from trial to trial.

On any given trial, the target item (if present) was presented along with eleven distractor Ls so that the total set size equaled twelve. If the target was absent then twelve distractor Ls were presented. Half of the repeated displays were designated to always be target present displays, while the other half were target absent displays. Likewise, in the unrepeated displays, half of the trials were target present and the other half were target absent. Thus, a repeated configuration of items could either inform a participant about the location of a target or about the absence of any target in that particular configuration. Participants were asked to search for the target, T, and to press a left key ("l") if it was present and a right key ("a") if it was absent. They were asked to respond as quickly but as accurately as possible. Participants completed a practice block of 24 trials before the experiment proper. An example display can be seen in Figure 1.

Figure 1 about here

Data analysis:

In order to assess whether there is a contextual cueing effect or not, we measure the difference between repeated and unrepeated configurations across the last three epochs. Chun & Jiang (1998) first used this method and we have also previously used it as a way of defining whether a given context benefits RTs (Kunar, Flusberg & Wolfe, 2006; Kunar, Flusberg & Wolfe, 2008a; Kunar, Flusberg, Horowitz & Wolfe, 2007). Although a CC Effect can emerge early in the experiment (as mentioned above it can be observed after five repetitions), in general, the more times a display is repeated, the greater the CC benefit.

Results and Discussion

One participant was removed from analysis due to high error rates (38%). In the remaining data, fewer errors were made when the target was absent ($F(1, 11) = 29.2$, $p < 0.01$) and marginally fewer errors were made when the target was in a repeated display ($F(1, 11) = 4.8$, $p = 0.051$). The interaction was not significant. As the error rates were low (6.6%) and we are more concerned with RTs, we do not discuss this further.

Here, and in all subsequent experiments, RTs below 200 msec and above 4000 msec were removed. An overall ANOVA with factors of Presence (Target present or Target absent), Display Type (Repeated or Unrepeated) and Epoch (Epochs 1-6) on RTs showed a main effect of presence, $F(1, 11) = 88.1$, $p < 0.01$, where RTs were faster for target present trials than for target absent trials, and a main effect of epoch, $F(5, 55) = 26.6$, $p < 0.01$, where RTs decreased across epoch. The Configuration x Presence interaction was marginally significant, $F(1, 11) = 4.0$, $p = 0.07$, and the Presence x Epoch interaction was significant, $F(5, 55) = 10.9$, $p < 0.01$. Repeated RTs were faster than unrepeated RTs in target present trials but not in target absent trials and RTs decreased more across epoch in absent trials than in present. None of the other interactions were significant.

As our main question of interest was to investigate the separate CC effects for both target present and target absent displays, two subsequent 2 x 2 ANOVAs (with factors of Configuration and Epoch) were conducted on present and absent RTs respectively (see Figure 2). Let us examine the present trials first. RTs from repeated displays were faster than those for unrepeated, $F(1, 11) = 5.1$, $p < 0.05$, and overall RTs decreased over epoch, $F(5,55) = 16.48$, $p < 0.01$. There was no interaction between Display Type and Epoch ($F < 1$). Taking our standard measure of contextual cueing, however, (i.e., the difference between RTs in repeated and unrepeated displays over the last three epochs) we see that a CC effect occurred for target present displays. Participants were 70 msec faster at responding in repeated displays compared to unrepeated, $t(11) = -2.6$, $p < 0.05$.

Figure 2 about here

In contrast, there was no benefit of repeating the context in target absent displays. Although RTs generally decreased across epoch, $F(5, 55) = 23.9$, $p < 0.01$, there was no main effect of display type nor a significant Display Type x Epoch interaction. Examining data from the last three epochs there was no evidence of a CC effect, $t(11) = 0.2$, p = n.s. If anything, participants were 5 msec slower at responding to repeated displays than unrepeated.

In this experiment although there was a CC effect in target present trials there was no CC effect when the target was absent. This fits with the hypothesis that the context is encoded relative to a target item (e.g., Brady and Chun, 2007). It argues against the notion that the context could inform an observer about the absence of a target.

Experiment 2

If a context is only associated with the absence of a target, CC is not observed. What happens when a spatial context specifies the location of a target, if that target is present, but where it is possible for the target to be absent on a given trial? There are four possible outcomes. First, a CC effect could occur in both target present and target absent displays. Participants may learn that in a given configuration the target will only appear at one location. If the target is not at that location then it is not there at all. Participants could use this information to speed both present and absent responses to repeated contexts. This would be the most obvious prediction of a model that argues that context guides attention to the target location. Second, a CC effect could occur in target present displays but not in target absent displays as in Experiment 1. Third, a CC effect could occur in target absent displays but not in target present displays. While logically possible, prior work makes this unlikely. In fact, Experiment 2 finds that the answer is the fourth logical option: CC effects do not occur in either target present or target absent displays. Having a distractor appear in the place of the target seems to disrupt learning of the target-distractor associations, rendering them 'unreliable'. A high degree of reliability may be required to produce a CC speeding of responses to targets (see also Jungé, Scholl & Chun, 2007).

Method

In Experiment 1, the target was present on 50% of trials. There were two versions of Experiment 2. In one, the target was present 50% of the time. In the other the target was present 75% of the time. For the remainder of trials the target was absent. In absent trials a distractor item appeared at the ‘target’ location.

Participants:

Thirteen naïve observers between the ages of 18 and 55 years served as participants for the 50% condition and twelve naïve observers served as participants for the 75% condition. All participants were recruited to fall within the age range of 18-55 and have normal or corrected to normal vision. All participants gave informed consent and were paid for their time.

Apparatus and Stimuli:

The apparatus and stimuli were identical to that of Experiment 1.

Procedure:

The procedure was similar to Experiment 1, except that here the target could either be present or absent when a repeated context was shown. For any repeated display, targets appeared on average 50% of the time in the 50% condition and 75% of time in the 75% condition. On the other trials, the target was absent and the ‘target location’ was filled with a distractor. For unrepeated displays, again the potential target locations were filled with targets on 50% of trials in the 50% condition and 75% of trials in the 75% condition. On the remaining trials the target was absent and the location was filled with a distractor. In the 75% condition the size of the stimuli varied depending on eccentricity (as visual acuity declines as function of the distance from the center point). Those closest the center subtended 1° visual angle, while those further away subtended 1.5° or 2.5° depending on their relative distance from the center of the display. The horizontal and vertical lines of the L also made a perfect right-angle and were not offset. Please note that these small changes do not affect the overall CC effect (see Kunar et al., 2007, who used these stimuli) though, as can be seen in the faster RTs of Figure 3, these simpler stimuli make the task somewhat easier.

For the 50% condition, the number of trials and epochs were similar to those in Experiment 1. For the 75% condition there were 448 experimental trials, divided into seven epochs of 64 trials each. Overall, there were four repeated displays and four unrepeated displays, each repeated eight times per epoch and participants were instructed to press the letter ‘m’ when the target T was present and the letter ‘z’ when it was absent. Although the number of repeated and unrepeated displays is decreased in this condition, the number of repetitions per display has increased. Previous research has shown that this increase in repetitions has led to a robust (and numerically large) CC effect (Kunar et al., 2006, 2007, 2008, see also the Training phase in Experiment 5). If a CC effect does occur when the target is sometimes absent, one would suggest that, with these conditions a CC effect should emerge here.

<u>Results and Discussion</u>

As can be seen in Figure 3, the main result of both versions of Experiment 2 is that CC was eliminated, even for the target present trials.

There were more errors on target present trials than on target absent trials, $F(1,12) = 71.2$, $p < 0.01$ in the 50% condition but not in the 75% condition. None of the other main effects or interactions were significant. Overall error rates were low in both the 50% and 75% condition (8% and 5%) and so are not discussed further.

An overall ANOVA with factors of Presence, Display Type and Epoch on RTs for each condition[1] showed there to be a main effect of presence, $F(1, 12) = 48.8$, $p < 0.01$ and $F(1, 11) = 26.0$, $p < 0.01$ for the 50% and 75% condition respectively, where RTs were faster for target present trials than for target absent trials, and a main effect of epoch, $F(5, 60) = 16.9$, $p < 0.01$ and $F(6, 66) = 6.4$, $p < 0.01$ for the 50% and 75% condition respectively, where RTs decreased across epoch. The Configuration x Presence interaction was marginally significant, $F(1, 11) = 3.5$, $p = 0.09$, and significant $F(1, 11) = 5.0$, $p < 0.05$ in the 50% and 75% condition respectively, and there was a significant Presence x Epoch interaction in the 50% condition, $F(5, 60) = 6.6$, $p < 0.01$. None of the other interactions were significant.

As we were interested in the CC effects for target present and target absent trials respectively, the data were split up into individual 2 x 2 ANOVAs with factors of Display Type and Epoch for each condition. Figure 3 shows RTs for both target present and target absent trials for both conditions. As can be seen, none of the target present nor target absent trials showed a CC effect. In fact, on target present trials in the 50% condition, RTs from repeated displays were actually slower than those for unrepeated, $F(1, 12) = 14.7$, $p < 0.01$. Overall, RTs decreased over epoch in both conditions, $F(5, 60) = 8.3$, $p < 0.01$ and $F(6, 66) = 5.0$, $p < 0.01$ for the 50% and 75%

[1] As the 50% condition and the 75% condition had different Epochs it was not viable to conduct an overall between-condition ANOVA on the two conditions

condition respectively. There was no interaction between Display type and Epoch in either condition. Taking our standard measure of contextual cueing we see that, unlike Experiment 1, there was no CC effect in either the 50% or 75% condition, $t(12) = 1.5$, p = n.s and $t(11) = -1.3$, p = n.s., respectively.

Figure 3 about here

In target absent trials, RTs from repeated displays were marginally slower than those for unrepeated, $F(1, 12) = 3.7$, $p = 0.08$, in the 50% condition and significantly slower in the 75% condition, $F(1,11) = 5.0$, $p < 0.05$. Overall RTs decreased over epoch, $F(5,60) = 18.4$, $p < 0.01$ and $F(6, 66) = 3.8$, $p < 0.01$, for the 50% and 75% condition respectively. There was no interaction between Display type and Epoch in either condition. Again using the standard measure of contextual cueing, there was no CC effect in either the 50% or the 75% condition, $t(12) = 0.1$, p = n.s., and, $t(11) = 1.4$ p = n.s., respectively.

Having a display be both 'target present' and 'target absent' seems to prevent the development of the CC effect. Using the standard measure of CC there was no benefit of having a predictive context. Indeed, the effect of context goes the "wrong way". A replication of this study, using set sizes of both 8 and 12, failed to find a main effect of display type at either set size. Again, in this replication RTs for target present repeated displays were marginally *slower* than RTs for unrepeated trials, $F(1, 7) = 4.46$, $p = 0.07$. Put together the data suggest that replacing a target with a distractor on target absent trials eliminates CC or, perhaps, even creates a modest “contextual confusion” on the present trials.

Makovski, and Jiang (2010), recently showed evidence of a contextual cost (where RTs for repeated displays were slower than those for unrepeated displays) under some conditions. In their experiments, they manipulated the CC effect observed when the target item systematically moved further away, in a test phase, from its learnt location in a training phase. In Experiment 1, they moved the target to an empty location while in Experiment 2 they swapped the location of the target and a distractor so that a distractor appeared in the previous target location. In this latter experiment a small contextual cueing cost emerged. Makovski and Jiang (2010) attributed this cost to the distance that the target had moved. However, in light of the present results, we suggest that the contextual cost may have occurred due to the presence of a distractor appearing in a target location.

Experiment 3

Experiment 2 showed that when the target was replaced with a distractor item, in target absent trials, then no CC effect was found in either present and absent trials. The root cause of this may be disruption of the normal CC effect by the presence of a distractor at the target location. Would the presence of a distractor at a target location continue to be disruptive if targets were present on every trial? We investigate this in Experiment 3 where the target is always present but where it can appear at a number of pre-designated locations. As we will see, the presence of a distractor in a target location is enough to disrupt CC. No CC effect is observed when the target can be found in more than one location in a repeated display; at least, not if distractors fill the other locations.

Method

In Experiment 3, a single target was present on each trial. Within a given, repeated configuration, targets could appear in one of one, two, three or four possible locations. If a location was not occupied by a target item, then it was filled by a distractor. The configuration was 100% predictive only when there was one possible target location. When there were two locations, participants could, in principle, learn that the target would always be at either location A or location B, and so forth for three or four locations.

Participants:

Sixteen naïve observers served as participants. All participants fell within the age range of 18-55 and had normal or corrected to normal vision. All participants gave informed consent and were paid for their time.

Apparatus and Stimuli:

The apparatus and stimuli were identical to Experiment 1.

Procedure:

Participants were asked to search for the target, T, and to press a left key (“a”) if it was rotated to the left and a right key (“l”) if it was rotated to the right. The target was always present. They were asked to respond as quickly and accurately as possible. On any given trial the target item was presented along with eleven distractor Ls so that the total set size equaled twelve. The experiment consisted of 120 blocks each containing 24 trials. Within a block, half of these trials had a repeated configuration. These configurations were repeated once in each block throughout the experiment. The other half of the trials were the unrepeated displays. Of the twelve repeated configurations, three of these had a single target location (akin to the standard CC paradigm), three had two possible locations, three had three possible locations, and three had four possible locations. Since there was only one target on any given trial, the other possible target locations contained a distractor. This preserved the exact spatial configuration for the repeated displays. The same rule applied to the choice of target locations for the unrepeated configurations. Of the twelve unrepeated configurations, three of these were constrained so that the target only appeared in one location, three where the target could appear in two possible locations, three where the target could appear in three possible locations, and three where the target could appear in four possible locations. Any simple location priming would be the same in repeated and unrepeated conditions. However, there could be no contextual cueing in the unrepeated conditions since the configuration of the rest of the display was not held constant.

As in Experiments 1 and 2, for purposes of analysis, blocks were grouped into sets of five to make 24 epochs. In the standard contextual cueing experiments of Chun and Jiang there were only six epochs and each display was presented 30 times (e.g. see

Chun & Jiang, 1998). Because we have increased the number of possible target locations within a configuration from one to four we also increased the number of epochs (and hence display repetition) four-fold. This ensured that, by the end of the experiment, every possible display combination was presented at least 30 times (comparable to previous contextual cueing studies and to Experiment 1 and 2 here). As the experiment took approximately four hours to complete, it was broken down into two sessions with the constraint that each session was run within a week of each other (as it has been found that successful contextual cueing effects persist for the time span of a week, Chun & Jiang, 2003).

Participants completed a practice block of 24 trials before the experiment proper. At the end of the experiment, participants were asked whether they noticed that some of the configurations were repeated and to identify which of the configurations they thought they had seen before. If they were unsure they were asked to guess. Example displays are shown in Figure 4.

Figure 4 about here

Results and Discussion

Overall error rates were quite low at 4% in both repeated and unrepeated displays, with no significant effects of display type or the number of target locations. Nor was the interaction reliable. As such, we do not discuss errors further. Eight of the participants reported having recognized that some of the configurations were repeated. However, when asked to explicitly report which configurations they had seen, all of them failed to do so correctly. Overall accuracy for configuration identification equaled 40% (with a chance level of 50%), with participants who reported explicit recognition averaging only 36% correct.

In all the following analyses, RTs from repeated displays were compared to those of the unrepeated displays with the same number of absolute target locations. Figure 5 shows RTs for repeated and unrepeated configurations depending on the number of potential target locations. As is clear from the figure, there was a convincing contextual cueing effect only when there was just one possible target location. Overall RTs became faster over time, $F(23, 345) = 27.8$, $p < 0.01$, and although there was no main effect of Display Type, $F(1, 15) = 1.6$, p = n.s., there was a reliable Display Type x Epoch interaction, $F(23, 345) = 1.7$, $p < 0.05$. RTs from repeated displays became faster across epoch relative to RTs for unrepeated displays. Taking the standard measure of CC we see that RTs from repeated displays were marginally faster than those from unrepeated displays, $t(15) = -2.0$, $p = 0.06$.

When there were two, three or four possible target positions none of the main effects of Display Type nor the Display Type x Epoch interactions approached significance. Taking the standard measure of CC we see that no CC effect was found when there were two or three possible target positions (all ts < 1). However, repeated RTs were faster than unrepeated displays when there were four possible target positions, $t(15) = -4.2$, $p < 0.01$.

Figure 5 about here

Examining our data, we see that not every participant showed a contextual cueing effect with one target location (and in fact, prior work has suggested that not all participants show a contextual cueing effect under standard conditions, Lleras & Von Muhlenen, 2004). Perhaps contextual cueing for displays with multiple target locations would be seen in the subset of observers who show the basic effect for a single location. Accordingly, we divided participants into two subsets: those who showed a contextual cueing effect with one target and those who did not (this was done by finding the difference in RTs between unrepeated and repeated configurations across Epochs 4 – 6 for each participant, see Chun & Jiang, 1998). Participants who were allocated to the contextual cueing group showed a positive overall contextual cueing effect (i.e. for this group, the difference between unrepeated and repeated RTs was greater than zero, $t(10) = 3.1$, $p = 0.01$), whereas participants who were allocated to the no contextual cueing group showed a negative effect (i.e. for this group, the difference between the unrepeated and repeated RTs was less than zero, $t(10) = 3.8$, $p = 0.02$). Five participants (29%) did not show a contextual cueing effect and so their data were excluded from further analysis. Figure 6 shows RTs, for the contextual cueing group only, for repeated and unrepeated displays depending on the number of potential target locations.

Figure 6 about here

Unsurprisingly, since they were selected on this basis, these observers show a contextual cueing effect when there was only one possible target location. Overall observers were faster at finding the target if they were embedded in repeated configurations than if they were in unrepeated, $F(1, 10) = 7.6$, $p < 0.05$. Likewise, RTs became faster across epochs, $F(23, 230) = 20.0$, $p < 0.01$. The Configuration x Epoch interaction did not prove reliable, $F(23, 230) = 1.3$, p = n.s. Taking the standard measure of CC repeated RTs were faster than unrepeated RTs, $t(10) = -3.4$, $p < 0.01$.

Of more interest, this was not the pattern of results when there were two, three, or four potential target locations. Overall, RTs for two, three, or four potential targets became faster over epoch (all Fs > 8.9, ps < 0.01). However, the main effects of display type failed to reach significance for two, three, or four target locations (all Fs < 2.2, ps > 0.17). RTs for repeated configurations did not differ from those with unrepeated configurations. If we examine Figure 6 closely, there is the barest hint of an effect. Repeated RTs are slightly faster than unrepeated for most epochs, especially it seems in the three target case. This gains some statistical support in the form of reliable Display Type x Epoch interactions for three and four potential target locations ($F(23, 230) = 2.1$, $p < 0.01$; $F(23, 230) = 1.6$, $p < 0.05$, respectively) but not for two target locations, $F(23, 230) = 0.7$, p = n.s. Data from the last three epochs (the standard measure of CC) showed there was no difference between repeated and unrepeated RTs when there were either two or three target locations (all ts < 1). When there were four target locations repeated RTs were on the whole faster than unrepeated, $t(10) = -2.5$, $p < 0.05$. Despite this, examining the figures it is clear that any CC effect is very weak and clearly different from the one target location case. Furthermore, any CC effect is not consistent across the latter epochs (e.g., the planned comparisons between repeated and unrepeated configurations for the last epoch do not prove reliable as would be predicted if a strong CC effect were present, all ts < 1.4, ps > 0.2). We would be hard pressed to claim a strong effect of repeating the display in any of the displays but the one target location.

A standard contextual cueing effect was observed when the configuration predicted only one target location. However, if the configuration predicted more than one target location, putting a distractor in a previous target location, then there was very little benefit of contextual cueing. This negative finding could have occurred for a number of reasons. First, it could reflect a lack of statistical power. Maybe the effect is present but too small to see reliably. This seems unlikely. The number specific pairings of context and target location was equal to or greater than that used in a standard contextual cueing experiment - even when the target could appear in one of four locations. If a standard contextual cueing effect is present with multiple target locations, this experiment should have produced it in all conditions. More plausibly, it could be that people do not show contextual cueing if a distractor sometimes appears in a potential target location (see also Experiment 2) as it disrupts the learning of the target-distractor associations. If the target is not *always* going to be in a specific location, the observers might not utilise the contextual information and instead search the display as if it had not been seen before, without the memory of any display regularities (see also, Kunar et al., 2008b, Oliva et al., 2004, Wolfe et al., 2000).

Given that there was a statistical Display Type x Epoch interaction for the three and four target location conditions, one could argue that maybe CC was present in these displays, but greatly reduced. This is plausible but it again points to the fact that having a distractor in a target location interferes with the CC effect so that it is reduced, at the very least, if not removed entirely. Other work has shown that contextual cueing can occur for multiple target locations. Chun and Jiang (1998) showed that up to two target locations can be cued by the same configuration. The critical difference between their work and our work presented here was that, in Chun and Jiang's work, the two potential target locations always remained unoccupied if the target did not appear at that position. A distractor never appeared in a target position. In our work, however, when the target was not present at one of the potential target locations a distractor occupied that place. This seems to be a key factor in establishing whether or not a contextual cueing effect was observed and was investigated further in Experiment 4.

Experiment 4

Experiment 3 suggested that it was the presence of a distractor item appearing in a target location that disrupts CC. If this was the case then a CC effect might re-emerge when there are multiple possible target locations but when a distractor never appears in a target location. This was investigated in Experiment 4.

Participants:

Twelve naïve observers between the ages of 18 and 55 years served as participants. All participants had normal or corrected to normal vision. All participants gave informed consent and were paid for their time.

Apparatus and Stimuli:

The apparatus and stimuli were identical to that of Experiment 1, except that here all the stimuli were presented within square, white, outline boxes ("placeholders"), which marked out the configuration of a display. All placeholders subtended visual angles of 1.7° x 1.7°.

Procedure:

Participants were asked to respond to the orientation of the letter T, as quickly and as accurately as possible. Twelve placeholders per configuration ensured that the overall shape and layout of the configuration was kept constant regardless of target location (see Kunar et al., 2007 and 2008, who also used placeholders to mark out a repeated configuration). Items could only appear within a placeholder. Each configuration had four possible target locations. Since the number of placeholders was fixed at twelve, and there were four potential target locations, there were eight distractor items presented alongside the target. Thus, the set size was nine items (Ts and Ls) or twelve placeholders. As in the four target condition of Experiment 3, in the unrepeated trials, the target position was limited to four possible locations, but the overall configuration of these displays varied across the experiment. However, unlike Experiment 3, a distractor item never occupied a possible target location. There were three repeated configurations and three unrepeated configurations. In each block, each of the three repeated configurations was repeated four times (once with each possible target location) and intermixed with twelve unrepeated configurations to make a total of 24 trials per block. There were 30 blocks in total so that each configuration-target combination was presented on the whole 30 times (with the overall placeholder configuration being repeated 120 times, 720 trials in total). Example displays are shown in Figure 7.

Results and Discussion

RTs for repeated and unrepeated configurations are presented in Figure 8. It is clear that this condition produces CC. Overall error rates were low at 1.4% in both old and new conditions, with no significant effects of configuration or epoch, or a significant Configuration x Epoch interaction. RTs from old configurations were faster than those from new, $F(1, 11) = 14.1$, $p < 0.01$, and RTs became faster across epoch, $F(5, 55) = 7.3$, $p < 0.01$. The Configuration x Epoch interaction did not prove reliable, $F(5, 55) = 1.8$, p = n.s. However, taking the standard measure of contextual cueing there was a reliable effect of configuration $t(12) = 3.9$, $p < 0.01$. RTs for repeated configurations became faster than unrepeated over time.

Figure 7 and 8 about here

Chun & Jiang (1998) found contextual cueing for two possible target locations. Experiment 4 extended that result to show contextual cueing for four target locations, as long as a distractor does not appear in a target location. These results clearly differ from those of Experiment 3, where any CC effect was minimal. It seems that having distractors appear in possible target positions weakens the CC effect. There are two possible reasons for this. First, having a distractor present in a target location might prevent *learning* of the repeated context by disrupting the target-distractor associations. Second, having a distractor in a target location might prevent the *expression* of contextual knowledge. We investigate this in Experiment 5 by training in a standard CC condition where observers learned the target-distractor associations in blocks of trials where the target was always present. In the test phase, we examined whether participants could express this CC knowledge when a target could either be present or absent in the same display (as in Experiment 2).

Experiment 5

Experiment 5 replicates the finding of Experiment 2. The results show that contextual cueing does not occur on target absent trials, even in conditions when participants have successfully learned the context. Furthermore, even for a previously learned CC configuration, there was no CC effect on target present trials if a distractor sometimes appeared in a target location. Target absent trials that place a distractor in the target location, prevent the expression of even previously learned knowledge.

Method

Participants:

Twenty-four naïve observers served as participants. All participants fell within the age range of 18-55 and had normal or corrected to normal vision. All gave informed consent and were paid for their time.

Apparatus and Stimuli:

The apparatus and stimuli were similar to that of Experiment 1, except here the experiments were programmed using Blitz Basic and run on PCs. In this experiment all the stimuli subtended a visual angle of 1.7° x 1.7° at a viewing distance of 57.4 cm.

Procedure:

The experiment consisted of 32 practice trials and 576 experimental trials. In the experiment proper participants were first given 448 'training' trials. In this phase participants completed a standard contextual cueing task (where half of the displays were repeated and the other half were unrepeated) similar to the target present trials in Experiment 1. There were four repeated displays and four unrepeated displays, each repeated eight times per epoch. There was always a target, T, present in each display and participants pressed the letter 'm' if the bottom of the T faced towards the right and the letter 'z' if the bottom of the T faced towards the left. The training phase was divided into seven epochs of 64 trials each and allowed participants to successfully learn the display contexts.

After the training phase participants were then given the 'test' phase consisting of 128 trials (64 trials in Epoch 8 and 64 in Epoch 9). The test phase was similar to the training phase, except that in each repeated and unrepeated display half the time the target was present and half the time the target was absent (similar to the procedure used in Experiment 2). Participants were asked to respond to the presence or absence of the T by pressing the letter ‘r’ if the target was present and ‘v’ if the letter was absent.

Results and Discussion

As can be seen in Figure 9, the introduction of absent trials in the test phase, disrupted the CC that had developed in the training phase.

Overall errors were low at 3.6%. The main effect of display type was not significant in the training phase. In the test phase, fewer errors were made in target absent trials than target present, $F(1, 23) = 18.2$, $p < 0.01$ and fewer errors were made in repeated trials than in unrepeated, $(F1,23) = 5.8$, $p < 0.05$. None of the interactions for the test phase were significant. We do not discuss errors further.

As expected, a CC effect developed during the training phase, indicating that participants successfully learned repeated contexts (Figure 9, “Training Phase”). A 2 x 2 ANOVA with factors of Display Type and Epoch on the Training Phase RTs showed that RTs were faster for repeated contexts than for unrepeated contexts, $F(1, 23) = 6.6$, $p < 0.05$ and RTs decreased with epoch, $F(6, 138) = 47.8$, $p < 0.01$. Although the Display Type x Epoch interaction was not reliable, the standard measure of CC was significant: repeated RTs were faster than unrepeated RTs over the last three epochs, $t(23) =-4.2$, $p < 0.01$.

Figure 9 about here

While the training phase established successful contextual learning, the test phase was used to examine whether this learned knowledge could be expressed in situations when the target was sometimes absent. An overall ANOVA with factors of Presence (Target present and Target Absent), Display Type (Repeated and Unrepeated) and Epoch (Epochs 8 and 9) on RTs in the Test Phase showed there to be a main effect of presence, $F(1, 23) = 122.3$, $p < 0.01$, where RTs were faster in target present trials than in target absent trials and a main effect of epoch, $F(1, 23) = 32.2$, $p < 0.01$, where RTs decreased with epoch. There was also a Presence x Epoch interaction, $F(1, 23) = 9.1$, $p < 0.01$, where RTs decreased more across epoch in the target absent trials than the target present. None of the other interactions were significant.

To examine the potential CC effects for target present and target absent trials individually, the data were split up into two 2 x 2 ANOVAs with factors of Display Type and Epoch for target present and target absent trials respectively. The results suggest that although people had learned the context in the training phase, the appearance of distractors in target locations, during the test phase, disrupted the CC effect on present trials (Figure 9, "Test Phase"). As before, there was no CC for absent trials. For target present trials, although there was an effect of epoch, $F(1, 23) = 16.3$, $p < 0.01$, there was no main effect of context, $F(1, 23) = 2.8$, p = n.s. Nor was there a significant Context x Epoch interaction, $F(1, 23) = 0.2$, p = n.s. Having a distractor appear in a target location appears to disrupt the expression of contextual knowledge, even when the context has been previously learned. We return to this point in the General Discussion. For target absent trials, as in the previous experiments, CC was not seen. Although there was an effect of epoch, $F(1, 23) = 24.8$, $p < 0.01$, there was no effect of context, $F(1, 23) = 0.6$, p = n.s., nor was there a significant Context x Epoch interaction, $F(1, 23) = 1.1$, p = n.s.

Perhaps one reason why there was no observed CC effect in the training phase was that any benefit of having learned the context was masked by a task-switch in the response keys pressed during the test phase. This may explain why there was an increase in RTs at Epoch 8. If so, one could argue that a CC effect would emerge if participants had undergone a practice session with the new response keys. Although possible, further analysis suggests otherwise. Examining RTs from just Epoch 9, we see that there was no evidence of contextual cueing, for either present or absent trials, $t(23) = 1.1$, p = n.s. and $t(23) = 0.3$, p = n.s., respectively. Here, participants would have become accustomed to the new response keys and so if it was just a matter of practice a CC effect should have occurred. Instead it seems that changing the overall response type from a discrimination task (i.e. is the T facing left or right) to a detection task (i.e. is the T present or absent) removed the CC effect. We discuss this further in the General Discussion.

General Discussion

Contextual cueing has been found using a number of different display types. When certain aspects of a display are repeated, responses to find targets are facilitated compared to when the display is not repeated. This can occur with repetition of the target-distractor configuration (Chun & Jiang, 1998), global background color (Kunar et al., 2006), photograph of a naturalistic scene (Brockmole, Castelhano, &

Henderson, 2006, Brockmole, & Henderson, 2006, Ehinger, & Brockmole, 2008) or co-variation with other objects (Chun & Jiang, 1999). The current paper investigates what happens to CC when there is no target present in configural contextual cueing displays. The results show that no CC effect is observed on target absent displays and the inclusion of absent trials, within a given context, disrupts CC on target present trials.

Previous results have shown that when a target is present, contextual cueing speeds RTs (e.g. Chun & Jiang, 1998). Brady and Chun (2007, see also Olson & Chun, 2002, Jiang & Wagner, 2004) suggested that it is the relationship between the target and its immediately surrounding distractor items that is important. Consistent with this idea, our data showed that a contextual cueing effect did not emerge in configural contextual cueing when the target was absent. Furthermore, these target-distractor associations appeared to be vulnerable whenever a distractor appeared in a likely target position.

In a related study, Jungé, Scholl & Chun (2007) found that increasing the amount of noise in a CC study led to a disruption of contextual learning. In a condition where participants were first shown a set of unrepeated trials which did not cue the target ('noise trials'), followed by repeated trials which did cue the target location ('signal trials'), no contextual cueing was observed. Jungé, Scholl & Chun (2007) suggested that if the visual system fails to pick up any display regularities initially (with this increased noise), it may conclude that there will be no predictive information in the display. A similar interpretation could be applied to our data. With the introduction of absent trials, and even more so when the same configuration can be used on present and absent trials, the system may conclude that it is ‘cheaper’ to simply search the display de novo than to retrieve the learned context (Wolfe et al., 2000, Oliva et al., 2004, see also Kunar, Flusberg & Wolfe, 2008b, who showed that search through memory was less efficient than search from vision).

Interestingly, when Jungé et al. (2007) presented the signal displays first, before the noise displays, a CC effect emerged. Our results show that even well-learned CC can be disrupted by the subsequent introduction of absent trials; at least, when distractors can appear in previously reliable target locations. The different fate of previously learned CC in these two studies might be due to differences in methodology. In Jungé et al.’s (2007) study the ‘noise’ trials did not share the same configuration as the ‘signal’ trials whereas in our study, configurations that had signaled the location of the target on 100% of trials became imperfect predictors after the introduction of absent trials. Perhaps any RT benefit of previously having learnt the location of the target is negated by the extra cost of searching elsewhere when the target is not present, and is replaced by a distractor. In these instances, the visual system may choose a strategy that favors searching the display rather than retrieving the learned configural cues (see also Makovski and Jiang, 2010, Wolfe et al., 2000, Oliva et al., 2004, Kunar et al., 2008b).

The results from Experiment 5 also give us an insight into whether a guidance or response selection mechanism may be responsible for CC. In this experiment, contextual knowledge of the target’s location had been previously learned. However, when the response changed from a target discrimination task (is the T facing left or right) to a target detection task (is the T present or absent) the CC effect was no longer there. An attentional guidance account of CC would not predict this. Here, the repeated display would guide attention to the target location and so, at the very least, a facilitation effect should still occur in target present trials. It did not. On the other hand, the data can be explained by a response selection account. Participants had previously learned to respond to the *orientation* of a T, however, this facilitation would not necessarily translate to a different and novel response dimension (e.g., see Cohen & Shoup, 1997; Feintuch & Cohen, 2002 who have suggested different perceptual dimensions have different response-selection processes). In this case a repeated display that had previously benefited orientation responses would not facilitate present or absent responses. This is what we observed.

Conclusion

In sum, contextual information can often facilitate response to a target. However, there are limits to when we encode and use that contextual information. This paper has shown that configural contextual knowledge is only learned when it leads to the target on target present trials. When the target is not there, then local context does not seem to be treated as useful information.

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Figure Legends

Figure 1. Example displays for Experiment 1.

Figure 2. Mean correct RTs (msec) across epochs for target present and target absent trials in Experiment 1. Please note that although there are different y-axis values on target present and target absent graphs the relative scale range of 1000 msec is equivalent.

Figure 3. Mean correct RTs (msec) across epochs for target present and target absent trials in Experiment 2.

Figure 4. Example displays for Repeated Trials in Experiment 3. Figure A and A' have the same repeated configuration. However a distractor in A' occupies the previous target location in display A.

Figure 5. Mean correct RTs (msec) for each condition in Experiment 3. Figure 5(a) shows RTs for trials that have 1 possible target location, Figure 5(b) shows RTs for trials that have 2 possible target locations, Figure 5(c) shows RTs for trials that have 3 possible target locations, and Figure 5(d) shows RTs for trials that have 4 possible target locations. Please note that error bars, for the most part are occluded by the symbols.

Figure 6. Mean correct RTs (msec) for each condition in Experiment 3 for participants who showed a valid contextual cueing effect with one target location. Figure 6(a) shows RTs for trials that have 1 possible target location, Figure 6(b) shows RTs for trials that have 2 possible target locations, Figure 6(c) shows RTs for trials that have 3 possible target locations, and Figure 6(d) shows RTs for trials that have 4 possible target locations. Please note that error bars, for the most part are occluded by the symbols.

Figure 7. Example displays for Repeated Trials in Experiment 4. Figure A and A' have the same placeholder repeated configuration. However the target in A' occupies a different placeholder than that in display A. In this experiment a distractor never occupies a potential target location.

Figure 8. Mean correct RTs (msec) across epochs in Experiment 4.

Figure 9. Mean correct RTs (msec) across epoch for target present trials in the Training Phase (Epochs 1-7) and target present and absent trials in the Test Phase (Epochs 8-9) in Experiment 5.

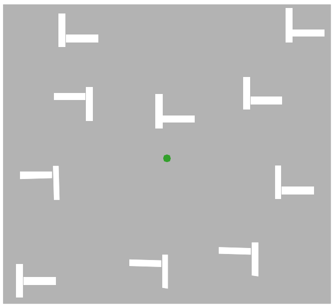
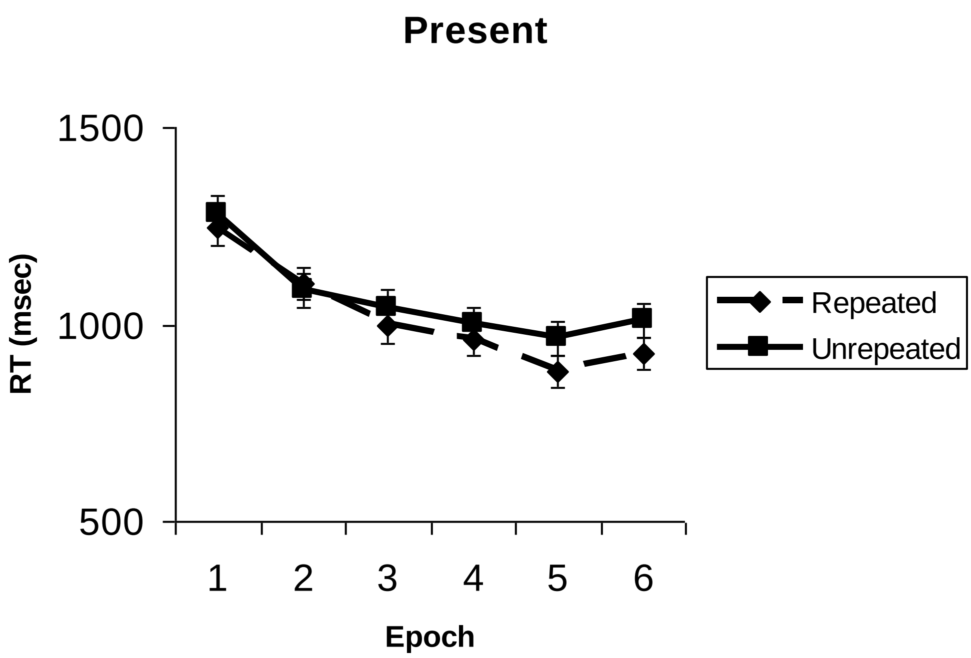


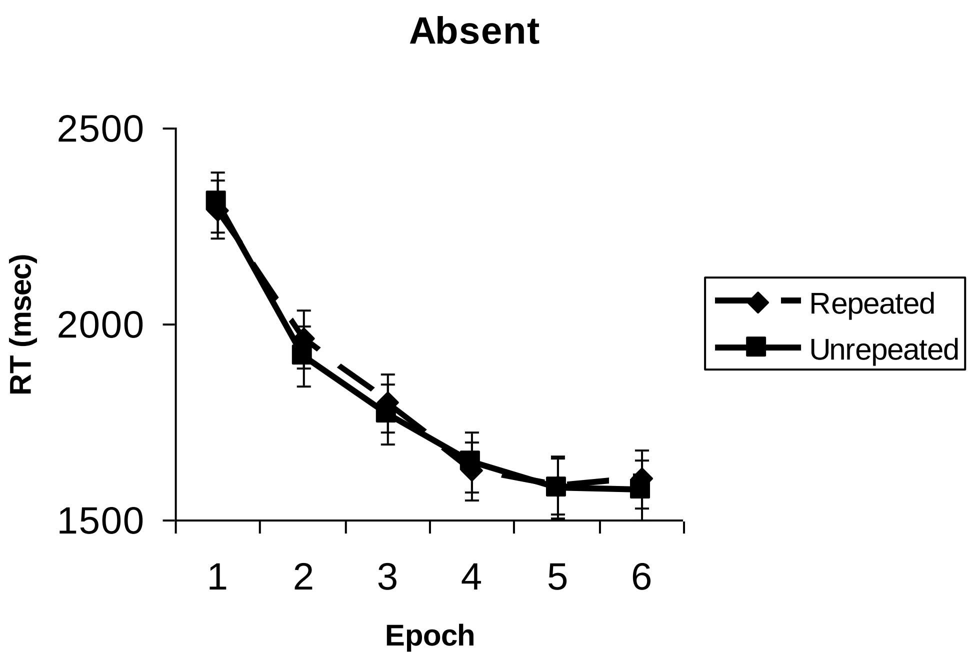
Figure 1

a)



Present
1500
1000
500
RT (msec)
1
2
3
4
5
6
Epoch
Repeated
Unrepeated

b)



Absent
2500
2000
1500
RT (msec)
1
2
3
4
5
6
Epoch
Repeated
Unrepeated

Figure 2

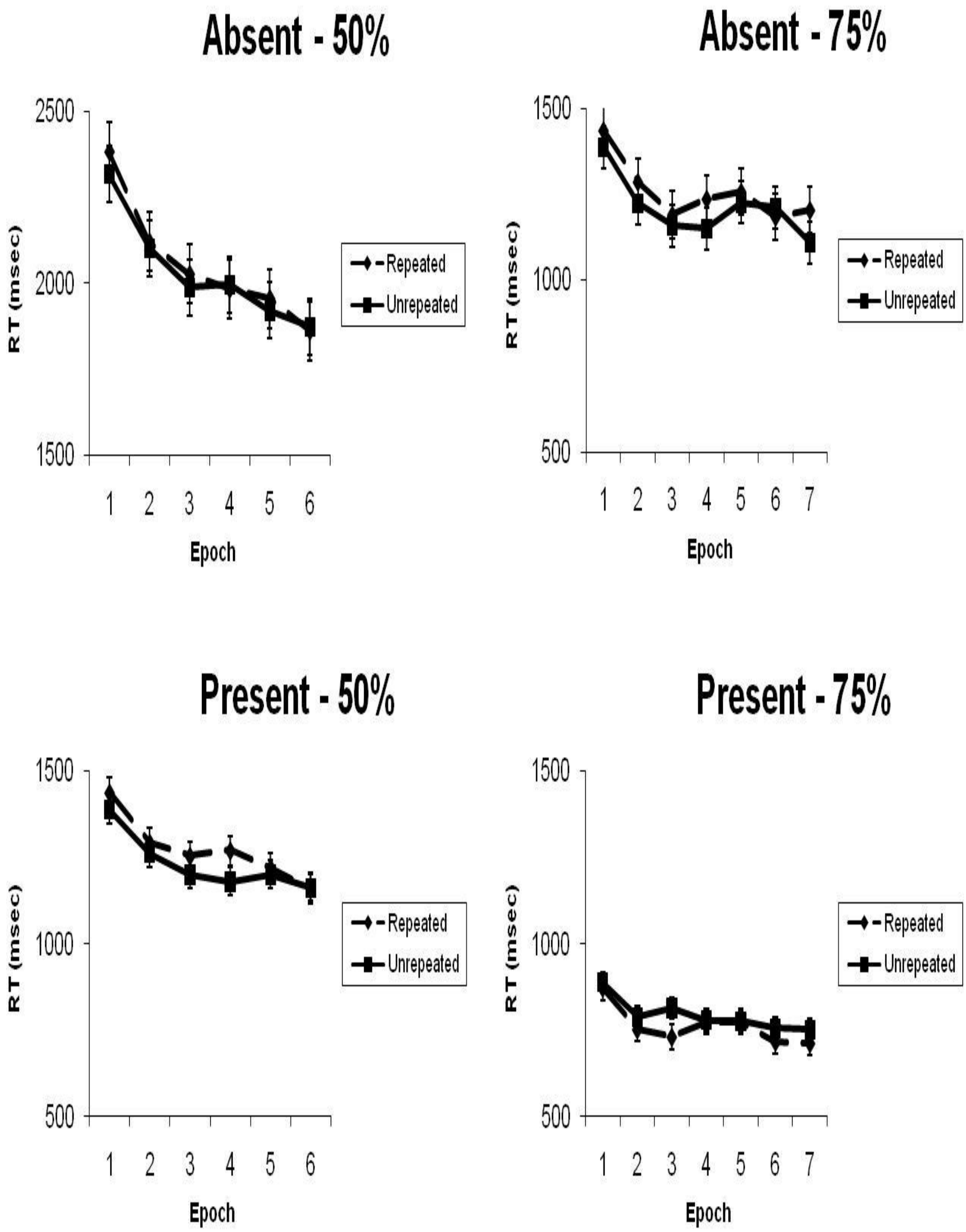

Absent - 50%
2500
2000
1500
RT (msec)
1 2 3 4 5 6
Epoch
Repeated
Unrepeated
Absent - 75%
1500
1000
500
RT (msec)
1 2 3 4 5 6 7
Epoch
Repeated
Unrepeated
Present - 50%
1500
1000
500
RT (msec)
1 2 3 4 5 6
Epoch
Repeated
Unrepeated
Present - 75%
1500
1000
500
RT (msec)
1 2 3 4 5 6 7
Epoch
Repeated
Unrepeated

Figure 3

A A’

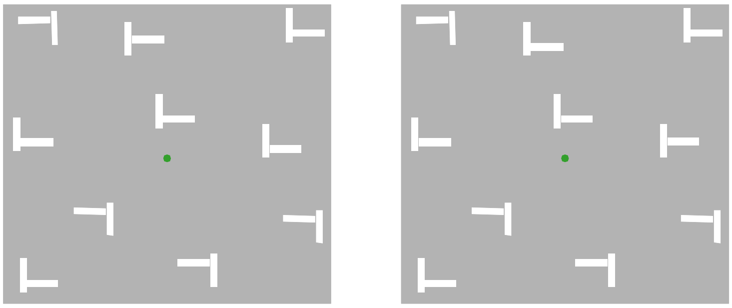


Figure 4

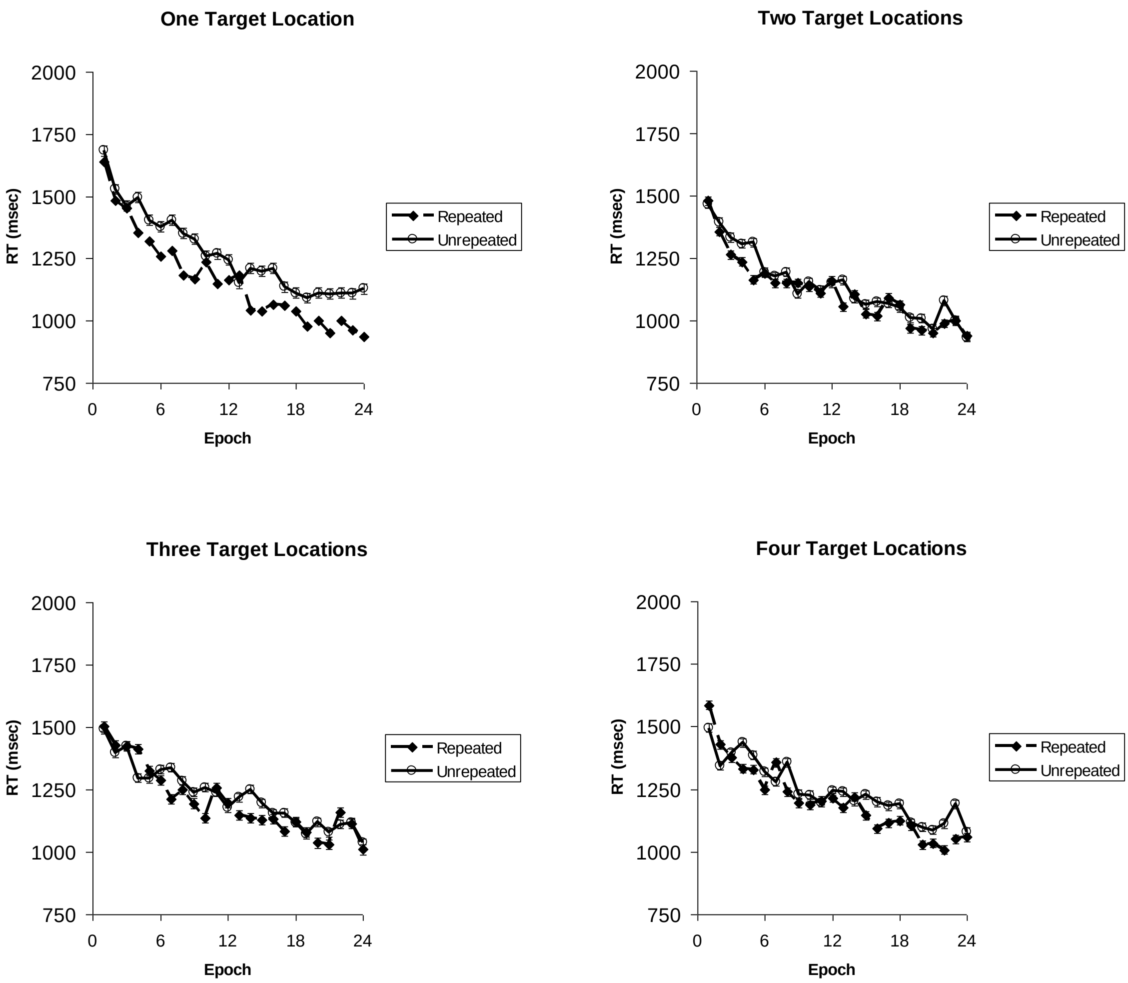

One Target Location
Two Target Locations
Three Target Locations
Four Target Locations
RT (msec)
2000
1750
1500
1250
1000
750
0
6
12
18
24
Epoch
Repeated
Unrepeated

Figure 5

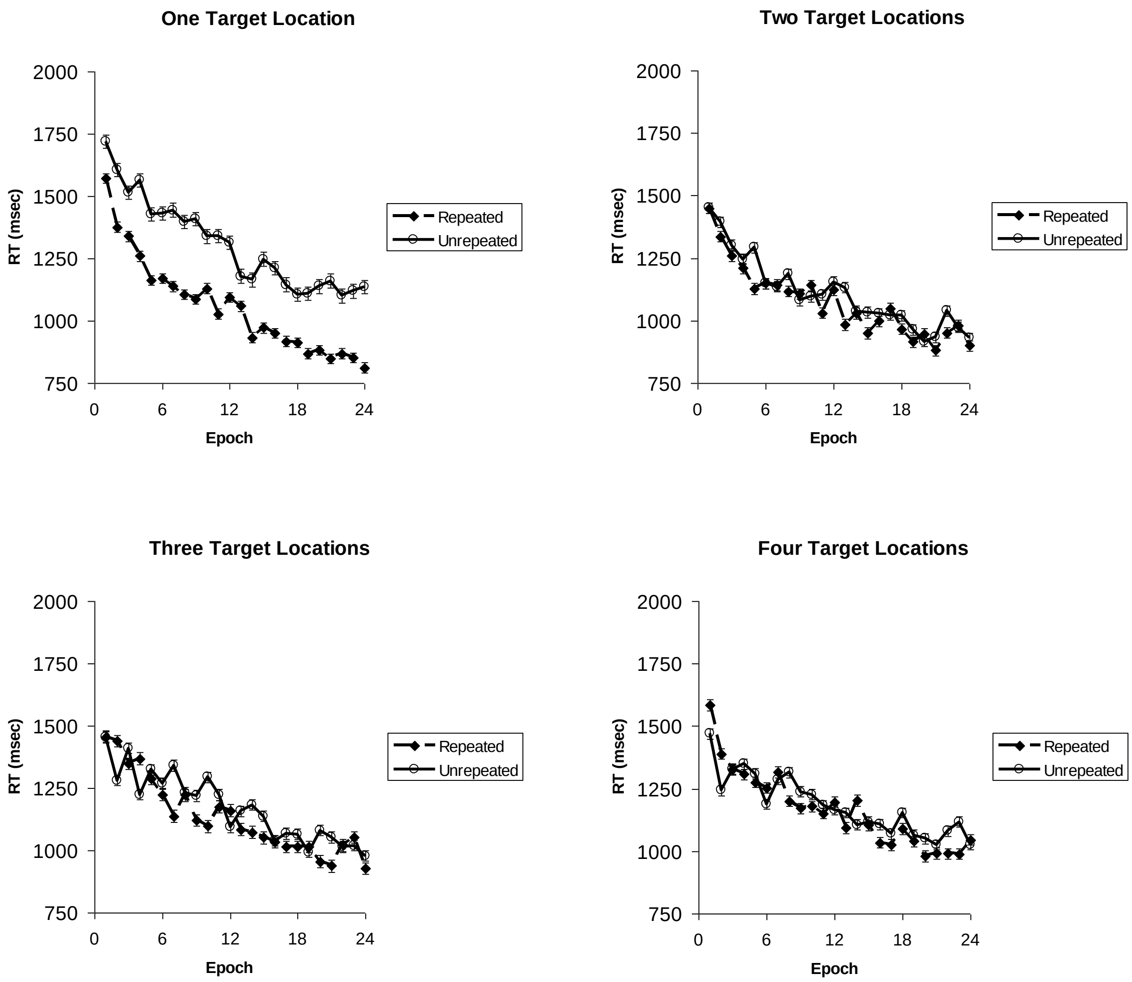
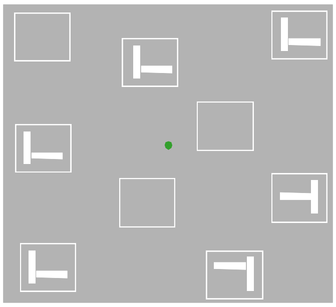

One Target Location
Two Target Locations
Three Target Locations
Four Target Locations
RT (msec)
Epoch
Repeated
Unrepeated
2000
1750
1500
1250
1000
750
0
6
12
18
24

Figure 6

A



A'

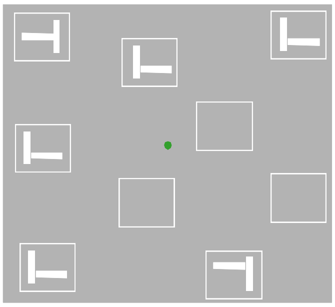


Figure 7

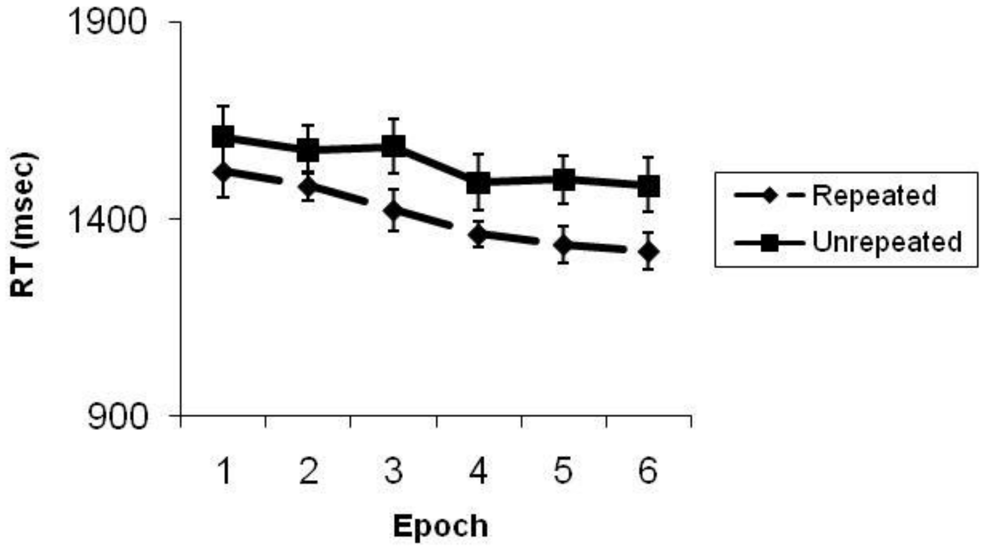


Figure 8

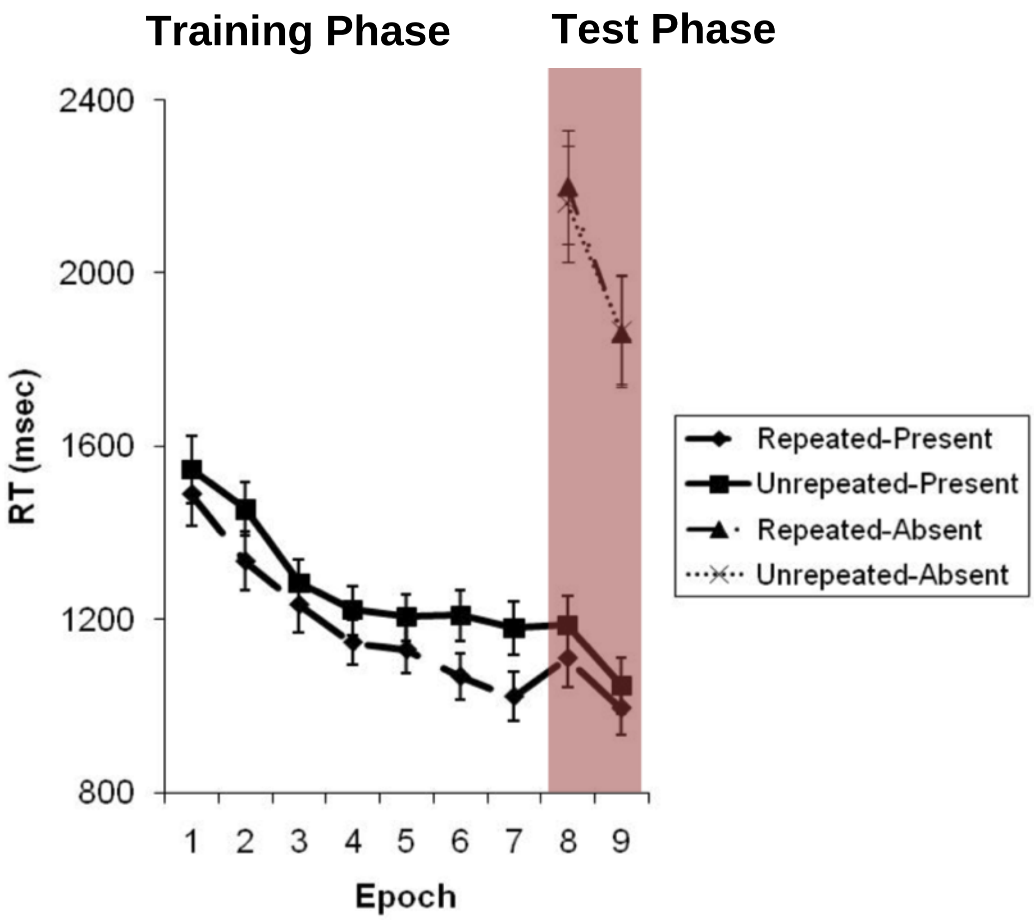

Training Phase
Test Phase
2400
2000
1600
1200
800
RT (msec)
1
2
3
4
5
6
7
8
9
Epoch
Repeated-Present
Unrepeated-Present
Repeated-Absent
Unrepeated-Absent

Figure 9