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Cued Attention and Learning of Spatial Context in Children

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Abstract

The contextual cuing effect refers to a robust phenomenon in which repeated visual context guides attention to relevant information by constraining search (Brady & Chun, 2007; Chun & Jiang, 1998). The effect is measured by an object search task in which a target (e.g., the letter T) is located within repeated or non-repeated visual contexts (e.g., configurations of the letter L). Shorter response times for the repeated configurations indicate that contextual information has facilitated search. Though the effect is robust among adult participants, recent attempts testing the effect with children yielded mixed results (e.g., Vaidya, Huger, Howard & Howard, 2007). Because contextual cuing could play a critical role in cognitive development, resolving this issue is important. The present study used child friendly paradigms to investigate whether children are sensitive to repeated contextual information. The study suggests that children as young as 3 and half year olds successfully show the contextual cuing effect when visual search tasks are age appropriate.

Keywords: Contextual cuing; development of attentional learning; visual search task

The Contextual Cuing Effect

Selectively attending to relevant information is central to efficient learning, because there are many objects and events competing for attention at any moment (Luck & Vogel, 1997). Attentional mechanisms can help people selectively attend to a specific set of objects and events (Chun & Wolfe, 2001; Kanwisher & Wojciulik, 2000; Pashler, 1998; Treisman & Gelade, 1980) and therefore help organize visual processing and experience.

Several factors have been shown to be relevant in organizing adult attention. Results in visual search tasks, for example, suggest that some objects enter attention because they are simply salient in a given scene (Egeth, Jonides, & Wall, 1972; Treisman & Gelade, 1980; Wolfe, 1994; Yantis, 1998), are unique (Bravo & Nakayama, 1992), or relatively novel (Johnston et al., 1990). Other research and models, most relevant to the present study, suggest effects of

learning—such as the learning of predictive relations—on attention (Kruschke, 2001; Le Pelley & McLaren, 2003; Mackintosh, 1975; Rescorla & Wagner, 1972). The idea is that cues in the environment provide relevant and irrelevant information, and that learning guides attention to the most relevant cues presented.

Though this beneficial learning effect has been robustly demonstrated in a number of phenomena with adult participants (Kruschke, 2003; Vidnyanszky & Sohn, 2003), little is known about how early learning interacts with attentional allocation, and further support subsequent learning. The present study directly tests integrated attention in early learning in the context of object search.

The present study considers one process known as the contextual cuing effect. The contextual cuing effect is the process of encoding the context surrounding a target, which guides attention toward a target item among distracting stimuli in a visual search task. Sensitivity to such contextual information has been documented in a visual search paradigm, known as the contextual cuing task.

In the original contextual cuing paradigm developed by Chun & Jiang (1998), computer-based search displays present adult participants with various configurations of stimuli. Some configurations were repeated across blocks, such that the spatial context of all of the distracters in a display predicted an embedded target location. Half of the configurations were novel and half were repeated throughout the experiment. The task used a T-shaped object as a target and L-shaped objects as distracters surrounding the target. Results indicated that participants found the target faster when configurations of distracters were repeated, indicating that contextual information facilitates search of the target. Along with other learning effects, this effect has been documented robustly and has been tested by a number of research findings.

Investigating the development of contextual cuing is important as this pervasive phenomenon in adult search could lead to greater insight into the development of attention and the underlying neural mechanisms of learning and attention more generally.

Developmental Studies

Despite the potential importance of contextual cuing in the developmental process, while a solid line of work has been suggesting a robust effect among adults, almost nothing is known about its development. Indeed, studies with school-age children have yielded at best mixed results— one study (Vaidya, Huger, Howard & Howard, 2007) suggested that children ages 6 to 13 years were unable to demonstrate an effect, while others (Barnes, et al., 2008, 2010; Dixon, Zelazo & De Rosa, 2010) have found that school-aged children are able to benefit from repeated contextual cues. The present study considers the length of the task (the number of trials), the density of repetition (the number of repeated configurations per block), and stimulus type to investigate the effect with adults and school-age children (Experiment 1), and to further investigate the effect in pre-school children (Experiment 2).

Experiment 1

In the experiment conducted by Barnes et al. (2008), 7- to 14-year-olds successfully demonstrated the contextual cuing effect with 6 epochs, 30 blocks, and 24 trials/block for a total of 720 trials. Vaidya et al. (2007) tested 6- to 13-year-olds with the same set-up and number of trials but failed to show the effect. With the present study we sought both to document the contextual cuing effect in school-aged children and to examine the task factors that may limit learning context cues for attention. This is a critical first step for programmatic studies of the development of contextual cuing.

To this end, we first conducted extensive pilot studies, varying the number of trials with older children (8- to 12-year-olds), and determined that the exact task set-up used by Barnes et al. (2008) and Vaidya et al. (2007) failed to produce an effect. Our pilot studies suggested that a total of 600 trials with six repeated configurations per block would be sufficient to yield the effect for 8 to 12 year old children and to ensure that children always completed the task. In this set-up, children were asked to sit through fewer trials, and to remember fewer repeated configurations, which were repeated more often than in Barnes et al., (2008) and Vaidya et al. (2007). Experiment 1 was a full experimental version of this pilot method with children 8 to 12 years old and adults as a control.

Moreover, to test the effect of stimulus type (i.e. illustrations of familiar objects), half of our child and adult participants participated in the task with traditional stimuli (T- and L-shaped objects) and the other half were tested with new stimuli (crayon shapes). This is to help us develop a child friendly contextual

cuing task for younger children for whom traditional letter stimuli may not be appropriate.

Method

Participants Thirty-nine undergraduate students at the University of Houston and 40 children ages 8 to 12 years ($m=10.03$ years) from the community participated in Experiment 1. Twenty children ($m=10.05$ years) and 18 adults were randomly chosen to participate with T- and L-shaped objects as stimuli, and 20 children ($m=9.75$ years) and 21 adults participated with crayon-shaped objects as stimuli.

Stimulus Materials As can be seen in Figure 1, there were two types of stimuli: T- and L-shaped objects (used in the Letters Condition), similar to Chun and Jiang's (1998) stimuli, and crayon-shaped objects (used in the Crayons Condition). The only difference between conditions was the stimulus type. Target objects in the Letters Condition were the T-shaped objects, and distractors were the L-shaped objects. Target objects in the Crayons Condition were the straight (non-broken) crayon-shaped objects, and distractors were the broken crayon-shaped objects.

From our pilot studies, we determined the number of trials and made modifications to the task structure.



Figure 1: Stimuli used in Experiment 1, targets are on the left, distractors on the right.

Procedure The task was computer generated, and stimuli were presented using MATLAB. Responses were key-based and made by pressing a key that corresponded to the orientation of the target. The target was oriented either to 0 degrees or 180 degrees, and distractors were oriented to 0, 90, 180, or 270 degrees. The display remained until the participant made a response. Feedback for incorrect responses was given in the form of a low auditory tone and the word “incorrect” displayed on the center screen. The task consisted of 600 trials, which were divided for statistical purposes into 5 epochs, each of which contained 10 blocks of 12 trials. Each block consisted of 6 repeated and 6 non-repeated configurations of stimuli. In each repeated configuration, the orientation of stimuli varied across blocks, but the spatial location of each stimulus was held constant. Each participant

was given the opportunity to take short breaks at intervals of 5 blocks.

Results

Chun and Jiang (1998) defined the contextual cuing effect as the difference between the average response times of repeated and non-repeated configurations over the second half of the experiment. This single number was used to determine the significance of the effect. Response times were expected to differ between repeated and novel configurations, and this difference was expected to increase as the task progressed (due to repetition).

In the present analysis, we also take the average difference between the averaged response times of the repeated versus novel configurations of the later epochs. The average difference of the initial two epochs was taken to confirm that response times did not differ across repeated and non-repeated configurations before the effect of repetition could be established.

Adult Performance: Average accuracy was very high for both conditions (above 98%). The contextual cuing effect was replicated across two stimulus types in adult participants. There were a significant differences in adults across the final two epochs for both conditions:

the Letters Condition $t(20)=2.12, p<.05$ and the Crayon Condition $t(17)=2.583, p<.05$, but not across the initial two epochs ($p>.1$). This suggests that the stimuli for repeated and non-repeated trials did not influence the search in different ways, and only the repetition generated the effect.

Child Performance: Average accuracy was very high for both conditions (above 97%). The contextual cuing effect was confirmed across two stimulus types in child participants. Response times were combined across the initial and final two epochs for both repeated and non-repeated trials for each participant. Significant differences were found across the final two epochs for both conditions: the Letters Condition $t(19)=4.716, p<.001$; the Crayon Condition $t(19)=2.452, p<.05$ —but not across the initial two epochs ($p>.1$). Comparisons revealed no significant differences in effect size between children and adults. Effect size also did not differ in regards to stimulus type for children or adults. These results, especially when observing no differences in effect size between adults and children, suggest the potential for learning effects in even younger children. The question is whether this effect develops relatively quickly. Experiment 2 directly addresses this developmental question by testing younger children,

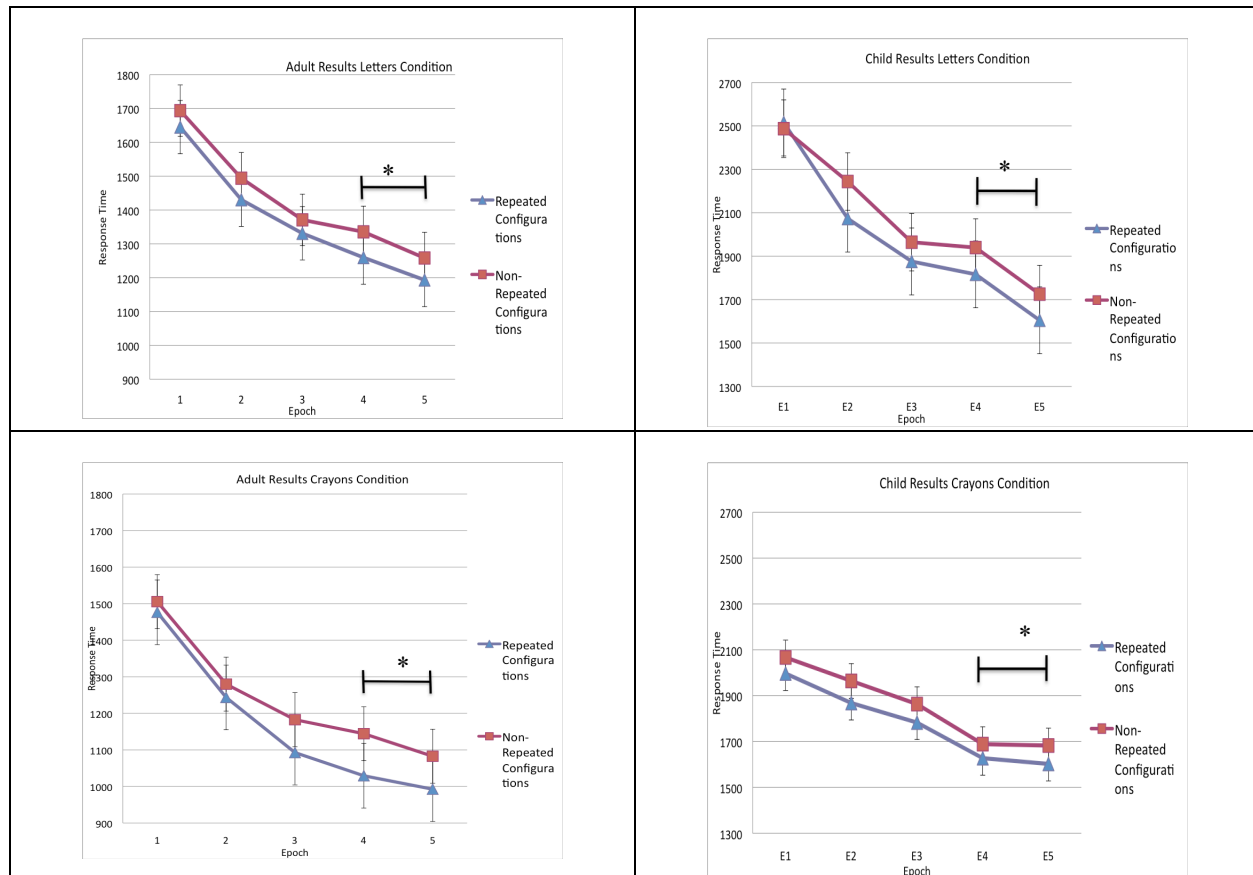


Figure 2: Response time of adult (left) and child (right) participants' search in Experiment 1.

ages 3 to 5.5 years old, with an age appropriate task.

Experiment 2

There is essentially no evidence of early contextual cuing effects with children younger than five years old. However, indirect evidence for such an influence of learning on attention has been documented in toddlers' learning, including noun generalization and category formation (Berger & Aguerra, 2010; Jones, Smith & Landau, 1991; Samuelson & Smith, 1998). Along with a fairly strong effect observed in Experiment 1 with children, developmental work suggests the potential effect even in earlier points of development. Experiment 2 tests preschool children to address this question. We chose the age group of 3 to 5.5 years, the age range with which early ability of attentional control has been accessed and demonstrated as effective attentional control (Carlson & Meltzoff, 2008; Yang, 2004; 2005). We developed a new contextual cuing task that required fewer trials and was presented with child-friendly stimuli.

Method

Participants Fifteen children ages 3 to 5.5 years old (range=37.3 to 66.0 months, $M=58.1$ months) from the Houston area and from Japan participated.

Stimulus Materials Results from Experiment 1 suggested that illustrations of familiar objects elicited the effect as much as the letter stimuli, thus we developed additional child-friendly illustrations of familiar objects (seahorses) for use in Experiment 2. The target stimulus was always an illustrated seahorse with a smiling mouth, and distractors were always illustrated seahorses with no visible mouth. Stimuli were presented on a white background, with a background which consisted of illustrations of bubbles that did not vary between trials (see figure 3).

Procedure The task was computer generated, and stimuli were presented using E-prime. Each target or distractor stimulus was oriented so that the seahorse was facing the right or left side of the display. Responses were key-based, depending upon the orientation of the target. Participants were given 7s to respond. Feedback for incorrect or timed-out responses were given in the form of a low auditory tone and the words "uh oh!" displayed on the screen. The task contained of 24 trials, which were divided for statistical purposes into 6 blocks. Each block contained 2 repeated and 2 non-repeated configurations of stimuli.

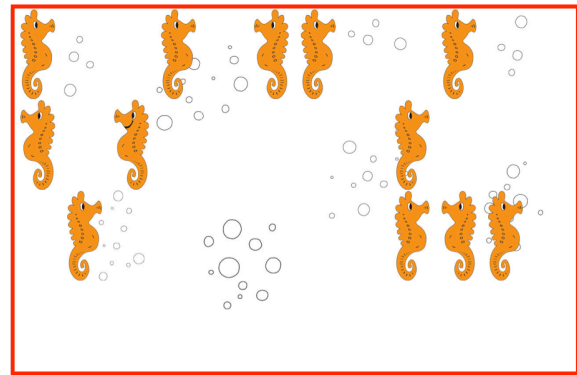


Figure 3: Stimuli used in Experiment 2.

Results

A contextual cuing effect was considered significant if response times over the final three blocks between repeated and non-repeated trials showed significant differences, while the initial three blocks did not differ.

Responses from one child was removed from the analysis due to the low overall accuracy (less than 30%). Trials with response times less than 1s or no response (i.e. failure to respond within the allotted 7s) were also excluded from analysis, leading to the removal of 9.8% of trials. The remaining trials had a response accuracy of 92.2% (trials with incorrect responses were removed from analysis).

A contextual cuing effect was observed in child participants. Response times were combined across the first half (blocks 1-3) and last half (blocks 4-6) of the experiment for both repeated and non-repeated configurations for each participant. Significant differences were found across the last half the experiment ($t(14)=2.371$, $p<.05$), but not the first half ($t(14)=.802$, $p>.1$).

Comparisons between younger (36-54 months) and older (55-72 months) children suggested no differences in effect size between these age groups ($t(5.710)=1.602$, $p>.1$). These results suggest that even preschool children's attention can be cued by the learning of repeated visual context. This is the first demonstration of contextual cuing effects in children younger than 5 years olds.

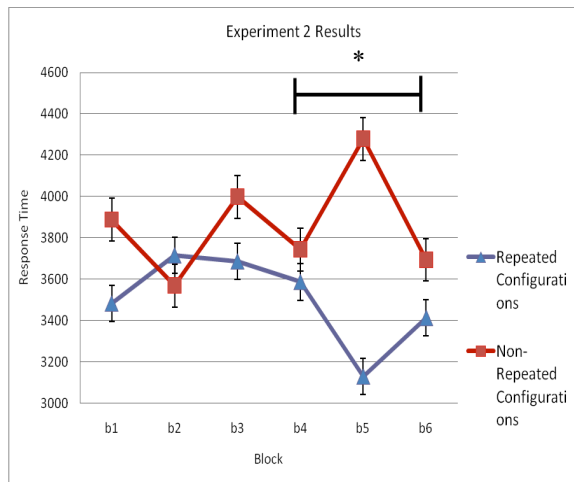


Figure 4: Response times (pre-school children) in Experiment 2.

General Discussion

In this study we replicated the results of Chun and Jiang's (1998) study examining the sensitivity of adults to repeated visual context in a search task, and the results support the effect in children (Barnes, 2008, 2010; Dixon, Zelazo & De Rosa, 2010). The results from Experiment 2, the first demonstration of the effect in pre-school children, indicate that the sensitivity to the contextual information and the learning effect on attention may emerge early in childhood. This effect was demonstrated using a new contextual cuing task with familiar child-friendly illustrated stimuli. Further work is needed to ensure that this task and our choice of stimuli effectively demonstrate contextual cuing across age groups.

How learning effects develop hinges on the mechanisms behind such learning. The mechanisms behind contextual cueing are still unclear. Some researchers (Kunar, Flusberg, & Wolfe, 2008; Peterson & Kramer, 2001) have suggested the contextual cuing effect is a result of effective recognition of the target item (as opposed to finding the target more quickly). A second idea proposed by Ogawa, Takeda, and Kumada (2007) is that contextual cuing is the result of collaboration between the separate processes of facilitation (increased attention toward target area) and inhibition (decreased attention toward non-target areas).

A third idea involves associative learning: contextual cuing occurs as a result of learning regularities and invariants across the scene. This suggests that the effect is based on simple pairwise associations between the distracter locations near the target and the target location (Brady & Chun, 2007; Chun & Jiang, 1998). Chun and Jiang (1998) considered contextual cuing to be the result of learned, memory-based associations between the global configuration of distracters and the

spatial location of the target. These associations interact to form context maps, which are simply memory representations of visual contexts that pair an input (the present image) with representations of past images that match it. In this view, identifying context is equally important for forming and storing the image in memory, especially for children whose cognitive processing is still developing. This hypothesis has important implications for how the effect can be relevant to other forms of basic learning such as statistical learning, and also how this effect can be relevant to the developmental processes of language learning, where early sensitivity to pairwise associations has been demonstrated in infants and children learning words (Fiser & Aslin, 2001, 2002; Saffran, Aslin, & Newport, 1996).

In future work, we will continue to investigate what factors help form associations and thus lead to the effect, and we will look at the possible role of stimuli and distribution effect of repeated contexts. Studying the effect in much younger children is potentially important as well, to further our understanding of the role of attention and memory. Discovering how early such an effect can emerge can increase our understanding of a fundamental learning mechanism and may also reveal the developmental process of linking previously learned associations to the present context.

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