CHILDREN'S SELECTIVE ATTENTION

IN CONTEXTUAL CUEING

by

YINGYING YANG

EDWARD C. MERRILL, COMMITTEE CHAIR
FRANCES A. CONNERS
JASON M. SCOFIELD

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ABSTRACT

In this thesis, 20 younger children (6–7 years old), 20 older children (9–10 years old) and 20 young adults (18–21 years old) were tested using a modified contextual cueing procedure. They located one particular cartoon character (target) among two sets of other cartoon characters (distracters). The main purpose was to investigate how age interacts with selective attention in contextual cueing. Selective attention was manipulated by varying the degree of similarity between two sets of distracters. Specifically, two levels were used: low heterogeneity (distracters were similar to each other), and high heterogeneity (distracters were different from each other). The results suggested that the younger children exhibited impaired implicit learning in the low heterogeneity condition yet intact implicit learning in the high heterogeneity condition. In contrast, the adults demonstrated robust implicit learning in both conditions. The older children performed at an intermediate level, exhibiting intact implicit learning in both conditions yet at a slower acquisition rate in the low heterogeneity condition than the adults. Therefore a clear transition pattern was observed indicating a developmental difference in selective attention in the acquisition of contextual cueing effects. Older children and adults were more capable of exhibiting contextual cueing effects in the absence of a salient feature difference between distracter sets, suggesting an effective selective attention mechanism based on expectancy. Younger children relied more on salient features than spatial co-occurrences in visual search, suggesting a deficit in the selective attention mechanism. This deficit might be related with factors such as difficulty in perceptual grouping, immature selective attention competence, and limited perceptual and working memory capacities.

LIST OF ABBREVIATIONS AND SYMBOLS

HH	High Heterogeneity condition
LH	Low Heterogeneity condition
POF	Proportion of Facilitation
RT	Response time
ADHD	Attention deficit hyperactivity disorder
MD	Mean Difference
SD	Standard Deviation
ns	Not significant
η_p^2	Partial eta squared: Measure of effect size for use in ANOVA
d	Cohen’s d: Measure of effect size for use with t-tests or ANOVA
F	Fisher’s F ratio: a ratio of two variances
M	Mean: the sum of a set of measurements divided by the number of measurements in the set
p	Probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value
t	Computed value of *t* test
<	Less than
=	Equal to

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INTRODUCTION

Imagine you get off work late and have to do some quick grocery shopping for bread. You enter the grocery store, go straight to the aisle where the bread is, grab the brand that you like, pay for it and leave. During this common scenario, I am interested in how you could find the bread aisle so quickly without any hesitation and how you also quickly find the brand you like even if it is mixed with other brands. The first question might be because the bread aisle is always next to the vegetable aisle, which is always very easy to see. You may have implicitly learned this spatial covariance and know that when you see the vegetable aisle the bread aisle is just around the corner. This phenomenon might involve a cognitive behavior called contextual cueing (Chun & Jiang, 1998), which refers to the learning of spatial configurations that can be used to guide attention toward the location of a goal object. The answer to the second question might be that you selectively attend to only the important information related to that particular brand of bread (unique color, size, package, etc) and ignore the irrelevant information that is unrelated to your goal. Therefore it might involve another cognitive activity called selective attention.

These two phenomena are not always independent of each other. Selective attention and contextual cueing actually interact with each other to optimize human cognitive processing (Jiang & Chun, 2001). Adults are very good at selecting the more relevant information in the context and using it to “cue” the location of the goal. Efficient attentional guidance and spatial learning would be valuable for young children as well. Children also need to effectively locate objects in their environment by virtue of selecting the more relevant information in the context.

My thesis was designed to compare how selective attention functions in contextual cueing for children and adults.

Contextual Cueing

Contextual cueing refers to a form of attentional guidance where individuals are drawn to the location of a target object that has been consistently associated with the locations of the non–target objects in the visual environment. Chun and Jiang (1998) developed the first paradigm to study contextual cueing. In their study, participants were shown displays containing a target (the letter T rotated 90 degrees) and several distracters (the letter L rotated 90 degrees). They were required to identify which direction the target T was pointing. Unbeknownst to the participants, some of the configurations of the distracters were consistently associated with the target location across trials and thus always predicted the location of the target (predictable condition). In contrast, some configurations of the distracters were random from trial to trial (unpredictable condition). After some exposure to the displays, response times were much faster in the predictable than unpredictable condition. Recognition tests conducted after the experiments indicated that the participants could not distinguish between the predictable and unpredictable configurations, thus demonstrating that contextual cueing was implicit in nature.

Some perceptual factors can impact contextual cueing. For example, Olson and Chun (2002) suggested that physical proximity was such a factor and simply learning half of the whole configuration was enough for contextual cueing (see also Jiang &Wagner, 2004). Furthermore, Brady and Chun (2007) used a mathematical model to illustrate that as few as two distracters that were close enough to the target could elicit contextual cueing. Other factors that affect contextual cueing were object identity (Endo & Takeda, 2004), good continuation (Fuggetta, Campana, & Casco, 2007), spatial arrangement of color (Huang, 2006), and semantic properties of distracters

(Goujon, Didierjean, & Mareche, 2007). Hence, contextual cueing is the product of robust implicit learning and can be elicited by a variety of visual characteristics that have predictive power on the location of the target.

Contextual Cueing and Attention

Attention and contextual cueing are integrally related. In one sense, contextual cueing guides attention. That is, attention is directed to the target on the basis of memory for invariant spatial configurations. On the other hand, attention is necessary for implicit learning to take place. Individuals must selectively attend to and learn the invariant aspects of the spatial environment for contextual cueing to be evidenced. Hence, the relation between contextual cueing and attention is inherently bidirectional.

Jiang and Chun (2001) indicated that selective attention could be directed to some distracters in a display but not others. They presented half of the distracters in the same color as the target (i.e., red) and half in a different color (i.e., green). Participants were also given the clear instruction to attend only to the relevant ones (i.e., red) instead of all the items. Results indicated that participants displayed significant contextual cueing when both the red and green distracters predicted the red target (both-old condition), when only the red distracters predicted the red target and the green distracters were random (attended-old condition) and when only the green distracters predicted the red target and the red distracters were random (ignored-old condition). They then made the L distracters look more similar to the target T assuming that it would take more attention to locate and identify the target thereby leave less attention to process the ignored distracters. In contrast to the previous easy condition, the contextual cueing in the ignored–old condition disappeared in the difficult condition. Yet a robust contextual cueing still existed in the attended-old condition. Therefore this research demonstrates a key role selective attention plays in contextual cueing (see also Geyer, Shi, & Müller, 2010).

Contextual Cueing and Development

As a form of implicit spatial learning, contextual cueing has important ecological importance. We may not recall the spatial layouts of our familiar environment exactly but it is much easier to find things in familiar than strange environment. This skill is also important for children. However, the extant research regarding whether children can display contextual cueing is equivocal.

Vaidya and her colleagues (2007) compared school-aged children (6–13 years old) with college students using the classic paradigm (Chun & Jiang, 1998). Unlike the adults, the children did not display contextual cueing. The researchers considered the possibility that the classic paradigm might be so difficult that it impeded the expression of implicit learning in children. They reasoned that the more difficult the task was, the less likely the participants were to show implicit learning. However, the adults still exhibited contextual cueing even when they had very slow RT baselines as the children had in the initial experiment. Hence the level of difficulty alone could not explain why children did not display contextual cueing. Vaidya and her colleagues concluded that children's immaturity of medial temporal lobes might account for their deficiency in contextual cueing (see also Couperus, 2004).

Contrary to the previous study, Dixon and his colleagues (2010) found intact contextual cueing in school-aged children (5–9 years old). They suggested that the previous experiments had not been engaging and interesting to the children. Therefore, they designed an age-appropriate version of the contextual cueing task. Children were asked to touch a red cartoon fish (the target) among a set of red and blue cartoon fish (the distracters). The researchers reasoned that the action of touching would help the children pay more attention to the spatial relations relative to the classic paradigm. Moreover, contextual cueing was still considered to be implicit because the children could not recognize the predictable displays in the recognition test. Merrill et al. (2010) found similar results after implementing a different modification of the contextual cueing task. They also suggested that implicit learning was relatively stable across children, young adults and older adults. Barnes and colleagues (2008, 2010) reported that even children with ADHD and autistic-spectrum disorder (ASD) could exhibit contextual cueing effects.

Statement of Problem

The purpose of my thesis was to address how selective attention modulates contextual cueing in children and adults. Specifically: what happens when only some of the distracters in the display predict the location of the target? How do participants determine which distracters are relevant to the target location? I hypothesize that two different selective attentional processes function in contextual cueing: “feature-based” selective attention and “expectancy-based” selective attention. Feature-based selective attention occurs when attention is directed to the relevant distracters that share salient features with the target. Expectancy-based selective attention occurs when, with repeated exposure, distracters that are initially perceived as similar are differentially attended due to some distracters predicting the location of the target and others not predicting it.

For “feature-based selective attention,” participants direct their attention on the basis of salient features prior to the establishment of contextual cueing. These features facilitate visual search because the participants can rely on them to limit their attention to the distracters that are perceptually similar to and even sharing defining attributes with the target. The subset of the relevant distracters is therefore regarded as a "pool" of the target candidates. Some very basic perceptual features such as color, size and shape can elicit feature-based selective attention that undergoes an explicit top-down process. The classic paradigm (Jiang & Chun, 2001) is an example of research based on this attentional process, wherein the subjects consciously knew to search among the relevant items (i.e., red) and ignore the irrelevant items (i.e., green) to locate the target (red) faster. Thus, feature-based selective attention is used to process basic features of objects at an early stage of processing and it is explicitly directed to the relevant features of the distracters.

In contrast to the above mechanism, what I am calling "expectancy-based selective attention" requires participants to direct their attention on the basis of the spatial co-occurrence of the target and a subset of distracters. A group of distracters (not necessarily all) are consistently paired with the location of target. As an implicit top-down process, the expectancy-based selective attentional process is presumed to identify predictable information within the context and generate an expectation of where the target will be. Attention is guided on the basis of developing such an expectation. Whereas feature-based selection occurs at an early stage, expectancy-based selection can only occur after participants have been exposed to repeated configurations for a number of trials. Hence, expectancy-based selective attention does not come into play until contextual cueing is established. This selective attentional process is also very robust in that a small amount of information can be enough to guide attention. For example, Brady & Chun (2002) found that just two predictive distracters close to the target could cue implicit spatial learning.

One specific purpose of the research proposed here was to study whether feature-based selective attention enhances expectancy-based selective attention to different degrees in children and adults. Feature-based selective attention can facilitate expectancy-based selective attention when the distracters that share the defining features with the target also predict the target location. For instance, participants could exhibit manifest contextual cueing effects when the distracters that attract feature-based selective attention (being red) also captivate expectancy-based selective attention (predicting the target location) (Jiang& Chun, 2001). It is reasonable to expect that contextual cueing would be faster when there are salient features to identify the distracters that co-vary with the target as opposed to when there are not. However, the impact of salient features may be more prevalent for children than adults. Hence, there should be little difference between children and adults when feature-based selective attention is easily accessible. Children, like adults, know consciously that they should find the target faster if they search among the distracters that are similar to the target. However, when feature-based selective attention is not available, children may require more exposure to the repeated configurations to exhibit contextual cueing if they exhibit it at all. It may be harder for children to find pure spatial correlations without any notable features. Hence, a deficiency in expectancy-based selective attention may result in children's heavy dependence on feature-based selective attention in order to exhibit contextual cueing.

I also tested two groups of children. One group included 6–7 year old children and the other group included 9–10 year old children. Research has shown that children between these ages undergo dramatic changes in attention and perception. For example, Korkman, Kemp, and Kirk (2001) assessed attention and executive functions, language, sensorimotor functions, visuospatial functions, and memory and learning for 800 children aged 5 to12 years old. With respect to attention and executive functions, the authors found that developmental changes were greatest between 5 and 8 years old and slowed rather dramatically between 9 and 12 years old. Therefore it seems that major features of attentional control might be achieved by 9 years old.

Trick and Enns (1998) also indicated that a large portion of the developmental change in visual search occurred between the ages of 6 and 10. In a conjunction search task, mean RT slope for target present trials were 32 ms per item for 6 year olds, who were significantly less effective than 10 year olds (13 ms per item) who were very similar to the 22 year olds (9 ms per item). With respect to contextual cueing, Couperus (2011) suggested that 10-year-old children are able to employ selective attention in the acquisition of contextual cueing effects using the classic paradigm. Even though Dixon et al. (2010) did find intact contextual cueing in children as young as 5 to 9 years old, their task did not require the efficient use of selective attention. Hence, it is still not known whether children younger than 10 years old are also able to employ selective attention in contextual cueing tasks. The current study was designed to focus on this issue. I further expected that the choice of 6–7 and 9–10 year old children as participants would allow me to observe age related differences in performance during a period in which changes are highly likely to occur.

My experiment was also designed to evaluate the relation between age and feature vs. expectancy-based attentional mechanisms in the acquisition of contextual cueing. For this study, the ability to use feature- and expectancy-based attention was manipulated by the degree of similarity between two sets of distracters (with two conditions: high heterogeneity vs. low heterogeneity). Both conditions actually resembled the attended-old condition in Jiang and Chun's classic paradigm (2001) in that only one subset of distracters predicted the target. In the high heterogeneity (HH) condition, the two subsets of distracters were very different to each other. One subset was more similar to the target than the other subset. Hence, there were strong and useful explicit cues available and participants should easily and effectively deploy their attention to the distracters that are more similar to the target (these distracters also predict the target). In the HH condition, both feature-based and expectancy-based selective attention should be able to facilitate visual search. In the low heterogeneity (LH) condition, the two subsets of distracters were very similar to each other and very similar to the target. Although participants can group all distracters into the two subsets, they cannot direct attention to one particular subset at first glance. Hence, in this condition only expectancy-based selective attention is available. To summarize, the magnitude of explicit cues that can elicit feature-based selective attention decreased from the HH to LH conditions. Meanwhile the implicit cues that can elicit expectancy-based selective attention did not differ across the two conditions.

I expected that contextual cueing effects would be acquired more easily in the HH condition than in the LH condition for all participants. To the extent that this was the case, I expected to see a greater difference between the repeated and control conditions for the HH relative to the LH displays. This could occur in either or both of two ways. Participants might exhibit larger contextual cueing effects overall for the HH condition or they might exhibit contextual cueing effects at a faster rate for the HH condition. With respect to development, I expected to see a larger developmental difference in the LH condition that in the HH condition. More specifically, I expected that adults would show the same magnitude of contextual cueing in both HH and LH conditions. In contrast, I expected both the younger and older children would show relatively intact contextual cueing in the HH condition, and perhaps not differ from adults. However, especially the younger children were expected to exhibit a deficiency in contextual cueing in the LH condition and perform significantly worse than the older children and the adults.

METHODOLOGY

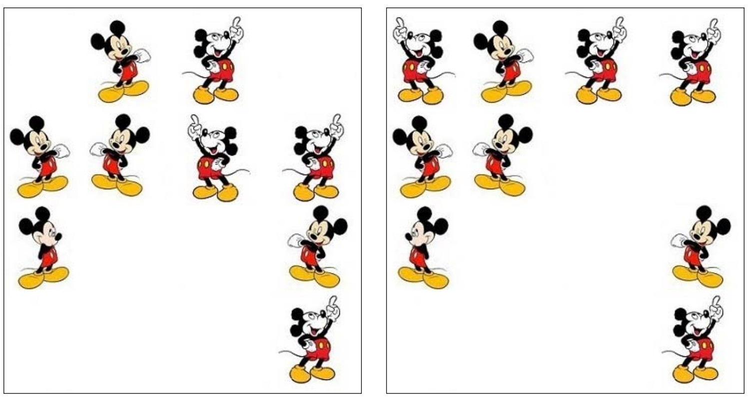
Participants

Twenty-one college students were recruited from Introductory Psychology Classes at the University of Alabama. One male participant had an error rate of more than 5% and his data were not included in the analyses. Child participants were recruited from local churches and home school programs. Twenty-two younger children (6–7 years old) and 20 older children (9–10 years old) were enrolled in the study. However, two of the younger children did not complete the task. They could not find where the target was or/and were not able to differentiate which response corresponded to which direction the target Mickey was facing. The remaining sample included 20 participants in each of the three groups. The younger children (6 males and 14 females) had a mean age of 6.86 years old (*SD*=0.64). The older children (10 males and 10 females) had a mean age of 9.77 years old (*SD*=0.56). The college students (4 males and 16 females) were approximately 18–21 years old. All child participants were given two $5 gift cards to compensate for their time and cooperation. College students received course credit for participating. Informed consents from the parents of the children as well as assents from the children and college students were obtained. All the recruiting procedures followed the guidelines of the University of Alabama Institutional Review Board.

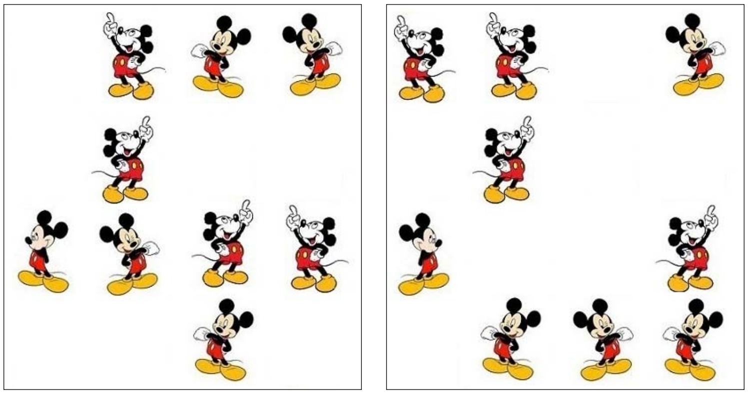
Material

Experimental materials were displays of cartoon characters presented on a computer monitor. Each display included nine characters (one target and eight distracters). The locations of all the distracters were randomly selected from an invisible 4×4 matrix. Each cartoon character, including the target, faced either left or right. In the LH condition, all of the cartoon characters were pictures of Mickey Mouse. Mickey Mouse designated as the target had both hands behind his back. There were four distracters of Mickey Mouse with a pointing finger and four distracters of Mickey Mouse with a fist. Hence, both subsets of distracters looked similar to the target in the LH condition (see Figure 1 (A) and Figure 1 (B)). In the HH condition, the displays included the same target Mickey, four Mickey distracters (with the fist), and four pictures of “Jerry” that served as distracters (see Figure 2 (A) and Figure 2 (B)). Therefore in the HH condition, one subset of distracters was similar to the target and the other was not.

(A). Repeated displays:



(B). Control displays:



(C). Recognition test display:

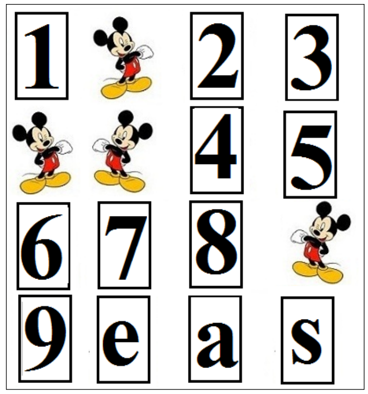
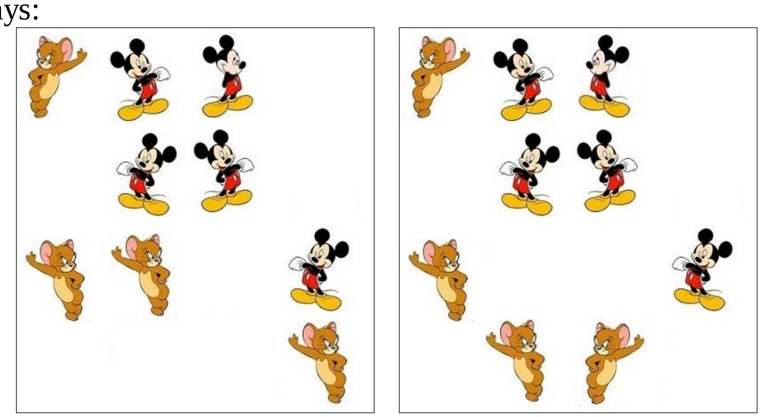
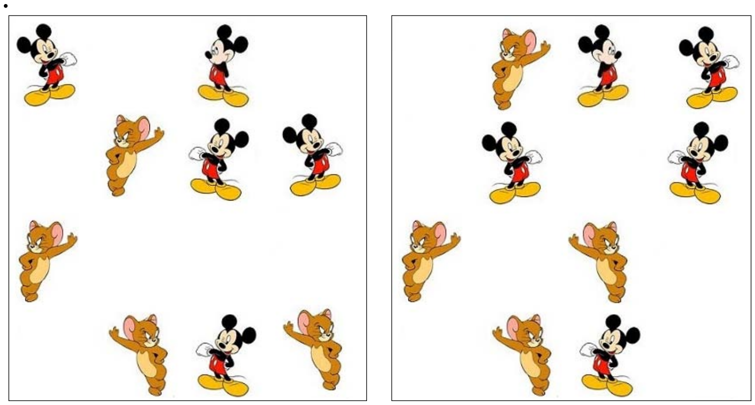


Figure 1. Experimental Stimuli in the low heterogeneity (LH) condition. The target is Mickey with both hands behind his back. (A) In the repeated displays, both the locations of the target and the Mickey cartoons with a fist were repeated while the locations of Mickey pointing up were random. (B) In the control displays, the locations of all the distracters varied from trial to trial while the target location remained the same. Here in the examples, both the control displays and the repeated displays have the same target locations. (C) In the recognition test displays, only the locations of Mickey with the fist in the repeated displays were presented. Here in the examples, the repeated displays and the recognition test display have the same spatial layouts of the predictive subset of Mickey.

(A). Repeated displays:



(B). Control displays:



(C). Recognition test display:

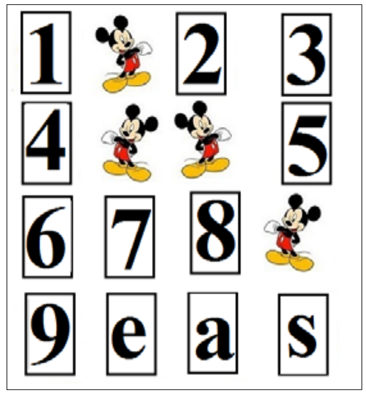


Figure 2. Experimental stimuli in the high heterogeneity (HH) condition. The examples here are presented in the same manner as the ones in Figure 1.

For each distracter condition four different displays were constructed for use as repeated displays at the beginning of the experiment. Each of these repeated displays was consistently paired with one target location and the target locations in these four repeated displays were evenly arranged in four quadrants. The repeated displays, however, did not predict the response in that the target Mickey in each repeated display could be facing either left or right. In each repeated display of both distracter conditions, the locations of one set of distracters (Mickey pointing) were invariant (predictive subset), but the locations of the other set of distracters (Mickey with a fist or Jerry) varied from trial to trial (unpredictive subset). I produced 160 total repeated displays such that 40 displays included each of the four configurations of the predictive distracters, with the unpredictive distracters being in random locations across the 40 displays. There were two kinds of new displays constructed for each distracter condition. In what I call new-location displays, all distracters varied their locations from trial to trial and the targets were in different locations than the targets in the repeated displays. There were 12 different possible target locations in the 48 displays that were produced. The purpose of the new-location displays was to prevent participants from developing the strategy of only memorizing and checking the 4 possible target locations associated with the repeated displays. In what I call control displays, all the distracters varied their locations from trial to trial but the targets were in the same locations as the targets in the repeated displays. There were also 48 displays of this type. Therefore any difference between the control and repeated displays would not be attributable to differences between target locations in the repeated and control displays.

Design & Procedure

The independent variables in the experiment were Age (younger children, older children and adults), Predictability (repeated and control), Distracter condition (HH and LH), and Presentation block (1 through 10). Predictability, distracter condition, and presentation block were manipulated within subjects. The dependent variable was response time to identifying which direction the target was facing. All participants completed both distracter conditions. Each condition was comprised of 10 blocks. Blocks 1–4 and 6–9 were considered learning phases for each distracter condition. In each block of the learning phases, there were 20 trials that included 16 trials of repeated displays and 4 trials of new-location displays. Within the 16 repeated displays, the four original repeated configurations were presented 4 times. For the new-location displays the target locations were both different from the locations in the repeated displays and from each other. The fifth and tenth blocks were test blocks. For each test block there were 52 trials that included 24 repeated displays, 24 control displays and 4 new-location displays. The control displays had the same target locations as the repeated displays. All trials were randomized within each block. For each type of display (repeated, control and new-location), there were always equal numbers of left and right responses within each block. Participants finished 264 trials in total for each distracter condition.

Participants were tested individually. All experiments were programmed using Superlab 4.5.2 Software. Response times and errors were recorded automatically. Prior to the start of each condition the participants were shown one model display and given instructions to find the target Mickey. They were told to press “S” using the left hand if the target Mickey was facing left and press “L” using the right hand if the target was facing right. Participants had no trouble complying with instructions. Speed and accuracy were emphasized. To finish both conditions, adults required about 25 minutes, older children 40–50 minutes and younger children 50–60 minutes. Breaks were included for the children to minimize issues with fatigue. The presentation order of two distracter conditions was counterbalanced within each age group.

Each trial started with the fixation cross which lasted for 1000 ms, followed by the target display. Each trial ended when the participant made a response. The next trial began automatically 1000 ms later. If participants made an error or did not respond within 10 seconds, a short beep was heard indicating an error was made. At the end of each block, there was a 10-second mandatory break (participants could take longer if they desired), after which participants could press any key to continue. There was also an optional longer break of up to 5 minutes after the completion of the first distracter condition. The children were given a $5 gift card each time they finished a distracter condition.

A memory test followed the completions of both distracter conditions for a sample of adult and older child participants. The purpose of the memory test was to evaluate explicit memory for the target locations. Eighteen adult participants and eight older children finished the recognition memory test. Two adult participants did not complete the memory test due to a technical failure. I assumed that if adults could not explicitly remember the repeated displays, children could not either. However, to evaluate this assumption, I still conducted the recognition memory test with eight randomly selected older children. Adults were shown repeated displays in which only the four predictive distracters were presented, with all the other locations occupied by numbers and letters (see Figure 1 (C) and Figure 2 (C) for examples of memory test displays). They were asked to indicate where they thought the target Mickey should be if he was in the picture by pressing the number or letter corresponding to that location. After responding to each display, they were also asked how confident they were regarding their judgment on a 1 to 6 scale (1 is just guessing and 6 is absolutely certain). They viewed eight displays in total, four for each distracter condition. Children were shown the same eight repeated displays and asked to indicate where the target Mickey should be, but did not provide confidence judgments.

RESULTS

Preliminary Analyses

Errors were extremely rare, with no age group in either distracter condition exhibiting error rates of more than 4%. Therefore error rate was not subjected to further analysis.

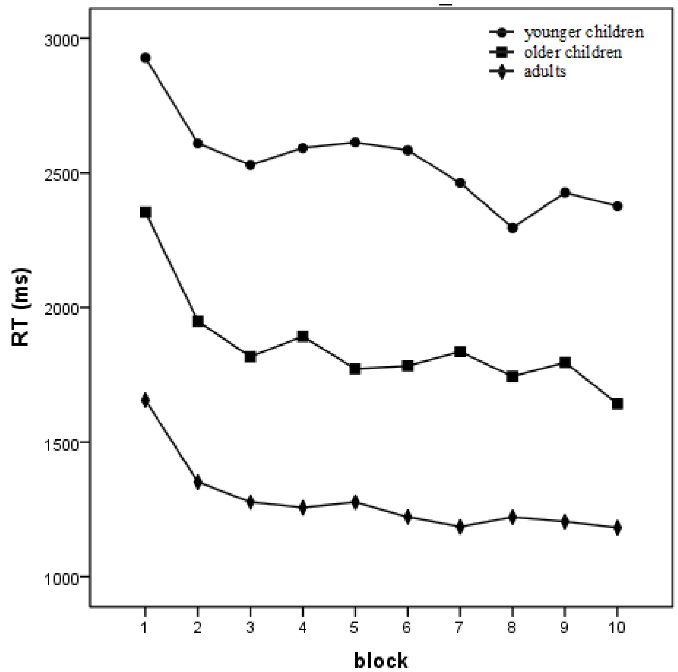
For the recognition memory test of explicit knowledge of target locations, participants selected which of 12 possible locations they thought the target would be when given the locations of the four predictable distracters. Hence, chance performance in this task was 1out of 12 over the eight recognition memory items (.67 overall). The adult participants made on average .72 correct responses (*SD*=1.18), which did not significantly differ from chance (t (17) =.12, ns). When I counted the responses in the same quadrant as correct responses, the adults made an average number of 2.28 correct responses (*SD*=1.41), which did not significantly differ from chance level of 2.25 (t (17) =.08, ns). The average confidence score associated with their responses was 2.14 (*SD*=0.95) out of 6.0 indicating that they were not confident in their responses. The older children made on average 1.0 correct responses (*SD*=1.06) when judging exact target location, which did not significantly differ from chance (t (7) =.87, ns). In addition, responses in the same quadrant for the children yielded an average number of 2.63 correct responses (*SD*=1.18), which also did not significantly differ from chance (t (7) =.89, ns). The children did not provide confidence ratings. I therefore concluded that neither the adult or older child participants explicitly learned even the relative locations of the targets in the repeated displays. We assumed that the younger child participants could not explicitly learn the target locations if the adults and older children did not.

Analysis of Response Times

The primary dependent variable was response time to identifying which direction the target was facing. Mean response times (RTs) were calculated for the repeated displays (in all blocks) and the control displays (in blocks 5 and 10) for each participant in the HH and LH conditions. RTs of trials in which an error was made were not included in the calculations. Due to the fact that this thesis was not interested in new-location displays which were not related to contextual cueing and that there were only 4 such displays in each block, new-location displays were not subjected to analysis.

General learning effects. First, I examined RTs of the repeated displays over the 10 blocks as a general reflection of practice. These data are presented in Figure 3. A 3 (Age: younger children, older children, adults) x 2 (Distracter condition: HH vs. LH) x 10 (Block) ANOVA with repeated measures on distracter condition and block was conducted. There was a main effect of age, F (1, 57) = 1372.52, $p < .001$, $\eta_p^2 = .65$, with adults (M=1378.76) responding significantly faster than older children (M=1920.84) who were significantly faster than younger children (M=2732.21). There was a main effect of distracter condition, F (1, 57) = 29.62, $p < .001$, $\eta_p^2 = .34$ with participants responding faster to the HH condition (M=1894.77) than the LH condition (M=2120.44). There was also a main effect of block, F (9, 513) =31.60, $p < .001$, $\eta_p^2 = .73$, with participants responding faster with increased practice. No significant interactions were found.

A. HH condition



B. LH condition

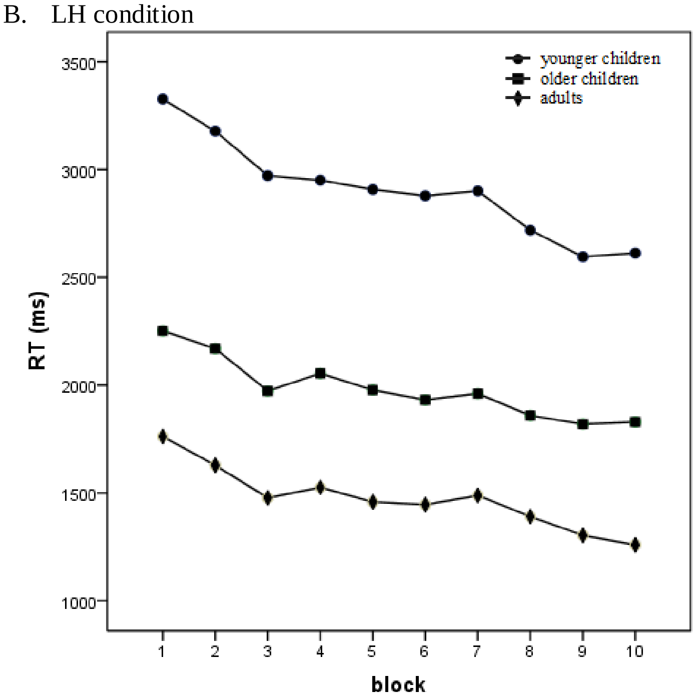


Figure 3. RTs of repeated displays as a function of block and age group.

Contextual cueing effects. I used two approaches to study the contextual cueing effects. First, I evaluated group differences between mean RTs for the repeated and control displays. Second, I calculated the proportion of facilitation (explained later) observed for each participant in each condition and subjected these values to analysis. These analyses are reported separately.

I first entered RTs for the repeated and control displays into a 3 (Age: younger children, older children, adults) x 2 (Predictability: repeated vs. control) x 2 (Distracter condition: HH vs. LH) x 2 (Exposure: block 5 vs. block 10) four-way ANOVA with repeated measures on the last three factors. The main effect of age was significant, F (1, 57) = 1197.84, $p < .001$, $\eta_p^2 = .61$, with adults (*M*=1340.03) responding faster than older children (*M*=1851.19) who then being faster than younger children (*M*=2632.93), indicating RT differences related with age. There was a main effect of predictability, F (1, 57) = 15.99, $p < .001$, $\eta_p^2 = .22$, with faster responses in the repeated displays (*M*=1909.14) than the control displays (*M*=1973.61), indicating a significant contextual cueing effect. The main effect of distracter condition was significant, F (1, 57) = 16.93, $p < .001$, $\eta_p^2 = .23$, with participants responding faster to the HH condition (*M*=1855.59) than the LH condition (*M*=2027.15). This indicates that it was more difficult to search for the target in the HH than LH condition due to the different levels of distracter heterogeneity. There was also a main effect of exposure, F (1, 57) = 51.79, $p < .001$, $\eta_p^2 = .48$, with faster responses in block 10 (*M*=2013.79) than block 5 (*M*=1868.96), indicating faster RTs with more practice.

There was a significant interaction between exposure and age, F (2, 57) = 3.23, $p = .047$, $\eta_p^2 = .10$. Planned comparisons suggested that younger children showed a larger difference between block 5 and block 10 (mean difference (*MD*) =217.00, $p < .001$) than the other two age groups (for older children, *MD*=113.72, $p < .001$; for adults, *MD*=103.79, $p < .001$). There was a significant interaction between exposure and predictability, F (1, 57) = 6.03, $p = .017$, $\eta_p^2 = .096$, with a significant difference between the repeated and new displays in block 10 (*MD*=103.74, $p < .001$), but not block 5 (*MD*=25.21, ns). Hence, contextual cueing effects were not observed until the second block across all the participants. The interaction between predictability and age was marginally significant, F (2, 57) = 2.79, p=.070, $\eta_p^2 = .09$, with both older children and adults responding faster to the repeated than control displays (*MD*=91.28, p=.002 and *MD*=91.53, p=.002, separately) yet younger children not doing so (*MD*=10.61, ns). Only adults and older children showed contextual cueing effects whereas younger children did not. The interaction between distracter condition and exposure was also marginally significant, F (1, 57) = 3.70, p=.059, $\eta_p^2 = .06$. Participants responded faster in the HH than LH condition in both block 5 (*MD*=211.90, $p < .001$) and block 10 (*MD*=131.22, p =.007). No other interactions were significant.

Because the focus of my research was on contextual cueing, I subsequently assessed whether each age group exhibited faster RTs to the repeated displays than the control displays in each condition (using one tailed tests). Table 1 presents the raw RTs in each condition. Table 2 presents the mean difference between RTs for the repeated and control displays in each condition.

Table 1

Mean RTs in different conditions (SD in parentheses)

Age	HH condition				LH condition			
	Block 5		Block 10		Block 5		Block 10	
	control	repeated	control	repeated	control	repeated	control	repeated
younger children	2609.80 (613.64)	2613.42 (752.00)	2510.0 (667.81)	2376.50 (636.74)	2834.49 (695.33)	2907.99 (792.58)	2598.64 (745.66)	2612.58 (848.82)
older children	1856.09 (419.57)	1772.28 (430.68)	1790.18 (421.85)	1642.37 (390.30)	2025.77 (356.84)	1977.93 (421.97)	1915.16 (292.65)	1829.48 (359.81)
adults	1318.24 (184.33)	1277.20 (215.99)	1318.70 (242.17)	1182.31 (210.15)	1513.97 (289.03)	1458.28 (282.91)	1392.26 (229.23)	1259.25 (189.58)

Table 2

Mean difference (RT of control displays - RT of repeated displays) in different conditions

Age	*MD* in HH condition		*MD* in LH condition	
	Block 5	Block 10	Block 5	Block 10
younger children	–3.62	133.50**	–73.50	–13.94
older children	83.81**	147.81**	47.84	85.68*
adults	41.04*	136.39**	55.69*	133.00**

Note: **p< .05 (indicating significantly longer RTs to the control than repeated displays). * denotes marginally significant p value.

For younger children, a significant contextual cueing effect was only observed in block 10 of the HH condition (*MD*=133.50), *t* (19) =1.86, *p*=.04, Cohen's *d*=0.42. For older children, significant contextual cueing effects were observed in block 5 of the HH condition, *MD*=83.81, *t* (19) =2.29, *p*=.017, Cohen's *d*=0.51, and block 10 of the HH condition, *MD*=147.81, *t* (19) =3.10, *p*=.003, Cohen's *d*=0.70. They also exhibited a marginally significant effect in block 10 of the LH condition, *MD*=85.68, *t* (19) =1.33, *p*=.099, Cohen's *d*=0.31. For adults, a significant contextual cueing effect was observed in block 10 of the HH condition, *MD*=136.39, t (19) = 4.54, $p < .001$, Cohen's d=1.04, and a marginally significant contextual cueing effect was observed in block 5 of the HH condition, *MD*=41.04, t (19) =1.60, p=.063, Cohen's d=0.37. They also showed a significant contextual cueing effect in block 10 of the LH condition, *MD*=133.00, t (19) = 4.58, $p < .001$, Cohen's d=1.07, and a marginally significant contextual cueing effect in block 5 of the LH condition, *MD*=55.69, t (19) =1.72, p=.051, Cohen's d=0.39.

To summarize, the results first suggested overall RTs decreased as the ages of participants increased. The manipulation of distracter condition was also successful in that RTs in the LH condition were longer than those in the HH condition. Added practice, as evidenced by the main effect of exposure, decreased responses times between blocks 5 and 10. However, of greater interest were the interactions of exposure with the other three factors (Exposure x Age, Exposure x Predictability, and Exposure x Distracter condition). Specifically, younger children benefited more due to more practice in that their RTs decreased the most from block 5 to block 10 although the other two age groups also got faster over time. More exposure also presented an advantage for the more difficult condition indicating that RTs decreased more from block 5 to block 10 in the LH condition than the HH condition. Moreover, in contrast to previous studies (e.g., Jiang & Chun, 2001) which implied that less than 20 exposures would be enough to elicit contextual cueing, these studies indicated that many more exposures to the displays may be necessary for contextual cueing to be observed under some conditions, especially when only a portion of the context predicts the target location.

Of major importance, the analyses indicated significant contextual cueing effects. A closer inspection of the data indicated that the rate of acquisition and the magnitude of contextual cueing were different for the different age groups. The adults showed roughly equivalent and significant contextual cueing in the HH and LH conditions. This revealed that they implicitly learned the spatial associations between the target locations and the spatial layouts of the distracters. Additionally, it indicated their competence to attend to and remember the predictable information presented in the repeated displays even when salient differences between stimuli were not available (as in the LH condition). In contrast, the younger children did not exhibit contextual cueing in the LH condition at all and they only exhibited contextual cueing in the HH condition at block 10 (after 44 exposures per display). Not surprisingly, the performance of the older children fell in between that of the adults and younger children. They exhibited a contextual cueing effect at a faster rate (by block 5) in the HH condition than did the younger children. However, they exhibited a contextual cueing effect at a slower rate (not until block 10) in the LH condition than did the adults. These data reflect a clear developmental trend of contextual cueing effects in two distracter conditions.

To compare the magnitude of contextual cueing effects across different age groups, I also calculated the proportion of facilitation (POF) as an index of contextual cueing effects based on the following formula (Jiang Song, & Rigas, 2005):

POF= (RT of control displays – RT of repeated displays) / RT of control displays

The advantage of using this formula is that it takes into account the RT baselines related with age (for examples of other approaches, see Pritchard & Neumann, 2009). It is especially crucial in my studies because the three age groups had significantly different RT baselines. For instance, although children might show a larger RT difference between the repeated and control displays than did adults, their overall RTs were also longer than adults' RTs. In that case, a larger RT difference between the repeated and control displays may not necessarily mean a larger contextual cueing learning outcome for children. POF would provide more accurate information about the extent to which learning was facilitated after accounting for motor response and processing speed differences related with age.

I conducted a 3 (Age: younger children, older children, adults) x 2 (Distracter condition: HH vs. LH) x 2 (Exposure: block 5 vs. block 10) ANOVA on the POF scores treating distracter condition and exposure as within-subjects variables. There was a main effect of age, F (2, 57) = 6.29, p=.003, η_p^2 = .18, with adults having the largest POF (M=.063) followed by older children (M=.047) and younger children (M=.005). There was also a marginally significant main effect of distracter condition, F (1, 57) = 3.33, p=.073, η_p^2 = .06, with a larger POF in the HH condition (M=.050) than the LH condition (M=.026). There was a significant main effect of exposure, F (1, 57) =7.14, p=.010, η_p^2 = .11, with a larger POF in block 10 (M=.058) than block 5 (M=.018). No interactions were significant. See Table 3 for Means and Standard Deviations of POF.

Table 3

Mean POF in different conditions (SD in the parentheses)

Age	Block 5 of HH	Block 10 of HH	Block 5 of LH	Block 10 of LH
younger children	.004(.114)	.047(.125)	-.027(.127)	-.005(.116)
older children	.044(.090)	.077(.097)	.024(.105)	.042(.145)
adults	.031(.088)	.098(.100)	.034(.091)	.090(.081)

Note: Three decimals are used here.

Several conclusions can be drawn from the three significant main effects observed in the analysis of POF. First, the facilitation effects were larger for adults than for younger children, with older children again performing at a level between these two groups. This is reasonable given that adults exhibited significant or marginally significant contextual cueing effects in all four conditions (see Table 2) while younger children only showed a significant contextual cueing effect in one condition and older children showed significant or marginally significant contextual cueing effects in three conditions. Second, contextual cueing was greater in the HH condition than the LH condition. This is likely due to younger children exhibiting significant contextual cueing effects in the HH condition but not in the LH condition, and older children exhibiting significant contextual cueing effects in both exposure conditions of the HH condition but not in the shorter exposure condition of the LH condition. I also found that contextual cueing effects continued to accrue from block 5 (22 exposures of each display) to block 10 (44 exposures of each display) for the stimuli used in this experiment. This result contrasts with other studies of contextual cueing that often find contextual cueing after just 5–10 exposures (Chun & Jiang, 1998).

DISCUSSION

I designed an age-appropriate version of the contextual cueing paradigm (Jiang & Chun, 2001) in order to investigate children's selective attention in contextual cueing. Two distracter conditions were used: HH condition in which the distracters were of two similar subsets, and LH condition in which the distracters were of two dissimilar subsets. Adults exhibited contextual cueing effects in both conditions. Older children exhibited contextual cueing effects in both conditions yet at a relatively slower learning rate in the LH condition than adults. Younger children only showed a contextual cueing effect in block 10 of the HH condition. In the discussion that follows, I first address the observation of contextual cueing effects in the LH condition for the adult participants. I then discuss the observation of developmental differences in contextual cueing, with a focus on children's strengths and weaknesses in contextual cueing effects associated with the LH and HH conditions.

Contextual Cueing Effects in the LH Condition

One of the important questions addressed by my thesis was whether or not it was possible to obtain contextual cueing effects when distracters that do and do not predict the location of the target are highly similar. My results indicate that in addition to conditions in which the predictive distracters are distinctive from the unpredictive distracters as shown in Jiang and Chun (2001), observers are also capable to acquire contextual cueing when the predictive distracters physically resemble the unpredictive distracters. It also appears that the acquisition of this effect was implicit because in the recognition test participants were still not aware that some displays had been repeated even after repeatedly seeing the same display 44 times. There are several possible variables that help to explain how the contextual cueing effect in the LH condition was accomplished. The most likely ones may be grouping distracters into two subsets, constructing context maps, and guiding search through feature-based and expectancy-based selective attention. These are discussed briefly in the next section. A triangle model that examines contextual cueing while systematically varying the degree of similarities among the target and the distracters is also included.

Grouping. One important factor that may enhance contextual cueing effects in the LH condition involves separating the distracters into two subsets (Jiang & Chun, 2001; Goujon, et al., 2007). Recently, Rausei and colleagues (2007, Experiment 2) presented participants repeated displays containing a target T and two subsets of similar L-shaped distracters. In their study, however, both subsets predicted the location of the target in the acquisition phase. During a subsequent test phase, participants showed fastest RTs to the test displays in which both subsets predicted the target, followed by RTs to the test displays in which only one subset predicted the target (which specific subset predicted the target did not matter). RTs to the control displays in which none of the distracters predicted the target location were the slowest. Although focusing on different questions than the current study, the results of Rausei et al. (2007) did forecast the possibility that one subset of distracters might be enough to elicit contextual cueing even if this subset looked quite similar to the other one.

Perceptual grouping is essential in information processing because it allows for efficient allocation of attention. If participants could limit their attention to one subset of distracters that most resemble the target based on perceptual grouping (Duncan, 1995; Kaptein, Theeuwes, & Heijden, 1995), it would reduce the number of distracters that need to be attended to into half and thus increase the efficiency of visual search (Kaptein et al., 1995; Nagy, Neriani, & Young, 2005; Friedman-Hill & Wolfe, 1995; Duncan & Humphrey, 1989). Even grouping by spatial proximity and temporal relations would help bring forth contextual cueing effects (Olson & Chun, 2002; Hodsoll & Humphreys, 2005).

One important difference between my research and previous research is that in most contextual cueing studies that employed two subsets of distracters (Jiang & Chun, 2001; Conci & Mühlenen, 2011; Couperus, 2011; Dixon et al., 2010; Goujon et al., 2007; Rausei et al., 2007), there were always clear-cut difference between two subsets of distracters varying size, color, shape or direction. In addition, the target always physically looked more like one subset than the other. It is thus obvious which subset was more relevant than the other. The HH condition is also such an example. Participants knew that looking at Jerry was not going to help find the target Mickey by any means. Different from previous studies, however, the LH condition in the current study used two subsets of cartoon characters that looked like each other and also the target. The pre-attentive selection process was hence disabled. However, even in the absence of prior knowledge and pre-attentive selection, participants still implicitly "picked up" that some distracters (one subset) in some displays (repeated displays) had been repeated and providing information about the location of the target. This resulted in faster RTs to the repeated displays than the control displays.

Guided search and context maps. Chun and Jiang (1998) originally used guided search (Wolfe, 1990) to explain contextual cueing effects in conditions where all the distracters in the displays predicted the target. They implemented the concept of context maps, which hold memory representations of visual context. The context maps prioritize the global image of the repeated displays which then optimize attentional deployment to the target location. Strictly speaking, in the best case scenario, attention is directly guided to the target in the repeated displays without wasting any time on the distracters.

Evidence from eye movements (Brockmole & Henderson, 2006; see also van Asselen, Sampaio, & Pina, 2011) provide only partial support for this proposition (for behavioral research evidence for and against guided search as an explanation of contextual cueing, see Kunar, Flusberg, Horowitz, & Wolfe, 2007; Kunar, Flusberg, & Wolfe, 2008). Peterson and Kramer (2001) suggest that the first fixation fell straight to the target in the repeated displays only a small percentage of the time. This is far from perfect attentional guidance. Nonetheless, there were typically fewer fixations needed to locate the target in the repeated displays compared with the control displays.

Rather than following a strict interpretation of guided search (Wolfe, 2007; Chun & Jiang, 1998), my view does not imply perfect attentional guidance to the target location. It seems likely that recognizing the layouts of the repeated distracters takes place in real time. Hence, attentional guidance in contextual cueing is not always perfect (Peterson & Kramer, 2001; Theeuwes, 2010). However, once the layouts of the predictive distracters are identified attention is more easily redirected to the target location. This results in reducing attentional load and increasing search efficiency, which are of a great ecological importance.

In my view, context maps are also considered representations of the layouts of the distracters and the target. Although there may be different types of context maps (e.g., context maps associated with all the target locations), I am specifically referring to maps that may be associated with a specific target location where the layouts of the distracters have yet to be learned. Expanding on Chun and Jiang (1998), I suggest that context maps are continuously updated along with each exposure of the displays. The layouts of each display with the same target overlay on top of each other in the context maps. Therefore the contextual information of each spot is gradually accumulated by the context maps. The more often a particular location in the 4 x 4 matrix has been consistently occupied by a particular distracter, the higher weights that location will be assigned (without any control display is especially valuable, see Jungé, Scholl, & Chun, 2007). The less often one particular location has been occupied by any distracter, the less weights that location will be assigned and the more likely it will be ignored in later encounters. Additionally, the context maps should be flexible and adjustable in that not all the distracters have to be repeated for a specific target location. They could easily register the information that only half of all the distracters (or even fewer, see Olson & Chun, 2002) have been repeated.

Feature-based and expectancy-based selective attention. In the framework of the current study, it is through the three processes of perceptual representation, feature-based selective attention and expectancy-based selective attention that context maps are constructed and eventually guide attention to the target location. Perceptual representation is determined by the features in the environment and typically occurs in a passive automatic way. Through perceptual representation the basic location information associated with each distracter and the target is represented in the context maps. Feature-based selective attention, where attention is determined by physical differences between the stimuli, guides attention to the target and to the distracters that share salient features with the target. Expectancy-based selective attention, where attention is determined by learned associations, guides attention to the distracters that spatially co-occur with the target. As discussed below, I believe these three processes operate differently in the LH condition and the HH condition. More specifically, perceptual representation and expectancy-based selective attention are likely to operate in both the LH and HH conditions. However, only the HH condition benefits from feature-based selective attention.

In the HH condition perceptual representation, as an automatic process, registers the basic perceptual information of identity and location of each object in the display. It is analogous to the initial context map. If observers know that they need to look for a specific version of Mickey, feature-based selective attention can be initiated. Feature-based selective attention, as an active process, is used to analyze the scene and narrow the necessary search domain based on identity information in a very easy way: that is, searching among the objects that most look like the target. This is successfully achieved in the HH condition. Feature-based selective attention is directed to the distracters that are similar to the target (Mickey subset) rather than the ones that are not (Jerry subset). Meanwhile, expectancy-based selective attention unfolds gradually. As participants experience the displays over time, this mechanism tries to narrow the necessary searching items based on location information: that is, searching among the objects that are most likely to spatially co-occur with the target. The more often some locations have been searched before the final locating of the target, the higher activation these locations will be given in the context maps. This is also achieved in the HH condition because the Mickey subset is consistently paired with the target location. Moreover, feature-based selective attention mechanisms make this process easier because they already make the Mickey subset more likely to be searched (due to the identity salience). Therefore, both feature-based and expectancy-based selective attention systems work together in the HH condition to elicit contextual cueing effects.

In the LH condition, perceptual representation also registers the basic perceptual information of identity and location of the distracters and the target. However, in the LH condition feature-based selective attention is not able to function due to the fact that there are no objects that are more physically similar to the target relative to others. Theoretically all the distracters receive equal attention and context maps do not differentiate the different distracters without additional processing. At the same time the mechanisms of expectancy-based selective attention are still available. With repeated exposure to the repeated displays, the expectancy-based selective attention registers the locations of the predictive distracters which spatially co-occur with the target, into the context maps. These predictive distracters (subset) have naturally distinctive features from the unpredictive distracters (subset). Therefore attention can be effectively allocated to the predictive subset. Adults did not show difference between the HH and LH conditions indicating that even without the help of feature-based selective attention, expectancy-based selective attention itself is sufficient and robust enough to elicit contextual cueing. Because children do exhibit a difference between the HH and LH conditions, it is reasonable to conclude that they rely more heavily on feature-based selective attention mechanisms to generate context maps than do the adults.

Triangle model. Figure 4 presents a triangle model aimed at systematically demonstrating how similarities impact the contextual cueing effects. The target and two distracter subsets are plotted at the three vertices of a triangle. The numbers 1, 2, and 3 denote the degree of similarity between each two combinations of stimuli. Although the degree of similarities between two objects is typically on a continuous scale, only extreme states are used here to simplify the discussion. Positive represents "similar" and negative represents "dissimilar". In my example, only one subset predicts the target (predictive subset) while the other subset does not (unpredictive subset). Four different conditions that correspond to different contextual cueing effects are discussed as follows.

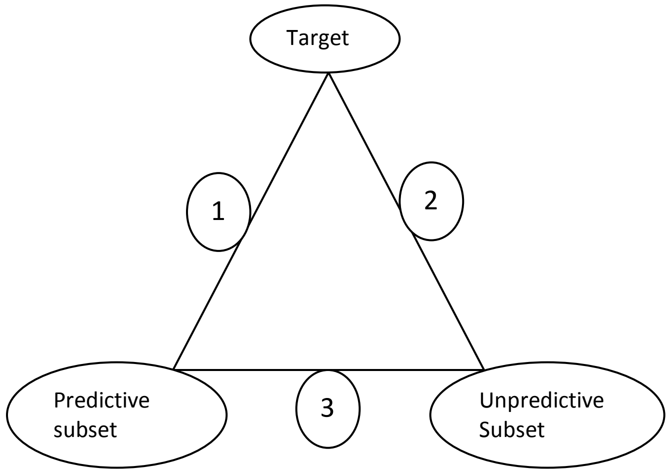


Figure 4. Triangle Model

I. When both 1 and 2 are negative, whether 3 is positive or negative, the target may just "pop out" (because the target is extremely different from the distracters). It is likely that this is entirely the result of perceptual representations. Contextual cueing effects do not develop and hence these conditions are not the main interest here.

II. When 1 is positive and 2 is negative, 3 is negative. This would be the HH condition in the current study. Initially, attention is focused on the predictive subset.

III. When both 1 and 2 are positive, 3 is also positive. This would be the LH condition. Initially, attention is evenly divided between two subsets.

IV. When 1 is negative and 2 is positive, 3 is negative. In this condition the predictive subset is distinct from the target. One example is to use blue distracters rather than red distracters to predict the red target location (see Experiment 2 in Jiang & Chun, 2001). Initially attention is focused on the unpredictive subset.

Although the predictive subset is present in all the conditions, the degree of difficulty with which contextual cueing develops is different, with condition II being the easiest, condition III intermediate, and condition IV the hardest. The examples for condition II abound in the extant studies (Chun & Jiang, 2001; Couperus, 2011). The current study might be the first example demonstrating contextual cueing for condition III. The development of a contextual cueing effect in condition IV is so difficult (see also Conci and Mühlenen, 2009) that it only occurs when attention could be “spilled over” to the predictive subset (Jiang & Chun, 2001, Experiment 3).

Contextual Cueing and Development

Adults exhibited contextual cueing effects in both the LH and HH conditions. In contrast, the younger children (5–6 years old) only exhibited contextual cueing effects in the second test block of the HH condition. They deployed attention to the predictive subset only if the unpredictive subset was substantially different from the target; otherwise no learning occurred. The performance of the older children was intermediate of that of the younger children and the adults. They showed contextual cueing effects in both the test blocks of the HH condition, and therefore learned at a faster rate than the younger children. Meanwhile, in the LH condition the older children only exhibited a marginal contextual cueing effect in the second test block, rather than in the first test block. Hence the older children were not as efficient as the adults. The developmental trends represented by three age groups in two distracter conditions indicated both strengths and weaknesses of contextual cueing effects in children.

Strengths in the HH condition. A key strength in children is that they were able of showing a contextual cueing effect in the second test block of the HH condition. The current study is the first to reveal an intact contextual cueing effect in children as young as 6 years old when only half of all the distracters predict the target. It indicates children can employ selective attention in the process of contextual cueing. Couperus (2011) recently suggested that only 10 year olds and above could show contextual cueing effects when selective attention was involved and that it only occurred when the predictive subset contained much more items (75% of all the distracters) than did the unpredictive subset (25%). My data indicated that younger children are more capable than once indicated. One reason for the discrepancy in results may lie in the different experiment stimuli in two studies. Couperus (2011) and Vaidya et al. (2007) both used stimuli from the classic paradigm composed of “T” and “L”s. Using more age-appropriate materials, such as the ones in the current study and Dixon et al. (2010), may be more engaging for children and thus permit a level of performance greater than that observed in previous studies.

As long as they are given enough exposure to the displays, younger and older children are able to deploy selective attention in a contextual cueing task in a manner that is similar to adults in the HH condition by the second test block. These results revealed that by first directing attention to the relevant and salient subset, the knowledge that this being attended subset also predicts the target location is gradually acquired by children and adults alike.

While children and adults were qualitatively similar in exhibiting contextual cueing effects in the HH condition, two quantitative differences may be noted. First, the POF in the second block of the HH condition of young children (4.7%) is almost half the size of the POF of adults (9.8%). It might be the case that younger children still had room to increase their performance were they given more repeated trials. Second, the learning rates for the three groups were different. Younger children did not show learning in the first test block while older children and adults did. This might be because younger children needed more time to become familiar with the general task procedure while older children and adults mastered the basic task requirements more quickly. Before becoming proficient, participants needed to learn what the target Mickey looked like and how the target looked different from the other distracters. They also needed to learn and remember the two responses: press “S” when the Mickey was facing to the left and press “L” when the Mickey was facing to the right. These features of the task might be more effortful for younger children. In fact, two younger children’s data could not be included in the final analysis due to their failure to find where the target was or/and not being able to differentiate which response corresponded to which direction the target Mickey was facing.

The slower learning speed in younger children might also indicate that implicit learning becomes more proficient with development. Even though implicit learning has long been viewed as phylogeny dependent and is not influenced by age or IQ (Reber, 1992; Don, Schellenberg, Reber, Digirolamo, & Wang, 2003; Vinter & Perruchet, 2000), an adequate test of this assumption has not been made. Thomas and her colleagues (2004) recently found developmental differences in a standard serial reaction time (SRT) task, which has been commonly known as one of the most frequently studied implicit learning paradigms. Of primary interest, their results were similar to the ones of the current study in that implicit learning also occurred a slower rate in children aged 7 to 11 years old than in adults. Therefore the ability to show contextual cueing as a form of implicit learning may become more competent with age, paralleling the growing of explicit learning (Thomas et al., 2004).

Weaknesses in the LH condition. The LH condition forms a quite different developmental picture than the HH condition does. There are clear developmental transitions in this condition with adults exhibiting learning in both test blocks, older children showing only marginal learning in the second test block, and younger children not showing learning at all. This contrasts to the HH condition in which children and adults demonstrated significant contextual cueing effects. Apparently the stimulus similarity as a manipulation between the HH and LH conditions had some bearing on this result. Four possible explanations for the difference observed between these conditions are discussed below.

First, children might not be able to accomplish successful perceptual grouping, which is a prerequisite for contextual cueing when selective attention is deployed. Admittedly, all participants were told that the two distracter subsets of Mickey were different from each other prior to the start of the experiments. Children, like adults, were aware that the two subsets had distinctive features. However, because perceptual identification ability keeps increasing until adulthood (Waszak, Schneider, Li, & Hommel, 2009; Hadad & Kimchi, 2006), it might take younger children longer to make finer discriminations between the two subsets. Older children and adults could distinguish between the two subsets in a rather short time. If children treat the two subsets as one unitary set, then learning to attend to the relevant distracters would be very difficult. In fact, other experiments conducted in our lab suggested that when all the distracters were identical and only half of them predicted the target location even adults could not show contextual cueing effects.

Second, children's impairments might be due to their less mature selective attention competence. It is well known that selective visual attention in terms of focusing on the central task and ignoring the incidental stimulus features improves with age (Plude, 1994; Kunar & Watson, 2011; Huang-Pollock, Maddox, & Karalunas, 2011). Recently lehman and colleagues (2010) recently conducted a national study on the development of visual attention with more than two thousand children aged 5 to 17 years old. They used three tests of attention which measured how well children were able to attend to relevant stimuli and inhibit competing stimuli. The results suggested a developmental trajectory of visual attention up to 15 years old. However, different from Korkman et al. (2001), they found a rather steady growth rate of attention development between adjacent age groups within the age range 5 through 15 years. Therefore these previous studies (Korkman et al., 2001; Lehman et al., 2010) provide us mixed evidence concerning whether children's selective attentional mechanisms are as mature as adults' by the time they are 10 years old. The current study does not clarify this issue. Measures of contextual cueing may not be sufficiently sensitive to identify true differences between the older children and adults. However, it is clear that younger children (6–7 years old) have a less mature selective attention system than older children (9–10 years old) and adults. The pattern of performance across ages in the development of selective attention is thus very similar to the pattern of performance of my participants in the LH condition.

The attention-selection process is also more difficult in the LH condition relative to the HH condition. It is rather easy in the HH condition because the salient subset, which easily draws attention, happens to be the predictive subset. Both children and adults can perform the necessary discrimination. On the other hand, the discrimination is more difficult in the LH condition because the predictive subset has to attract attention without the help of the salient features. It might be an arduous task for young children to selectively attend to one particular subset when it is very similar to the other subset. Seven- to eight-year-old children are especially susceptible to the impact of the high similarities between the target and the distracters compared with older children and adults (Lobaugh, Cole, & Rovet, 1998; see also Scialfa & Joffe, 1997). The addition of a second distracter subset of Mickey rather than a unique subset of Jerry makes the overall target-distracter similarities much higher in the LH condition than the HH condition. Hence, younger children exhibit relatively greater deficits in inhibiting the irrelevant information (Hommel, Li, & Li, 2004; Baranov-Krylov, Kuznetsova, & Ratnikova, 2009; Johnson & Proctor, 2004), and are more easily distracted than older children and young adults.

Third, children's impairments in contextual cueing may be attributed to age differences in managing perceptual load. In the HH condition, it is only necessary to search the four Mickey distracters and the target Mickey. In the LH condition, however, it is necessary to search all the eight Mickey distracters and the target Mickey. Hence, there is a greater perceptual processing load in the LH than in the HH condition. The increased perceptual load might then consume a majority of the already limited attentional resources available to children (Astle & Scerif, 2011) and leave little space for the encoding and processing of spatial associations between the predictive distracters and the target. Therefore, they are more likely to be overwhelmed by the high perceptual demand (Hong-Pollack, Carr, & Nigg, 2002; see also Couperus, 2011 and Lavie, 1995). In contrast, the greater perceptual processing capacity of adults would make them less susceptible to processing overload problems. Therefore they would still be expected to exhibit contextual cueing effects in the LH condition.

Fourth, children may show impairments of contextual cueing in the LH condition because of their limited working memory capacity. Manginelli and her colleagues (2011) indicated that a concurrent visuospatial working memory load task could interrupt the development of a contextual cueing effect. This might be because that visuospatial working memory is necessary for comparisons between the current display and the "context map" established in long-term memory (see also Kessels, Meulenbroek, Fernández, & Rikkert, 2010; Kim, Kim, & Chun, 2010). Working memory matures through late childhood and into late adolescence (from 8 to 19 years old, see Luna, Garver, Urban, Lazar, & Sweeney, 2004). Therefore it is likely that adults would be more able than children to exhibit contextual cueing effects when displays include a large amount of spatial information.

While I have presented these as independent influences on the development of contextual cueing effects, we should keep in mind that different cognitive components are likely to interact with each other. For instance, both the high perceptual load and working memory load in the LH condition might further disturb the fragile attention selection processes for child participants (Couperus, 2011; Gomarus, Althaus, Wijers, & Minderaa, 2006; Huang-Pollock, Carr, & Nigg, 2002). Further explorations systematically manipulating different underlying cognitive elements such as working memory and discriminability might help better shed light on which specific factor(s) contribute to the diminished contextual cueing effects in children relative to adults.

CONCLUSION

I investigated how selective attention functions in contextual cueing in adults and children. It was found that when a predictive subset of distracters was physically distinct from an unpredictive subset of distracters, adults, older children, and younger children were all able to show intact contextual cueing effects. When the predictive subset of distracters was similar to the unpredictive subset of distracters, adults exhibited contextual cueing at a faster rate than older children and that younger children were not able to show contextual cueing effects at all. These results suggested that younger children relied more on salient features to acquire contextual cueing, whereas older children and adults were also able to guide their attention based on the learned spatial co-occurrence between the predictive distracters and the target. Future studies may look more closely at how systematically changing similarities between different subsets of distracters and between the distracters and the target could impact contextual cueing. It would also be interesting to investigate how selective attention influences contextual cueing over a wider age range of children in addition to 6–7 and 9–10 year olds. Future studies may also explore other variables (e.g., perceptual load, working memory) that could potentially explain the developmental difference I observed in contextual cueing effects.

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APPENDIX

Appendix: IRB certificate

June 15, 2011

Office for Research

Office of the Director of
Research Compliance

THE UNIVERSITY OF
ALABAMA
RESEARCH

Dr. Edward C. Merrill
Department of Psychology
College of Arts and Sciences
The University of Alabama

Re: IRB # 11-OR-202 "Selective Attention in Contextual Cueing"

Dear Dr. Merrill:

The University of Alabama Institutional Review Board has granted approval for your proposed research.

Your application has been given expedited approval according to 45 CFR part 46. Approval has been given under expedited review category 7 as outlined below:

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Your application will expire on June 14, 2012. If the study continues beyond that date, you must complete the IRB Renewal Application. If you modify the application, please complete the Modification of an Approved Protocol form. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, please complete the Request for Study Closure form.

Should you need to submit any further correspondence regarding this application, please include the assigned IRB application number.

Good luck with your research.

Sincerely,

Carpantato T. Myles, MSM, CIM
Director & Research Compliance Officer
Office for Research Compliance
The University of Alabama

152 Rose Administration Building
Box 870104
Tuscaloosa, Alabama 35487-0104
(205) 348-5152
FAX (205) 348-8882

IRB Project #:

UNIVERSITY OF ALABAMA
INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN SUBJECTS
REQUEST FOR APPROVAL OF RESEARCH INVOLVING HUMAN SUBJECTS

I. Identifying information

	Principal Investigator	Second Investigator	Third Investigator
Names:	Edward C. Merrill	Yingying Yang	
Department:	Psychology	Psychology	
College:	Arts and Science	Arts and Science	
University:	The University of Alabama	The University of Alabama	
Address:	Gordon Palmer 194	Gordon Palmer 400	
Telephone:	(205)348-1932	(509)863-2679	
FAX:	(205)348-8648	(205)348-8648	
E-mail:	emerrill@bama.ua.edu	yyang39@crimson.ua.edu	

Title of Research Project: Selective Attention in Contextual Cueing

Date Submitted:
Funding Source: N/A

Type of Proposal	☒ New	☐ Revision	☐ Renewal Please attach a renewal application	☐ Completed	☐ Exempt
			Please attach a continuing review of studies form		
		Please enter the original IRB # at the top of the page			

UA faculty or staff member signature: ______________________________

II. NOTIFICATION OF IRB ACTION (to be completed by IRB):
Type of Review: ______ Full board _____ Expedited

IRB Action:
___ Rejected Date: _________
___ Tabled Pending Revisions Date: _________
___ Approved Pending Revisions Date: _________
___Approved-this proposal complies with University and federal regulations for the protection of human subjects.

Approval is effective until the following date: 6/14/2011

Items approved:
X Research protocol (dated 6/15/11)
X Informed consent (dated 6/15/11)
___ Recruitment materials (dated ________)
Other (dated ________)

Approval signature Date 6/15/2011