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Contextual Cueing Effects Across the Lifespan

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Abstract

The authors evaluated age-related variations in contextual cueing, which reflects the extent to which visuospatial regularities can facilitate search for a target. Previous research produced inconsistent results regarding contextual cueing effects in young children and in older adults, and no study has investigated the phenomenon across the life span. Three groups (6, 20, and 70 years old) were compared. Participants located a designated target stimulus embedded in a context of distractor stimuli. During exposure, the location of the target could be predicted from the location of the distractors in each display. During test, these predictable displays were intermixed with new displays that did not predict the target location. Response times to locating predictable relative to unpredictable targets were compared. All groups exhibited facilitation effects greater than 0 (95% CIs [.02, .11], $d = .4$; [.01, .12], $d = .4$; and [.01, .10], $d = .4$, for the children, young adults, and older adults, respectively) indicating that contextual cueing is robust across a wide age range. The relative magnitude of contextual cueing effects was essentially identical across the age range tested, $F(2, 103) = 1.71$, $\eta^2 = .02$. The authors argue that a mechanism that uses environmental covariation is available to all age ranges, but the expression of the contextual cueing may depend on the way it is measured.

Keywords

contextual cueing; implicit learning; lifespan development

One long-standing goal of research investigating cognitive abilities across the life span is to document the patterns of gains and losses observed for specific abilities that can be attributed to age-related changes (Baltes, 1987). This process typically involves the

generation of developmental trajectories relating age with performance associated with various cognitive abilities and activities. The evaluation of these developmental trajectories can provide researchers with information about different aspects of the developmental process. First, it is possible to identify the age at which gains and losses for particular abilities become evident during typical development, which can be subsequently used to contrast performance of persons with various developmental anomalies. Second, it is possible to use an analysis of developmental trajectories to make inferences about the developmental mechanisms that may be responsible for any observed gains and losses in performance that may be associated with age (see Craik & Bialystok, 2006), and by extension, to identify basic cognitive abilities and processes that may be relatively invariant with respect to age. The research reported here was designed to focus on this second use of developmental trajectories in the evaluation of a cognitive ability referred to as contextual cueing (Chun, 2000; Chun & Jiang, 1998; Jiang & Chun, 2001).

Contextual cueing effects involve an attentional guidance mechanism that makes use of previously experienced visuospatial regularities in the environment to facilitate search for a target object. In a typical contextual cueing study, participants are presented displays of multiple stimuli and are required to search for a particular target. The relative location of the target in some displays can be predicted by the positions of the other stimuli in the display, which remain the same over repeated trials during the procedure. Participants simply search for the target over a large number of trials that include some of these predictable target displays and some unpredictable target displays. After many repetitions, learning in this task is evidenced by faster response times on displays in which the target location can be predicted from the other stimuli relative to displays in which the target cannot be predicted (Chun & Jiang, 1998). This learning is generally considered implicit for young adults because participants cannot identify where the target should be in the displays when the displays are presented without the target postlearning (Chun, 2003). Although challenges to the claim that contextual cueing reflects a purely implicit process have been made (e.g., Smyth & Shanks, 2008), it is reasonable to suggest that many young adult participants who exhibit facilitation effects based on spatial regularities found in complex visual stimuli do so without full explicit awareness of the covariation between the target and other items in the displays.

Very little research has looked at contextual cueing with young children and older adults, and none has looked at both ages in the same study. A study conducted by Vaidya, Huger, Howard, and Howard (2007) recently reported that performance on the contextual cueing task developed by Chun and Jiang (1998) varies with development. They compared the performance of children (ages 6–13 years) with young adults (ages 18–22 years). Both groups received extensive exposure to the repeating and predictable displays (each of 12 predictable displays was repeated 30 times). Following exposure, the young adults exhibited significantly faster response times when responding to the repeating displays relative to novel displays. The children did not exhibit a reliable difference between the repeating and novel displays. However, Dixon, Zelazo, and DeRosa (2010) did observe contextual cueing with a sample of 5–9-year-old children in a simplified version of the standard procedure. They used stimulus displays consisting of pictures of red and green fish drawings where both the location of individual fish and the overall red-green color pattern of the display

predicted the location of the target. With repeated exposure to the simplified predictable displays, the young children in their study did exhibit faster response times to the predictable displays relative to new displays. However, the simplified task was not used with older children or adults, so it is not known if the young participants exhibited a similar magnitude of facilitation as would be found for older participants under similar conditions. Couperus, Hunt, Nelson, and Thomas (2011) also reported significant contextual cueing in children as young as 10 years old as long as the signal to noise ratio of predictive to unpredictable distractors in the displays was relatively high (75% predictive and 25% unpredictable distractors). Hence, it appears that whether children exhibit contextual cueing may depend on the specific task conditions used to measure it.

With respect to older individuals, the available data are limited to select categories of persons above the age of 65 years. Persons typically referred to as healthy older adults perform similarly to younger adults on tests of contextual cueing (Howard, Howard, Dennis, Yankovich, & Vaidya, 2008; Negash et al., 2007). However, persons diagnosed with mild cognitive impairment do not appear to exhibit contextual cueing effects (Negash et al., 2007). Somewhat surprisingly, healthy older adults who carry the apolipoprotein E $\epsilon 4$ (ApoE $\epsilon 4$) allele that has been linked to Alzheimer's disease also do not exhibit contextual cueing effects (Negash et al., 2007).

The inconsistency of these results, especially those involving children, highlights a dilemma for developmental researchers. How is it possible to investigate a basic cognitive process across the lifespan when the performance on the task may reflect the difficulty of the task rather than the abilities of participants? In the case of the contextual cueing procedure introduced by Chun and Jiang (1998), their young adult participants had to search through a context of randomly spaced rotated *L*s to find a target letter *T* that was rotated 90° to the right or left. The task was to determine which way the *T* was pointing, which means that there were two cognitive responses involved, one involving a search for the location of the target, and the other a decision about the direction in which the target was pointing. Further, predictable displays were intermixed with unpredictable displays throughout the task. It may be the case that younger adults and older adults with cognitive impairments are slower to learn this information. That is, they would eventually show effects of contextual cueing, but they were not given enough practice to learn.

There are two ways to rectify the situation. One is to increase the number of trials in the task and the other is to simplify the task. Because the task is tedious already and because Dixon et al. (2010) showed that simplifying the task produces a contextual cueing effect in children, we chose the latter approach. In this study we used a contextual cueing task that could be used for persons between the ages of 6 and 80 years. In our task, participants searched for a designated target (Jiminy Cricket) presented in a matrix of nontargets (several other cartoon characters). This is similar to Chun and Jiang's (1988) task except for the content of the target and distractors. However, in our task the participants' task was simply to indicate the quadrant of the display in which the target was located, rather than indicate the direction in which the target pointed. We believed that our task would be a better measure of contextual cueing effects for young children and older adults because it was a response tied more directly to the results of the visual search (i.e., where is it?) than a

direction response was (i.e., where is it and which way is it pointing?). Further, in our learning phase, the arrangements of the nontarget characters perfectly predicted the target's location in every display. Only after learning was at asymptote did we introduce unpredictable displays. In Chun and Jiang's task, predictable and unpredictable displays were mixed throughout the task. Again, we believed that our task would be a better measure of contextual cueing effects because it ensured that young children and older adults could learn the covariations in the displays to the same extent. Taken together, our adaptations increased the likelihood that our measure of contextual cueing would reflect true differences in response times associated with the predictable displays compared to the unpredictable displays.

Three different age groups completed our study: young children (ages 6–7 years old), young adults (ages 18–23 years old), and older adults (>60 years old). The general cognitive ability level of participants in the child and young adult groups was within the average ability range. However, we allowed the relative cognitive abilities of older adults to vary. None of the older adults received a clinical diagnosis of mild cognitive impairment on the basis of current definitional standards; nevertheless, about half of the older participants had some degree of cognitive impairment. Hence we were able to evaluate possible differences in contextual cueing effects as a function of both age and level of cognitive functioning (in the older adults).

Method

Participants

Thirty-two young children (M age = 6.30 years, SD = 0.60 years) were recruited from the first and second grades of local elementary schools. There were 18 girls and 14 boys in the group. Forty-six young adults (M age = 19.80 years, SD = 2.00 years) were recruited from introductory psychology classes at the University. There were 31 women and 13 men in this group (sex was not recorded for two participants), which is consistent with the makeup of the classes. Performance in the procedures reported here was part of a larger study involving these participants, and took place over two sessions of approximately 45–60 min, as described subsequently. College participants received course credit for their participation and the children received a small prize.

Thirty participants over the age of 60 years (21 women and 9 men) were recruited from senior citizen condominiums, recreational centers, or in response to advertisements placed in a local newspaper. The average age of the 30 participants was 72.17 years (SD = 6.62 years, minimum age = 62 years, maximum age = 87 years). In terms of their education, six had less than a high school degree, five had a high school degree or GED, nine had vocational or college training, and 10 had a bachelor's or master's degree. These participants performed the contextual cueing task as part of a separate larger study. They were given \$30 for participating in the full study, which included the brief telephone screening of cognitive ability and two separate 1.5-hr sessions.

Measures

Mini mental state exam—Older adults completed the Mini Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975) to provide a brief measure of general cognitive ability. The MMSE has 11 questions that cover five general areas of cognitive functioning (orientation, short-term memory retention, short-term memory recall, attention, and language). Scores can range from 0 to 30. The exam takes 5–10 min to administer. For our study, participants were classified as lower functioning if they had a score of 27 or less on the MMSE. Fourteen of our participants met this criterion ($M = 25.10$, $SD = 1.69$). Two participants scored below the generally accepted cutoff of 24 (one scored 21 and one scored 22) for the classification of dementia (e.g., Tombaugh & McIntyre, 1992). However, the data from these participants did not change the results of the study and were therefore included in the analyses. The remaining 16 participants scored between 28 and 30 ($M = 29.35$, $SD = 0.81$) and were classified as higher functioning.

Kaufman brief intelligence test—All participants completed the matrices subtest of the Kaufman Brief Intelligence Test–Second Edition (KBIT-2). The matrices (nonverbal) subtest consists of 48 visual analogies presented on either 2×2 or 3×3 matrices with one element missing. The participants' task is to choose the answer that best completes the pattern (no time limit). We used the KBIT-2 as an index of general cognitive functioning for participants across all age groups.

Contextual cueing task—A modified version of the procedure used by Nissley and Schmitter-Edgecombe (2002) was used to measure contextual cueing effects. In this task, participants were required to search for a designated target presented in a matrix of nontargets. The stimuli we used were small cartoon characters. The general arrangement of stimuli is presented in Figure 1. There were five different cartoon characters (Dale, Donald Duck, Goofy, Mickey Mouse, and Pluto) that appeared in each matrix four times each, plus a target cartoon character (Jiminy Cricket) that appeared once in place of one of the other characters. Each matrix was divided into four quadrants. Each quadrant contained the five different characters presented in an *X* shape. The quadrants were separated by the fixation cross, which remained on the screen throughout the experiment. The target replaced one of the characters in the display and appeared anywhere except the locations closest to the center of the screen. The display was presented in the center of a computer monitor and was approximately 10×10 inches in size. The participants' task was to locate the quadrant in which the target was presented. Responses were made using the computer mouse. Participants moved the mouse arrow to the quadrant in which the target was presented and clicked the mouse. They did not have to locate the precise position of the target, only the quadrant. Each subsequent trial was initiated by the participant clicking on the fixation cross following his or her response. This was done to ensure that the mouse cursor was in the center of the screen prior to the initiation of each trial. Participants were asked to respond as rapidly as possible without error, and response times were recorded to the nearest ms. The presentation of the contextual cueing task was coordinated through the Superlab experimental lab software program, Version 2.1 (Cedrus Corporation, San Pedro, CA).

Unbeknownst to the participants, the quadrant in which the target appeared was perfectly predictable from the arrangement of the nontargets in the other quadrants during the learning phase of the procedure. Participants were also unaware that only four displays were used. These displays were presented 160 times, 40 times each. To track responses across trials, the displays were presented in blocks of 24, with each display presented six times in random order within each block. This resulted in four blocks of trials (learning phase). After participants complete the fourth block, 48 additional trials were presented (test phase). This time, half of the displays had targets in locations that were not predicted by the arrangement of the nontargets, and half had targets in their predicted locations. The difference in speed of response between predictable and unpredictable trials, with predictable trials being faster, reflects the extent to which responses were facilitated by learning (implicitly) where to expect the target based on the location of other cues in the display (i.e., the context).

To assess the possible influence of explicit learning processes in the performance of our task, we included one additional measure to assess whether participants were aware of the relation between the location of the target and other objects in the displays. Following Chun and Jiang (2003), we presented the predictable displays with the Jiminy Cricket target replaced by one of the other cartoon characters and asked our participants to guess the quadrant in which the target would be if it was in the display. We assumed that if participants performed at or near chance level of 25% on this measure that explicit learning of the relation between the target and distractor locations had been minimized. The contextual cueing task was completed in 10–15 min by the young adults and 20–30 min by the children and older adults.

Because some of our older adult participants were unfamiliar with using a mouse, a training exercise was introduced before the contextual cueing task began for these participants. In this training session, an *X* appeared in one of the quadrants and the participants had to move the mouse to that quadrant and then click the mouse. They did this 6–12 times perfectly before initiating the contextual cueing task, depending on their past experiences using a mouse.

Procedure

As indicated previously, the procedures were part of larger studies for all groups of participants, with participation taking place over two days of testing separated by approximately one week. Older participants received the MMSE and KBIT-2 during the first session. The children and young adults were given the KBIT-2 during the first session. The mouse training (if necessary) and the contextual cueing task were given during the second session.

Results

The data from one older adult and one child were removed from the analysis because of equipment failure during the contextual cueing task. Hence, analyses were based on 31 young children, 46 young adults, and 29 older adults (15 higher and 14 lower functioning older adults). Data of our primary measures are reported in Table 1.

Performance on the KBIT-2 is reported in terms of nonverbal IQ scores. Analysis of the KBIT-2 indicated a significant difference between groups, $F(2, 103) = 7.98, p < .01, \eta^2 = .13$. The older adults performed more poorly on the matrices subtest than did the children and the young adults (both $ps < .05$, using Tukey's HSD). However, this effect appeared to be carried by the lower functioning older adults, who performed significantly more poorly than did the higher functioning older adults (90 vs. 100), $t(27) = 1.93, p < .05$. The performance of the higher functioning older adults did not significantly differ from that of the children or young adults.

Prior to the main analyses, we conducted a preliminary analysis of performance on the training trials of the contextual cueing task. These data are presented in Figure 2. The data reflect group means of median response times (excluding trials with errors) as a function of presentation blocks. Errors were relatively rare (less than 3.0% for each group) and error rate by group was not analyzed for this reason. A 3 Group $\times$ 4 Acquisition Block analysis of variance (ANOVA) conducted on the response times yielded a main effect of group, $F(2, 103) = 73.06, p < .01, \eta^2 = .58$. As expected, children and older adults performed more slowly overall than did the young adult participants (3489 ms for children, 3892 ms for older adults, and 1293 ms for young adults). There was also a significant main effect of acquisition block, $F(3, 309) = 30.25, p < .01, \eta^2 = .26$, with participants exhibiting a decrease in response time with practice. The interaction was also significant, $F(6, 309) = 4.53, p < .01, \eta^2 = .06$, suggesting that improvement in performance across acquisition blocks was significantly different among the groups. As is evident from Figure 2, children and older adults whose initial response times were significantly slower than those of the young adults exhibited a greater decrease in response times than did the young adults. Of course, this difference may reflect differences associated with learning to perform the basic task as well as possible differences in facilitation due to contextual cueing.

Contextual Cueing Effects

As a reminder, contextual cueing effects are reflected in faster response times exhibited by participants on the predictable relative to the unpredictable displays during the test phase of the contextual cueing task. These scores were computed by obtaining a median score for each participant in the predictable and unpredictable conditions of the test phase excluding errors. Error rates during the test phase were very low (less than 2.0% across conditions and participants) and were not considered any further.

Median response times in the predictable and unpredictable conditions of the test phase of the contextual cueing task (see Table 1) were subjected to a 3 Group $\times$ 2 Predictability mixed design analysis of variance. The analysis again indicated the expected significant main effect of group, $F(2, 103) = 92.88, p < .01, \eta^2 = .65$. In addition, we observed a main effect of predictability, $F(1, 103) = 17.13, p < .01, \eta^2 = .11$, with response times in the predictable condition being significantly faster than response times in the unpredictable condition (2238 ms and 2383 ms, respectively), indicating that significant contextual cueing effects had occurred. However, the interaction of group by predictability, $F(2, 103) = 1.71, \eta^2 = .02$, was not significant. The implication is that the magnitude of contextual cueing did not vary as a function of age.

It is possible to argue that this nonsignificant interaction could be due to lack of power. However, a power analysis shows that we had enough participants to detect an interaction. Using a repeated measures ANOVA with within-between interaction, effect size was .14 (based on $\eta^2 = .02$), alpha was .05, power was .95, and correlation among the repeated measures (predictable, unpredictable) was .96, with a total sample size of 21 needed (Faul, Erdfelder, Lang, & Buchner, 2007). Our sample size was 106, five times larger than the minimum suggested by the power analysis. Further, the nonsignificant interaction contrasts with the significant interaction between group and block during the learning phase. Therefore, we conclude that any differences in contextual cueing effects across the groups are not practically or theoretically significant.

Nevertheless, to further examine this result, we converted response times to a single measure reflecting percent of facilitation for each participant and using the formula,

$$(\text{UNPREDICTABLE} - \text{PREDICTABLE}) / \text{PREDICTABLE}.$$

This measure adjusts for the expected overall response time differences across groups. One-sample *t* tests were conducted comparing the obtained facilitation effects to zero for each group to evaluate the significance of the contextual cueing effects. The analyses revealed a significant facilitation effect for each group, for children, $t(30) = 2.29$, $d = .4$; for young adults, $t(45) = 2.80$, $d = .4$; for older adults, $t(28) = 2.27$, $d = .4$ (all $ps < .05$). Further, a one-way ANOVA comparing facilitation effects across groups confirmed that there was not a significant group difference in the amount of facilitation that could be attributed to contextual cueing (6.2%, 6.7%, and 5.5% facilitation for the children, young adults, and older adults, respectively), $F(1, 103) < 1.0$, $p = \text{ns}$. Note that these values were based on calculating facilitation effects for each participant and then computing the average for the groups and do not necessarily equate with the computation of facilitation effects based on group response times. Importantly, the results of the analysis again show that the extent of contextual cueing effects does not differ across the groups.

To assess the extent to which performance in the contextual cueing task involved the explicit learning of the target location, the test phase was followed by asking the participants to view the four predictable displays used during acquisition (with the target replaced by another character) and asked to guess where Jiminy Cricket would have been in each slide as presented during acquisition and testing. Performance on this task did not differ significantly from chance level of 25% for any group, and did not significantly differ as a function of participant group (36% correct for children, 27% correct for young adults, and 28% correct for older adults). Hence, the indication is that participants were not sufficiently aware of the covariations in the display to have learned the covariations explicitly; hence, we have some support for the claim that contextual cueing involves predominantly implicit learning mechanisms.

Supplemental Analyses

Because the older adults varied in general cognitive ability, we were able to evaluate possible differences in contextual cueing effects as a function of participants' performance on the MMSE. There were 15 participants in the higher functioning group (MMSE > 27) and 14 participants in the lower functioning group (MMSE 27 or less). The data for the split older adults groups are reported in Table 2. Median response times in the predictable and unpredictable conditions of the test phase were subjected to a 2 Group (lower functioning and higher functioning) $\times$ 2 Predictability mixed design ANOVA. This analysis revealed a main effect of predictability, $F(1, 27) = 6.36$, $p < .05$, $\eta p^2 = .19$, with response times in the predictable condition being significantly faster than response times in the unpredictable condition (3197 ms and 3416 ms, respectively). However, neither the main effect of group, $F(1, 27) = 2.47$, $\eta p^2 = .08$, nor the interaction of group and predictability, $F(1, 27) = 0.71$, $\eta p^2 = .03$, was significant. Again, an a priori power analysis was conducted using a repeated measures ANOVA showed within-between (2×2) interaction, an alpha of .05, power of .95, effect size of .18 (based on $\eta p^2 = .03$), and correlation of .95, which provided similar results: Only 14 participants were needed to detect an interaction. Our sample size of 29 was twice as large. As a further test of the similarity in contextual cueing exhibited by higher and lower functioning adults, we calculated a Pearson correlation evaluating the relation between facilitation effects [(Unpredictable – Predictable)/Predictable] and performance on the KBIT-2 for the older adults. The correlation coefficient was not significant ($r = -.23$) and in the opposite direction of what would be expected if higher functioning participants were more likely to exhibit contextual cueing effects.¹ The implication is that the magnitude of contextual cueing effects did not systematically vary with level of cognitive functioning in the older adults. The implication is that the magnitude of contextual cueing effects did not systematically vary with level of cognitive functioning in the older adults.

Discussion

We compared the performance of children, young adults, and older adults in a modified contextual cueing procedure. Our results revealed a fundamental similarity in the performance of the three groups in the cueing task. All of our groups exhibited a significant improvement in performance with increased exposure to the stimulus displays, locating the target faster as practice continued. More importantly, all three groups exhibited facilitation resulting from the contextual covariation of the target and distracters. Target locations that could be predicted from previously experienced covariations were responded to faster than target covariations that could not. We attribute this result to implicit rather than explicit learning because the participants could not explicitly state where the target should be in a predictable display when the target was absent. Because the magnitude of facilitation was very similar for the children and older adults as it was for the younger adults, we conclude that contextual cueing effects are relatively stable across a wide age range. In addition, we observed a similar magnitude of contextual cueing effects for lower and higher functioning

¹A similar correlation was conducted between facilitation effects and performance on the KBIT-2 for all participants, yielding an r very close to zero ($-.08$).

older adults in this study, suggesting that contextual cueing effects may also be relatively robust to variations in cognitive ability.

One benefit of conducting an analysis that evaluates performance across a wide age range is that it is possible to make inferences concerning characteristics of the mechanisms and processes responsible for performance. Two important characteristics of performance on our version of the contextual cueing procedure can be inferred from the results of this study. First, the memory-based attentional guidance effect we observed was not susceptible to the influence of changes resulting from increases in experience or knowledge. Even though age-related changes in functional memory capacity have been observed across the age range of our participants (Riggs, McTaggart, Simpson, & Freeman, 2006), such changes do not impact contextual cueing or we would have observed increases in the magnitude of contextual cueing effects between 6 and 20 years of age. At the very least, we can infer that working memory capacity is not directly related to the expression of contextual cueing effects. Second, the attentional guidance effect we observed does not appear to be influenced by known age-related variations in cognitive control that are found in many cognitive activities (e.g., de Neys & Van Gelder, 2009; Jenkins, Myerson, Hale, & Fry, 1999; Trick & Ens, 1998). Presumably, the mechanisms responsible for contextual cueing effects do not directly involve cognitive control.

Our young child data are clearly more consistent with the results of Dixon et al. (2010) and Couperus et al. (2011) than with Vaidya et al. (2007) in indicating that young children can benefit from repeated exposure to stimulus regularity to guide attention to objects in the environment. Dixon et al. suggested that Vaidya et al.'s task was too difficult for young children and as a result the lack of contextual cueing effects for them was inconclusive. In fact, when the task emphasized the location of the target and not the direction in which the target was facing, young participants' performance to the repeated, predictable displays began to diverge from the new, unpredictable displays after relatively few presentations (as few as 4–5 repetitions). In our experiment we chose to keep a complex display—our displays included 25 items with five different distractor characters in each display—and instead made learning the covariations in the display easier by including only predictable displays in the learning phase. This is not to say that learning in our task was easy. The overall configuration was identical for each display, making it necessary for participants to learn individual associations between the target location and the locations of the distractors. Hence, it appears that the complexity of display may not have been the critical difference between the tasks used by Dixon et al. and Vaidya et al. We would argue that the younger children may have benefited from the simplified response requirements instead. In Vaidya et al.'s task, and in the original Chun and Jiang (1988) task, there were two components to the task: locating where the target was and determining which way it was pointed. It is likely that focusing children on the importance of location in our tasks primed them for learning the relative locations of the distractors, albeit it without intention to do so, and making that information available for guiding attention in subsequent presentations of the predictable, repeated displays. We also believe that the older children investigated by Couperus et al. may have been helped by the attention requirements of their task. Focusing attention on a subset of the display may have provided participants with the ability to systematically search

the predictive stimulus and allow the 10-year-old children to benefit from the regularities inherent in the displays.

Despite the observation of contextual cueing effects in young children by Dixon et al. (2010), Couperus et al. (2011), and the present research, it is reasonable to conclude that there may be important limits on whether or not contextual cueing will be expressed by children under the age of 10 years. Certainly, the results of Vaidya et al. (2007) indicate that there will be conditions in which young adults exhibit contextual cueing effects and children do not. Hence, any view of implicit contextual cueing effects in children as the necessary result of repeated exposure to regularities in the environment would obviously be incorrect. Variables that are known to influence the expression of contextual cueing in young adults include various manipulations of attention (e.g., Kunar, Flusberg, & Wolfe, 2008; Ogawa, Takeda, & Kumada, 2007), prior exposure to unpredictable displays (Jungé, Scholl, & Chun, 2007), and manipulating various aspects of the perceptual environment (Brockmole, Castelano, & Henderson, 2006; Olson & Chun, 2002). To the extent that these variables and others are systematically related to developmental level, then we should expect differences in the expression of contextual cueing effects to result as well.

The observation of contextual cueing effects across groups that differed in age and ability level has both theoretical and applied implications. From a theoretical perspective, this research adds to the growing body of results that indicate that there may be some general mechanism responsible for learning and remembering statistical regularities in the world that is available early in life (e.g., Fiser & Aslin, 2002; Saffran, Aslin, & Newport, 1996). Such an ability would clearly facilitate infants' learning about their world (Kirkham, Slemmer, & Johnson, 2002). It is also reasonable to expect that such basic abilities are associated with recognition of and feeling comfortable in familiar environments and developing independence at successful navigation through one's environment at any age. From a more applied perspective, the possibility that implicit learning of statistical regularities may remain intact for persons with relatively lower explicit abilities is also important. It is important because implicit learning strategies can be developed that make use of this intact cognitive process to ameliorate declines in other more explicit cognitive processes. Broadly speaking, any preserved function may be useful in adapting to declines in other cognitive abilities. Of particular importance to many older adults is maintaining independence. The more it is possible to rely on these preserved cognitive processes rather than declining cognitive processes, the greater the likelihood of maintaining independence.

To summarize, our research provides additional support for the conclusion that young children can use statistical regularities in the environment to guide attention to the location of target objects in the environment. In addition, we observed a similar magnitude of this contextual cueing effect across variations in age and cognitive ability. Nevertheless, we suggest that there may be some important limits on the expression of this general ability that require further exploration.

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References

- Baltes PB. Theoretical propositions of life-span developmental psychology: On the dynamics between growth and decline. *Developmental Psychology*. 1987; 23:611–626.
- Brockmole JR, Castelano MS, Henderson JM. Contextual cueing in naturalistic scenes: Global and local contexts. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 2006; 32:699–706.
- Chun MM. Contextual cueing and visual attention. *Trends in Cognitive Sciences*. 2000; 4:170–178. [PubMed: 10782102]
- Chun, MM. Scene perception and memory. In: Irwin, D., Ross, B., editors. *Psychology of learning and motivation: Advances in research and theory: Cognitive vision*. Vol. 42. San Diego, CA: Academic Press; 2003. p. 79–108.
- Chun MM, Jiang Y. Contextual cueing: Implicit learning and memory of visual context guides spatial attention. *Cognitive Psychology*. 1998; 36:28–71. [PubMed: 9679076]
- Chun MM, Jiang Y. Implicit, long-term spatial contextual memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 2003; 29:224–234.
- Couperus JW, Hunt RH, Nelson CA, Thomas KM. Visual search and contextual cueing: Differential effects in 10-year-old children and adults. *Attention, Perception, & Psychophysics*. 2011; 73:334–348.
- Craik FIM, Bialystok E. Cognition through the lifespan: Mechanisms of change. *Trends in Cognitive Sciences*. 2006; 10:131–138. [PubMed: 16460992]
- De Neys W, Gelder EV. Logic and belief across the lifespan: The rise and fall of belief inhibition during syllogistic reasoning. *Developmental Science*. 2009; 12:123–130. [PubMed: 19120420]
- Dixon ML, Zelazo PD, De Rosa E. Evidence for intact memory-guided attention in school-aged children. *Developmental Science*. 2010; 13:161–169. [PubMed: 20121872]
- Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*. 2007; 39:175–191. [PubMed: 17695343]
- Fiser J, Aslin RN. Structural learning of higher-order temporal structure from visual shape sequences. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 2002; 28:458–467.
- Folstein MF, Folstein SE, McHugh PR. Mini-mental state: A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*. 1975; 12:189–198. [PubMed: 1202204]
- Howard JH Jr, Howard DV, Dennis NA, Yankovich H, Vaidya CJ. Implicit spatial contextual learning in healthy aging. *Neuropsychology*. 2004; 18:124–134. [PubMed: 14744195]
- Jenkins L, Myerson J, Hale S, Fry AF. Individual and developmental differences in working memory across the life span. *Psychonomic Bulletin & Review*. 1999; 6:28–40. [PubMed: 12199312]
- Jiang Y, Chun MM. Selective attention modulates implicit learning. *Quarterly Journal of Experimental Psychology*. 2001; 54:1105–1124. [PubMed: 11765735]
- Jungé JA, Scholl BJ, Chun MM. How is spatial context learning integrated over signal versus noise? A primacy effect in contextual cueing. *Visual Cognition*. 2007; 15:1–11. [PubMed: 18725966]
- Kaufman, AS., Kaufman, NL. Kaufman brief intelligence test. 2. Circle Press, MN: American Guidance Service, Inc; 2004.
- Kirkham NZ, Slemmer JA, Johnson SP. Visual statistical learning in infancy: Evidence for a domain general learning mechanism. *Cognition*. 2002; 83:B35–B42. [PubMed: 11869728]
- Kunar MA, Flusberg SJ, Wolfe JM. Time to guide: Evidence for delayed attentional guidance in contextual cueing. *Visual Cognition*. 2008; 16:804–825. [PubMed: 18846248]
- Negash S, Petersen LE, Geda YE, Knopman DS, Boeve BF, Smith GE, ... Petersen RC. Effects of ApoE genotype and mild cognitive impairment on implicit learning. *Neurobiology of Aging*. 2007; 28:885–893. [PubMed: 16701920]

- Nissley HM, Schmitter-Edgecombe M. Perceptually based implicit learning in severe closed-head injury patients. *Neuropsychology*. 2002; 16:111–122. [PubMed: 11853352]
- Ogawa H, Takeda Y, Kumada T. Probing attentional modulation of contextual cueing. *Visual Cognition*. 2007; 15:276–289.
- Olson IR, Chun MM. Perceptual constraints on implicit learning of a spatial context. *Visual Cognition*. 2002; 9:273–302.
- Riggs K, McTaggart J, Simpson A, Freeman R. Changes in the capacity of visual working memory in 5- to 10-year olds. *Journal of Experimental Child Psychology*. 2006; 95:18–26. [PubMed: 16678845]
- Saffran JR, Aslin RN, Newport EL. Statistical learning by 8-month-old infants. *Science*. 1996; 274(5294):1926–1928. [PubMed: 8943209]
- Smyth AC, Shanks DR. Awareness in contextual cuing with extended and concurrent explicit tests. *Memory & Cognition*. 2008; 36:403–415. [PubMed: 18426069]
- Tombaugh TN, McIntyre NJ. The Mini-Mental State Exam: A comprehensive review. *Journal of the American Geriatrics Society*. 1992; 40:922–935.
- Trick LM, Enns JT. Lifespan changes in attention: The visual search task. *Cognitive Development*. 1998; 13:369–386.
- Vaidya CJ, Huger M, Howard DV, Howard JH Jr. Developmental differences in implicit learning of spatial context. *Neuropsychology*. 2007; 21:497–506. [PubMed: 17605582]

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FIGURE 1.
Example of stimulus displays. (Color figure available online.)

FIGURE 2.
Means of median response times for training trials of the contextual cueing procedure.

TABLE 1
Mean KBIT-2 Scores and Average Median Response Time to Predictable and Unpredictable Displays of the Test Block

Group	KBIT-2		Predictable displays		Unpredictable displays	
	M	SD	M	SD	M	SD
Children	105	8.1	2939	670	3133	918
Young adults	105	8.2	1162	297	1226	318
Older adults	95	16.4	3197	976	3416	1294

Note. KBIT-2 = Kaufman Brief Intelligence Test–Second Edition.

TABLE 2

Average Median Response Time to Predictable and Unpredictable Displays of the Test Block for Higher and Lower Functioning Older Adults

Group (older adults)	Predictable		Unpredictable	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Lower functioning	3489	1143	3784	1566
Higher functioning	2924	727	3072	899