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# The acquisition of contextual cueing effects by persons with and without intellectual disability

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ABSTRACT

Two experiments were conducted to compare the acquisition of contextual cueing effects of adolescents and young adults with intellectual disabilities (ID) relative to typically developing children and young adults. Contextual cueing reflects an implicit, memory based attention guidance mechanism that results in faster search for target locations that have been previously experienced in a predictable context. In the study, participants located a target stimulus embedded in a context of numerous distracter stimuli. During a learning phase, the location of the target was predictable from the location of the distracters in the search displays. We then compared response times to locating predictable relative to unpredictable targets presented in a test phase. In Experiment 1, all of the distracters predicted the location of the target. In Experiment 2, half of the distracters predicted the location of the target while the other half varied randomly. The participants with ID exhibited significant contextual facilitation in both experiments, with the magnitude of facilitation being similar to that of the typically developing (TD) children and adults. We concluded that deficiencies in contextual cueing are not necessarily associated with low measured intelligence that results in a classification of ID.



## 1. Introduction

The ability to learn spatial layouts is integral to a number of important everyday activities. This is true for persons with intellectual disability (ID) as well as those without ID. For example, navigating a workplace, school, or local mall calls upon several abilities related to learning and remembering spatial layouts. Researchers have shown that learning spatial layouts can be accomplished in two fundamentally different ways. First, persons may explicitly memorize exact locations in the spatial layout and retrieve declarative information from long-term or visuo-spatial working memory (Meneghetti, De Beni, Gyselinck, & Pazzaglia, 2013; Nori, Grandicelli, & Giusberti, 2009). Second, persons may learn important features of the environment in an incidental and seemingly virtually implicit manner as evidenced by the phenomenon of contextual cueing (Chun & Jiang, 1998; Jiang & Chun, 2001). Our research is designed to focus on the implicit learning of spatial information.

Contextual cueing refers to a form of attentional guidance where the consistent pairing of a target's location with the locations of surrounding nontarget items apparently draws an individual's attention to the location of the target object without conscious awareness (Chun & Jiang, 1998). Hence, it is a memory-based attentional mechanism that reflects the learning of associations between a specific target location and the spatial arrangement of the context in which the target is

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embedded. In the initial studies demonstrating contextual cueing effects, participants were shown displays containing a target (e.g., the letter T rotated 90° in either direction) and several distracters (e.g., the letter L rotated 90°). Participants searched for the target and identified which direction the tail of the T was pointing. Because some of the configurations of the distracters were consistently associated with specific target locations across trials they always predicted the location of the target (repeated display condition). In contrast, some configurations of the distracters were random from trial to trial (new display condition). Even though participants were not told of the relation between the target and distracter locations, after several exposures to the repeated displays they responded faster to the repeated than new displays. This difference in response time was said to reflect a learning process referred to as contextual cueing. Importantly, tests of explicit memory for the layouts were conducted after the experiments. These tests indicated that the participants could not distinguish between the predictive and unpredictive configurations, suggesting that contextual cueing effects in this and similar procedures do not rely on explicit memory but are likely learned more implicitly and without awareness.

Recent research has shown that children and young adults with mixed-etiology ID do not necessarily have significant difficulty with implicit learning. In several studies persons with ID have actually performed as well as typically developing individuals of the same chronological age (Atwell, Conners, & Merrill, 2003; Maybery, Taylor, & O'Brien-Malone, 1995; Vinter & Detable, 2003). These findings are consistent with Reber's assertion that implicit learning is an evolutionarily primitive form of learning and should not vary with age and general intelligence (Reber, 1992). In addition, they suggest it is a form of learning that appears to be little affected by global cognitive impairments. However, it is now clear that implicit learning is not a unitary construct. There are several varieties of implicit learning (e.g., artificial grammar learning, serial reaction time learning, and contextual cueing) that operate in different domains of learning (Barnes, Howard, Howard, Kenealy, & Vaidya, 2010). It is reasonable to consider the possibility that a difference between persons with and without ID may exist in some forms of implicit learning and not in others.

All varieties of implicit learning share the same general characteristics. As a first basic tenet, researchers require that implicit learning involve a kind of learning that is largely unintentional. For example, in artificial grammar learning participants are exposed to a sequence of stimuli that is constructed on the basis of a set of probabilistic rules (e.g., Reber, 1967, 1976). With repeated exposure to the sequences (e.g., in a simple memory test) and without any mention of the rules used to construct them, participants are able to distinguish between new sequences that are constructed using the same rules from random sequences. In contextual cueing, participants are repeatedly exposed to a set of spatial layouts and asked to find a particular target. The participants are not told that each individual layout predicts where the target will be located. Yet, they become faster at locating the target in the repeated displays relative to unpredictable, random spatial layouts. In serial reaction time learning, participants are shown a series of cues and are asked to press a specific key for each cue. If the cues repeat in sequence, participants are faster to respond to repeated relative to random sequences even though they are not made aware of the repetition. Hence, none of these tasks relies on explicit instructions or learning to produce the expected effects. As a second basic tenet, participants must be generally unaware of what it is they have learned when they produce the effects. In artificial grammar learning, participants are unable to identify the rules of the grammar when asked to do so (Reber, 1992). In serial reaction time learning, participants are unable to reproduce the sequence from memory. In contextual cueing, tests of explicit memory for target locations typically yield performance at or near chance, indicating that participants are not aware of the relation between the target location and the surrounding context (e.g., Chun, 2003; Yang & Merrill, 2014).

Despite sharing these general characteristics of learning, the tasks that measure implicit learning are structured very differently and utilize different brain mechanisms for their execution. Based on brain imaging studies, researchers have concluded that contextual cueing seems to involve the hippocampus and adjacent medial temporal lobe structures (Chun & Phelps, 1999; Greene, Gross, Elsinger, & Rao, 2007). In addition, it appears that amnesiac patients with hippocampal damage do not show contextual cueing effects (Chun & Phelps, 1999). In contrast, implicit serial reaction time learning has been linked to the cerebellum and basal ganglia (Knowlton, Mangels, & Squire, 1996). Artificial grammar learning has been linked to Broca's area and implicit judgments of grammaticality are supported by the left superior occipital and inferior parietal cortex (Skosnik et al., 2002) while the medial temporal lobe is less active (Petersson, Folia, & Hagoort, 2012). Because different brain structures support different forms of implicit learning, it is reasonable to expect that performance levels associated with implicit learning can vary within individuals and depend on the form of implicit learning that is tested. Indeed, this position has received empirical support with dissociations between types of implicit learning being reported for persons with Parkinson's disease who exhibit impaired probabilistic serial reaction time learning but intact artificial grammar learning (Witt, Nuhsman, & Deuschl, 2002). Therefore, it is important to assess persons with ID on the different measures of implicit learning.

The two studies reported here are the first to evaluate implicit spatial learning using the contextual cueing task in persons with intellectual disability. In particular, we were interested in whether very low measured intelligence scores, as exhibited by persons with mild and moderate ID, would result in deficiencies in implicit spatial associative learning reflected by contextual cueing effects. Hence, we chose to compare the performance of adolescents and young adults with ID of mixed-etiology to typically developing (TD) children of similar mental age and young adults of similar chronological age who were used as a baseline of optimal performance against which to compare the other participants. In both experiments, we compare the relative magnitude of contextual cueing effects of adolescents/young adults with ID to typically developing children (TD) of approximately the same mental age (MA).

## 2. Experiment 1

In Experiment 1, we conducted a general assessment of the acquisition of contextual cueing effects. Participants were first exposed to repeated presentations of predictable displays in which the target location was 100% predictable from the locations of all of the distracters in the display. Following a series of exposures to the predictable displays, these displays were intermixed with new, unpredictable displays in which the location of the target could not be predicted from the location of the distracters. Contextual cueing effects were to be evidenced during this phase by faster response times to the predictable than to the unpredictable displays. Because implicit learning is presumed to be robust across varying levels of age and intelligence (Reber, 1992), we predicted that our participants with ID would exhibit significant contextual cueing under conditions similar to those in which TD children and adults without ID exhibit contextual cueing. This result would indicate that the mechanisms that support contextual cueing are available to persons with ID. However, no specific predictions about the relative magnitude of contextual cueing effects are possible based on the available literature. Any conclusion that suggests equivalence in contextual cue effects for persons with and without ID would necessarily require the acceptance of a null hypothesis. Hence, several replications with compelling similarities in performance would likely be needed to justify such a conclusion.

### 2.1. Method

#### 2.1.1. Participants

All procedures were approved by the IRB of the University of Alabama. Participants initially included 17 adolescents and young adults with intellectual disabilities (IDs) recruited from University of Alabama Intellectual Disability Registry, 15 typically developing first and second grade children recruited from local schools, and 15 college students recruited from Introductory Psychology classes at the University of Alabama. Two of the participants with ID were not able to finish the task due to a failure to understand the basic procedure and were dismissed from the study. In the final sample of participants with ID (11 males and 4 females), two had a diagnosis of Down syndrome, one had a diagnosis of Fragile X syndrome and 12 were of unknown etiology. The average chronological age (CA) for the ID group was 18.3 years old (sd: 5.7 years) and their average nonverbal mental age was 6.6 years (sd: 2.6 years) as measured by KBIT-II Matrices. The 15 typically developing children had a mean CA of 6.7 years (sd: 0.7 years) and a mean nonverbal MA of 6.9 years (sd: 0.6 years). The 15 college students had a mean CA of 18.9 years old (sd: 1.7 years) and a mean nonverbal MA of 16.2 (sd: 0.8). The MA scores for the TD and ID groups were not significantly different ($t(28) = .75$, $p = .46$). The CA scores for the college and the ID groups were not significantly different ($t(28) = .26$, $p = .80$).

#### 2.1.2. Measures

*2.1.2.1. Kaufman Brief Intelligence Test.* All participants completed the matrices subtest of the Kaufman Brief Intelligence Test: Second Edition. The matrices (nonverbal) subtest consists of 48 visual analogies presented on either $2 \times 2$ or $3 \times 3$ 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 matching TD children and participants with ID and to ensure that TD participants fell within the range of typical functioning. Webber and McGillivray (1998) reported good split half and test–retest reliability for 107 adolescents with ID between the ages of 12 and 16 (for composite scores, $r = .93$ and .88, respectively; for Matrices scales, $r = .71$ and .76, respectively). In addition, scores from the KBIT correlate substantially with scores from WISC-R (for composite scores, $r = .73$ and .52, respectively) and Raven Matrices (for the Matrices scales, $r = .53$ and .51, respectively).

*2.1.2.2. Contextual cueing.* Experimental materials for the contextual cueing task were patterned after Jiang and Chun (2001). In this visual search task, participants were presented displays containing a rotated letter "T" and 15 distracter letters (rotated letter "L"). The tail of the T and L could point to the right or the left. The participants needed to locate the T and identify which direction it was pointing by pressing the appropriate key on the computer keyboard. Response times were recorded to the nearest ms. The distracters were presented in two colors: red and blue. The target T was always in blue. Eight distracters were red and seven were blue, yielding an equal number of blue and red stimuli in each display.

Four configurations were constructed as the predictive displays. Unbeknownst to the participants, the quadrant in which the target appeared (but not the direction the T was pointing) was perfectly predictable from the arrangement of the nontargets in the displays during the learning phase of the procedure. Participants were not told that only four configurations of distracters were used during the learning phase. For the test phase, an additional 24 unpredictive displays were constructed in which the distracters in the displays were presented in random locations and did not predict the target location. See Fig. 1 for examples of these displays.

#### 2.1.3. Design and procedure

The KBIT matrices subtest was completed first by all participants. After a short break, this was followed by practice on the contextual cueing task for the children and participants with ID. The experimental version of the contextual cueing task was given after these participants mastered the practice version. The contextual cueing task consisted of two phases: a learning

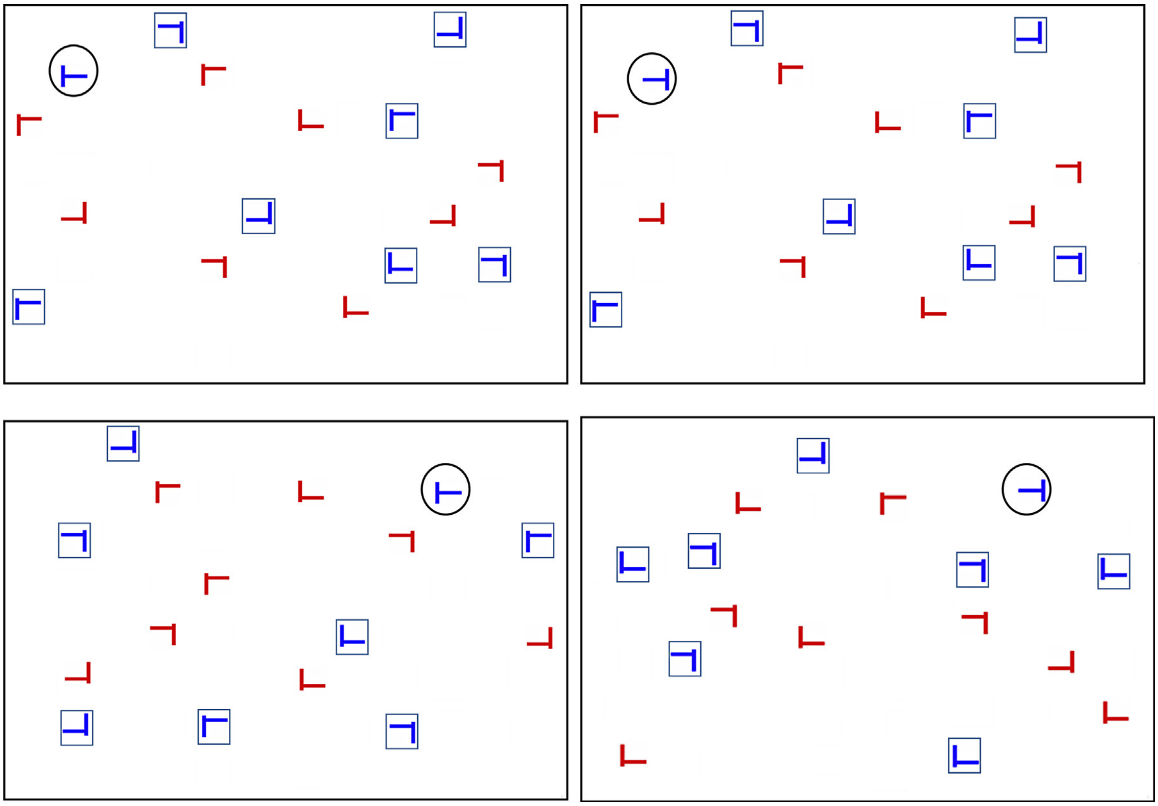

**Fig. 1.** Examples of the predictive (top) and unpredictive (bottom) displays used in Experiment 1. The circle used in each display was to highlight the location of the target for the readers' convenience and was NOT used in the actual testing. The squares (also not used in testing) designate the location of the blue distracters. In the predictive, repeated displays, the configurations of the distracters remained the same and they were consistently associated with the target. However, the configuration did not predict the specific response (which way the target T was pointing). In the unpredictive, new displays, all objects were presented randomly within the display and did not predict the location of the target stimuli. These trials were included in the test phase and served to test for implicit learning.

phase and a test phase. In the learning phase, there were 5 blocks with 48 predictable displays in each block. Each distracter configuration was presented 12 times per block, with the target facing left in half of the displays and right in half of the displays. Therefore during the learning phase each predictive distracter configuration was repeated a total of 60 times. It was followed by a test phase in which the predictive distracter configurations were presented 6 times each (24 total) and intermixed with the 24 new unpredictive distracter configurations. Participants were not informed of this change and completed the test block in the same manner as the learning phase. Participants completed 288 trials in total. The entire task took approximately 40 min to complete for the children and participants with ID. College students completed the task in about 20 min.

Prior to initiating the experimental procedure, children and participants with ID completed a practice test of 12 trials using displays of increasing complexity to familiarize them with the task. In the first four practice trials, there were two blue distracters and one blue target. Participants looked for the target and pressed the correct key based on the direction the T was facing. Keys were marked with a T facing left or right and participants were instructed to press the key that matched the target direction. In the next four practice trials, the displays contained three red distracters in addition to the blue distracters and the target. The last four trials consisted of the same number of distracters as the experimental trials. Participants continued in the formal experiment only after demonstrating they understood the task and knew how to respond. Participants were told explicitly that the target was always in blue. However, they were not told that some displays would be repeated. Both speed and accuracy were emphasized throughout the testing. A break was provided after each block and participants could take as long as they wished until they were ready to continue. During breaks, the experimenter engaged the TD children and participants with ID in conversation and encouraged continued high level of performance in the task. Breaks lasted until participants said they wanted to continue. All of the children indicated a readiness to continue prior to initiating the next block of trials. To further engage TD children and participants with ID, they were provided with a picture of a football field and a football player figure. Each time they finished a block of trials, they moved the football player twenty yards down field toward the end zone. A touchdown was scored when they complete the task. Children and participants with ID were paid $5.00 for their participation. College students received course credit.

## 2.2. Results

### 2.2.1. Data analysis plan

Data were analyzed in four steps. First, we evaluated error rates across all trials and then separately for the test trials. After deleting error responses, median reaction times (RTs) were obtained for each participant for each block and each type of display. We used medians rather than means to limit the influence of extreme scores on the analysis, which were slightly more common for the participants with ID and the TD children than for the college students. These data were subjected to three primary analyses. First, we compared RTs of the learning phase for repeated trials. This analysis provided a measure of general learning and performance. Improvement in performance during this phase might include changes in, for example, search efficiency, decision making, and contextual cueing (which would be expected to develop over the course of the learning phase). Second, we compared RTs of the predictive vs. unpredictive trials of the test phase as a measure of contextual cueing. Contextual cueing would be evidenced by faster RTs in the predictable vs. the unpredictable trials. Third, we converted RTs to a measure of facilitation for predictive relative to unpredictive trials to compare the benefit of contextual cueing across groups. The purpose of this analysis was to evaluate the relative magnitude of contextual cueing exhibited by the three groups after taking into account differences in overall RT. These analyses are reported separately below.

### 2.2.2. Error rates

Overall average error rate across all the trials for the participants with ID was 10.7% (range: 0.3–26.4%). Average error rate for the TD children was 2.6% (range: 0–13.5%). Average error rate for the adults was 1.7% (range: 0–4.5%). Analysis revealed a significant difference between groups $F(2, 42) = 11.87$, $p < .001$, $\eta^2 = .361$. Post hoc comparisons using Tukey HSD suggested that both adults and TD children committed fewer errors than did the participants with ID, both $p$'s $< .05$, but did not differ from each other. We subsequently looked at error rates separately for the test phase, during which contextual cueing was actually measured, and found that average error rates were less than 2.0% for all groups (1.9% for the ID participants, 0.6% for the TD participants, and 0.2% for the adult participants). These error rates were deemed acceptable and were not subjected to further analysis.

### 2.2.3. Reaction times in the learning phase

A 3 (Group: Adult, TD children, and ID) × 5 (blocks) ANOVA with repeated measure on block was conducted to assess general practice and learning effects (see Fig. 2 for data). The analysis indicated a significant main effect of group, $F(2, 42) = 14.55$, $p < .001$, $\eta^2 = .409$ (Greenhouse–Geisser method was used since sphericity was not assumed). Tukey HSD comparisons indicated that adults (mean = 2414.67 ms) responded significantly faster ($p < .001$) than TD children

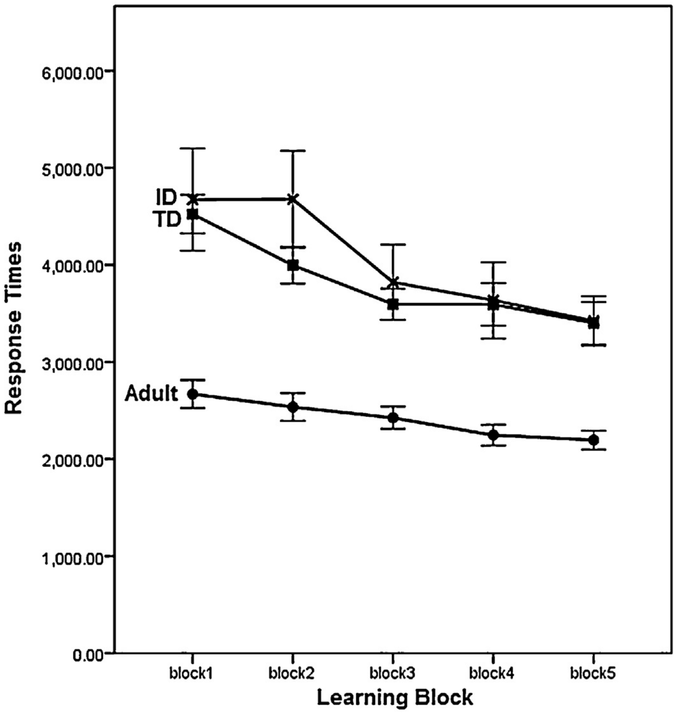


**Fig. 2.** RTs in each acquisition block in Experiment 1. Error bars = ±1.0 SE.

**Table 1**
Mean RT (ms) in the test phase of Experiments 1 and 2 (standard error in parenthesis).

| | Predictive displays | Unpredictive displays | Contextual cueing (predictive–unpredictive) | Sig. (two tailed) |
|---|---|---|---|---|
| Experiment 1 | | | | |
| Adults | 2071 (78) | 2408 (94) | 337 (94) | $p = .003$ |
| TD children | 3571 (228) | 4203 (298) | 632 (271) | $p = .035$ |
| People with ID | 3237 (339) | 3817 (353) | 594 (103) | $p < .001$ |
| Experiment 2 | | | | |
| Adults | 2179 (131) | 2394 (115) | 215 (90) | $p = .031$ |
| TD children | 3098 (281) | 3584 (337) | 486 (180) | $p = .017$ |
| People with ID | 2629 (237) | 2929 (258) | 300 (116) | $p = .021$ |

*Note*: Significance levels were established based on paired sample *t*-tests between predictive and unpredictive displays of each group.

(mean = 3821.65 ms) and participants with ID (4045.33 ms), who did not differ from each other. There was also a significant main effect of block, $F(2.49, 104.53) = 16.00$, $p < .001$, $\eta^2 = .276$, indicating that participants responded faster over time. The interaction between block and group was not significant, $F(4.98, 104.53) = 1.74$, $p = .132$, $\eta^2 = .077$, suggesting similar decreases in RT with block for all three groups. In addition, these data indicate that there was not a decline in performance that could be attributed to fatigue with the contextual cueing task over time.

*2.2.4. Reaction times in the test phase*

We conducted a 3 (Group: Adult, TD children, and ID) $\times$ 2 (Type: predictive vs. unpredictive) ANOVA on RTs of the test phase (see Table 1 for mean RTs). There was a significant main effect of group, $F(2, 42) = 12.83$, $p < .001$, $\eta^2 = .379$. Tukey HSD indicated that adults responded significantly faster (*p*s $< .001$) than TD children and participants ID. The TD children and participants with ID were not different from each other. The main effect of Type was also significant, $F(1, 42) = 25.78$, $p < .001$, $\eta^2 = .380$, indicating that participants responded faster to the predictive than unpredictive displays. The interaction between group and type, however, was not significant, $F(2, 42) = 80$, $p = .458$, $\eta^2 = .036$. Hence, the primary analyses indicated that all three groups demonstrated significant contextual cueing effects and the magnitude of contextual cueing did not differ significantly between groups. We subsequently confirmed that significant contextual cueing was observed for each group using paired *t*-tests comparing RTs in the predictive and unpredictive conditions for each group (see Table 1).

*2.2.5. Proportion of facilitation*

To be able to directly compare contextual cueing effects of groups who have different reaction time baselines, we also calculated the proportion of facilitation (POF) as defined as:

$$\text{POF} = \frac{\text{unpredictive RT} - \text{predictive RT}}{\text{unpredictive RT}}.$$

These data are reported in Table 2. This approach thus takes into account that the different age groups had different RT baselines. POF essentially reflects the degree to which RTs were facilitated by exposure to the predictive displays. A one way ANOVA on the POF scores indicated that the difference between three groups was not significant, $F(2, 42) = 0.24$, $p = .787$, $\eta^2 = .011$. Hence, the analysis of POF scores confirmed that groups did not significantly differ in the magnitude of contextual cueing effects.

## 3. Experiment 2

In Experiment 2, we assessed whether the presence of unpredictive stimuli in the predictive displays interfered with the acquisition of contextual cueing effects for participants with ID. Jiang and Chun (2001) have demonstrated that contextual cueing can be acquired by young adults without ID when as few as half of the distracters predict the location of the target. In their study, the target letter T was presented in red and the distracters were either red or green. When only the distracters that were in the same color as the target predicted its location (with the different color distracters being in random locations with each repetition of the display), contextual cueing still accrued with repeated exposure. We wanted to assess this in participants with ID for two reasons. First, it is reasonable to think that spatial regularities in the world are seldom 100%

**Table 2**
Percent of facilitation (POF) in three age groups in Experiments 1 and 2 (standard error in parenthesis).

| | Adults | TD children | People with ID |
|---|---|---|---|
| Experiment 1 | 12.9% (3.7%) | 12.0% (5.5%) | 15.9% (2.6%) |
| Experiment 2 | 8.7% (3.56%) | 10.9% (4.66%) | 8.7% (4.1%) |

predictable. Hence, the introduction of irrelevant and unpredictive distracters would be necessary to understand contextual cueing in non-laboratory settings. Second, the ability to exhibit contextual cueing effects under these conditions has been shown to vary with age. Couperus, Hunt, Nelson, and Thomas (2011) used the Jiang and Chun procedure with children and found that while adults exhibited contextual cueing effects when the predictive to unpredictive distracter ratio in the displays was 50:50, 10 year old children did not exhibit contextual cueing unless 75% of the distracters predicted the location of the target. Therefore, in Experiment 2 we repeated the basic procedure of Experiment 1 with the exception that only 50% of the distracters in the repeated, predictive displays accurately predicted the location of the target. Based on the results of the child participants in Couperus et al. (2011), we expected that adults without ID would exhibit contextual cueing effects in Experiment 2, whereas the TD children and participants with ID would not.

### 3.1. Method

#### 3.1.1. Participants

The participants in Experiment 2 included 18 adolescents/young adults with intellectual disabilities (IDs) recruited from the UA Intellectual Disability Participant Registry, 15 typically developing children recruited from local schools, and 15 college students recruited from Introductory Psychology classes at the University of Alabama. Two of the participants with ID committed too many errors (over 50%) and one insisted on using one hand rather than two hands to respond. The data from these three participants were not included in the final analyses. In the final sample of participants with ID (seven males and eight females), seven had a diagnosis of Down syndrome, and eight were unknown etiology. The average chronological age for the ID participants was 21.5 years old (sd: 4.9). The average MA as measured by KBIT-II Matrices for the ID participants was 7.2 years old (sd: 3.3). The 15 typical developing children had a mean CA of 6.7 (sd: 0.5) years and a mean nonverbal MA of 6.9 years (sd: 0.6). The 15 college students had a mean CA of 19.4 years (sd: 2.3) and a mean nonverbal MA of 16.4 (sd: 0.7). The MA scores for the TD and ID groups were not significantly different ($t(28) = .52$, $p = .61$). The CA scores of the college and ID groups were not significantly different ($t\ (28) = 1.48$, $p = .15$).

#### 3.1.2. Experiment materials and procedures

The materials were identical to Experiment 1 with the exception of the predictable, repeated displays. In the predictable displays of Experiment 2, only the locations of the blue distracters (referred to as attended distracters) predicted the locations of the target while the locations of the red distracters (referred to as unattended distracters) were randomly located from trial to trial. Hence, overall 50% of the distracters on each trial predicted the location of the target in these displays. As in Experiment 1, the direction the T was pointing was not predicted from the location of the distracters. Examples of the predictive displays are presented in Fig. 3. The general procedures and order of testing were identical to Experiment 1.

### 3.2. Results

#### 3.2.1. Data analysis plan

As in Experiment 1, data were analyzed in four steps. First, we evaluated error rates across all trials and then separately for the test trials. Next, we compared median RTs of the learning phase for repeated trials. Then, we compared median RTs of the predictive vs. unpredictive trials of the test phase as a measure of contextual cueing. Finally, we converted RTs to a measure of facilitation for predictive relative to unpredictive trials to compare the relative magnitude of contextual cueing exhibited by the three groups.

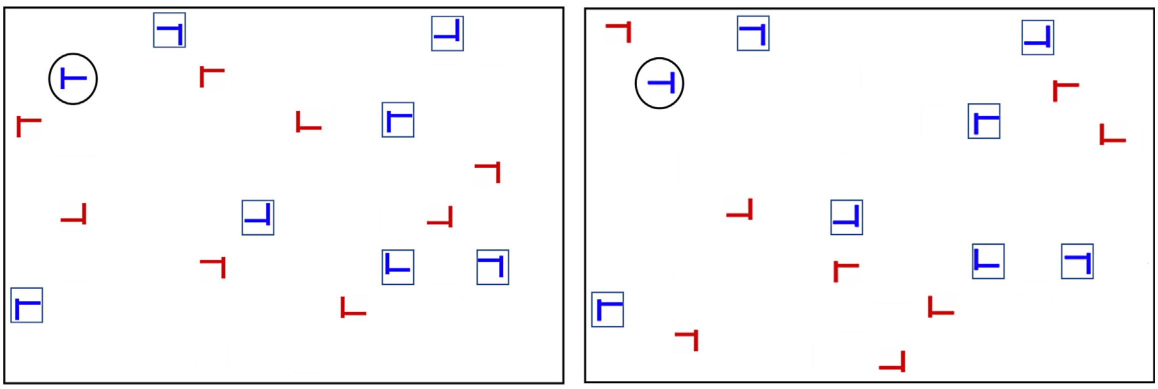

**Fig. 3.** Examples of the predictive displays in Experiment 2. The circle used in each display was to highlight the location of the target for the reader's convenience and was NOT used in the actual testing. The squares (also not used in testing) designate the location of the blue distracters. In these repeated displays, the configurations of the blue distracters remained the same and they were consistently associated with the blue target. Meanwhile, the configurations of the red distracters were random from trial to trial.

*3.2.2. Error rates*

Average Error rate for the ID group was 10.0% ranging from 0.3% to 36%. Average error rate for the TD children group was 3.0% ranging from 0% to 17.7%. Average error rate for the adult group was 1.4% ranging from 0% to 4.1%. Analysis of the error rates indicated a main effect of group, $F(2, 42) = 6.88$, $p = .003$, $\eta^2 = .247$. Post hoc comparisons using Tukey HSD again suggested that both adults and TD children committed fewer errors than did the participants with ID, both $p$'s $< .05$, but did not differ from each other. As was the case with Experiment 1, average error rates during the test phase were less than 2.0% for all groups (1.6% for the ID participants, 0.6% for the TD participants, and 0.3% for the adult participants). Again, these error rates were deemed acceptable and were not subjected to further analysis.

*3.2.3. Reaction times in the learning phase*

A 3 (Group: Adult, TD children, and ID) $\times$ 5 (blocks) ANOVA with repeated measure on block was conducted to assess general practice and learning effects (see Fig. 4 for data). There was a main effect of block, $F(3.09, 130.0) = 12.25$, $p < .001$, $\eta^2 = .226$ (Greenhouse–Geisser method was used), indicating that participants responded faster with practice. The main effect of group was also significant, $F(2, 42) = 6.34$, $p = .004$, $\eta^2 = .232$. Post hoc comparison indicated that adults (mean = 2404.17 ms) responded significantly faster ($p < .05$) than TD children (mean = 3418.41 ms) and participants with ID (3306.61 ms), with the latter two groups not differing significantly from each other. The interaction between block and group was also significant, $F(6.17, 130.0) = 3.75$, $p < .001$, $\eta^2 = .151$. Post hoc comparison tests were conducted to compare the RTs among three groups in each block. Results indicated that adults consistently responded significantly faster than TD children and ID participants, but that the magnitude of the difference was somewhat larger in Block 1 than it was in Block 5 between the ID and adult participants ($p < .05$). As in Experiment 1, these data also indicate that there was not a decline in performance that could be attributed to fatigue with the contextual cueing task over time.

*3.2.4. Reaction times in the test phase*

We conducted a 3 (Group: Adult, TD children, and people with ID) $\times$ 2 (Type: predictive vs. unpredictive) ANOVA on reaction times in the test phase (see Table 1 for data). There was a main effect of group, $F(2, 42) = 5.23$, $p = .009$, $\eta^2 = .200$. Tukey HSD post hoc tests suggested that adults responded significantly faster ($p = .002$) than TD children. The participants with ID did not differ from either adults ($p = .139$) or TD children ($p = .092$). The main effect of Type was also significant, $F(1, 42) = 18.56$, $p < .001$, $\eta^2 = .306$, indicating that overall participants responded faster to the predictive than unpredictive displays. The interaction between group and type, however, was not significant, $F(2, 42) = 1.07$, $p = .354$, $\eta^2 = .048$. As in Experiment 1, the primary analyses indicated that all three groups demonstrated significant contextual cueing effects and the magnitude of contextual did not different significantly between groups. We subsequently confirmed that significant

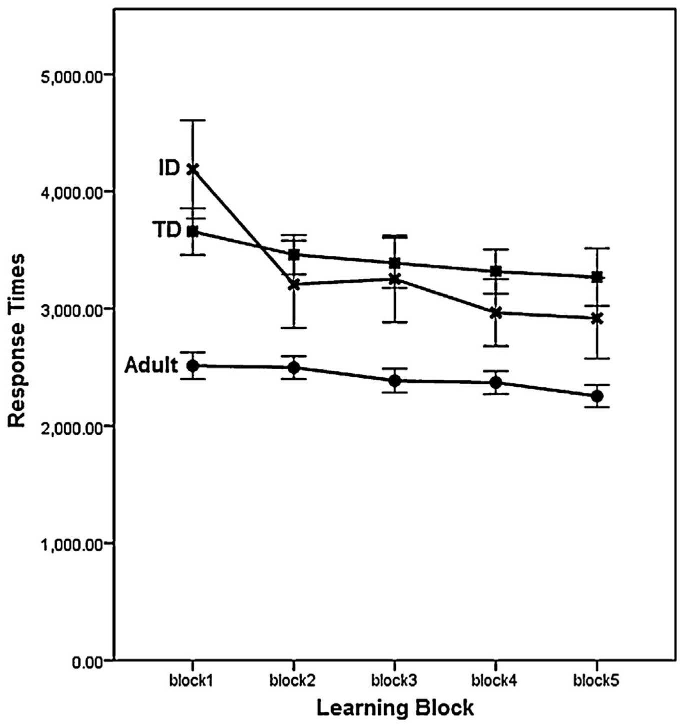


**Fig. 4.** RTs in each acquisition block in Experiment 2. Error bars = ±1.0 SE.

contextual cueing was observed for each group using paired *t*-tests comparing RTs in the predictive and unpredictive conditions for each group (see Table 1).

*3.2.5. Proportion of facilitation*

As in Experiment 1, we also calculated POF associated with contextual cueing to evaluate possible group differences (see Table 2). A one-way ANOVA on POF for the three groups indicated the effect of Group was not significant, $F(2, 42) = 0.097$, $p = .908$, $\eta^2 = .005$. Hence, as in Experiment 1, it appears that the magnitude of contextual cueing effects was essentially the same for the three groups tested.

## 4. Supplemental analysis

To compare the magnitudes of contextual cueing between Experiments 1 and 2, we conducted a 2 (Experiment: 1 vs. 2) x 3 (Group: Adults, TD children, and people with ID) ANOVA on the POF scores. The main effect of Experiment was not significant, $F(1, 84) = 1.18$, $p = .282$, $\eta^2 = .028$. The main effect of Group was also not significant, $F(2, 84) = 0.093$, $p = .912$, $\eta^2 = .004$. In addition, the interaction was not significant, $F(2, 84) = 0.212$, $p = .810$, $\eta^2 = .010$. Therefore the three groups appear to have exhibited similar magnitudes of contextual cueing whether all the distracters predicted the target (i.e., in Experiment 1) or only the distracters that shared the same color with the target were predictable (i.e., in Experiment 2). However, as discussed earlier these conclusions are based on a failure to reject the null hypothesis and will require confirmation in future studies.

## 5. Discussion

We compared the performance of TD children and adults with participants with ID in two versions of a contextual cueing procedure. In Experiment 1, all of the distracter locations in the repeated displays accurately predicted the location of the target. In Experiment 2, only the distracters that were the same color as the target predicted the location of the target. In both experiments, our results revealed a fundamental similarity in the performance of the three groups in the contextual 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 also 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 have attributed this result to implicit rather than explicit learning because previous research with adults using the same task indicated that they could not explicitly state where the target should be in a predictable display when the target was absent. In addition, because the magnitude of facilitation was very similar for the TD children, adults, and participants with ID, we concluded that contextual cueing effects are relatively stable across a wide IQ range.

Throughout this discussion, we have presumed that the participants had performed our contextual cueing task in a relatively implicit manner. However, we did not directly test participants' conscious awareness of the relation between the target locations and distracters in the repeated trials of these experiments. Our presumption is based on the general observation that TD adults and children are unable to explicitly report where the target should be in repeated displays similar to the ones we used here even after they have viewed them as many as 25–30 times each (see Chun, 2003; Chun & Jiang, 1998; Merrill, Conners, Roskos, Klinger, & Klinger, 2013; Yang & Merrill, 2014). Because of these data, we are reasonably certain that given their difficulties with explicit learning and memory, the performance of the participants with ID was also relatively implicit in nature. Hence, we have concluded that the improved performance of all participants reflects more of a feeling of knowing experience rather than an explicit memory of the target locations.

The observation that persons with ID and TD children exhibited facilitation effects in the contextual cueing task that are similar in magnitude to the adult participants is consistent with Reber (1992) who suggested that implicit learning, in general, should be relatively robust across variations in age and ability. While contextual cueing has previously been reported in children as young as 6 years old (Merrill et al., 2013; Yang & Merrill, 2014), this is the first study to report contextual cueing effects in persons with ID. We believe that our results indicate that the memory-based attentional guidance effect we observed is not directly susceptible to the influence of changes resulting from increases in ability, experience or knowledge. For example, even though variations in functional memory capacity have been observed across the age range of our participants (Riggs, McTaggart, Simpson, & Freeman, 2006) and between persons with and without ID (Schuchardt, Gebhardt, & Mäehler, 2010), such differences do not impact contextual cueing. Hence, we can infer that the expression of contextual cueing is not directly related to working memory limitations. In addition, there are well documented variations in cognitive control that are related to age (e.g., De Neys & Van Gelder, 2009, Trick & Enns, 1998) and IQ (e.g., Conners, Carr, & Willis, 1998; Danielsson, Henry, Rönnberg, & Nilsson, 2010; Levén, Lyxell, Andersson, Danielsson, & Rönnberg, 2008). The fact that we found fairly equivalent contextual cueing effects across age and IQ indicates that the mechanisms responsible for cognitive control do not impact the expression of contextual cueing.

Interestingly, we did not find that the introduction of irrelevant distracters in Experiment 2 had a differential impact on acquiring contextual cueing effects as a function of age or IQ. This is somewhat surprising in light of the fact that differences have been reported between young adults and 10 year old children using a similar procedure (Couperus et al., 2011). Couperus et al. (2011) reported that 10-year-old children exhibited contextual cueing effects only if the displays included a high ratio (75:25) of predictive distracters (those appearing in the same color as the target that consistently covaried with the location of the target) to unpredictive non-targets (those appearing in a different color from the target that did not covary with the location of the target). Young adults, but not the 10 years old, were able to learn the repeated spatial layouts when only 50% of the distracters predicted the location of the target. In the study reported here, young TD children (6–7 years old) and participants with ID demonstrated contextual cueing effects when the ratio of predictive and unpredictive distracters was 50:50. We would hypothesize that the difference in results is due to a relatively small difference in experimental procedures. Couperus et al. mixed repeated, predictive displays with new, unpredictive displays throughout acquisition whereas we did not introduce the unpredictive displays until the test phase. It is reasonable to conclude that our procedure provided for a greater signal to noise ratio overall than did the Couperus et al. procedure. More specifically, 50% of the displays during exposure were essentially random noise in the Couperus et al. study. In addition only 50% of the distracters in the predictive displays predicted the location of the target, making only 25% of the distracter information relevant signal. In our study, 50% of the distracters provided a relevant signal. Hence, it is reasonable to expect that we would observe contextual cueing in our procedure where it was not observed in previous research.

It is important to note that selective attending to the predictive distracters in our Experiment 2, as well as those used by Jiang and Chun (2001), may have been a byproduct of the visual search process (see also Yang & Merrill, 2014). It is generally thought that results such as these indicate that if the predictive and nonpredictive context can be separated on the basis of simple visual features such as color (Jiang & Chun, 2001) then the subset of distracters that are less similar to the target can be rejected preattentively and attention can be focused on those distracters that share a feature with the target. Preattentive selection processes are typically presumed to operate on a small set of basic visual features such as color, orientation, and size (see Treisman, 1988; Wolfe, 1994, 2007). Hence, the contexts of Experiment 2 may have functionally been treated as 100% predictable. Nevertheless, the signal to noise ratio distinction between our research and that of Couperus et al. (2011) would still apply. Signal would be available in 100% of the exposure trials in our Experiment 2 and only 50% of the exposure trials in Couperus et al. This pattern of difference suggest that one important goal of future research may be to determine the particular ratios of signal and noise that are necessary for contextual cueing to be established as a function of age and intellectual ability.

Despite the general similarity in contextual cueing effects we observed in these two studies, we cannot conclude that implicit spatial learning will operate similarly for persons of all ages and ability levels in all conditions. First, it is important to acknowledge that in our experiments we only evaluated the end product of learning. More specifically, by the time the test phase was initiated all participants were performing at near 100% on the search task. It is true that performing at 100% accuracy does not indicate that learning had necessarily reached asymptote by the time testing had occurred. There are a number of processes that could still be changing in efficiency during the test phase (overall search efficiency and decision-making strategies). Nevertheless, the amount of exposure during the learning phase should have been sufficient to allow the emergence of contextual cueing effects. Chun and Jiang (1998) have observed contextual cueing in as few as five repetitions of the target displays. Hence, our data do not address possible differences in the rate at which contextual cueing effects develop across groups, rather only that the end product seems very similar.

Second, there may be important limits on whether or not contextual cueing will be expressed by children and by persons with ID under different conditions. Research with young adults without ID indicates it is unlikely that implicit contextual cueing effects are the necessary result of simple, repeated exposure to regularities in the environment. Further, several variables are known to influence the expression of contextual cueing. These 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 manipulation of various aspects of the perceptual environment (Brockmole, Castelhano, & Henderson, 2006; Olson & Chun, 2002). To the extent that these variables and others are systematically related to age and ability level, then we should expect differences in the expression of contextual cueing effects to be related to age and ability level as well.

Our results are also limited to conclusions about the role of low intelligence on the expression of contextual cueing and are not generalizable to all etiologies that result in ID. Recent research has indicated that some etiologies leading to an ID classification exhibit impairments in some forms of implicit learning. Vicari, Verucci, and Carlesimo (2007) compared the performance of persons with ID resulting from Williams syndrome to those with ID resulting from Down syndrome on an implicit serial reaction time task. They found that implicit procedural learning of the persons with Williams syndrome was impaired relative to that of the persons with Down syndrome. In addition, the performance of the persons with Down syndrome was similar to that of a mental age matched comparison group. Hence, the expression of implicit learning in the serial reaction time task was dependent on etiology even though the two groups were matched on IQ. However, even though Vicari and colleagues reported similar serial reaction time learning between persons with Down syndrome and a typically developing mental age comparison group, Klinger and Dawson (2001) reported that persons with Down syndrome were impaired relative to a similar comparison group on a task measuring implicit prototype formation, which reflects the learning of an average category exemplar through the simple exposure to several different instances of that category. Results such as these also reflect the importance of systematically evaluating the different varieties of implicit learning paradigms in persons with ID resulting from different etiologies.

We fully expect that the products of implicit spatial learning will complement those of explicit learning. In many situations, implicit knowledge should facilitate later explicit learning. For example, implicit knowledge of a neighborhood should make it easier to explicitly learn how to find other locations in that neighborhood. Implicit knowledge also allows us to keep track of where to find important signals in the environment when explicit processes are otherwise engaged (e.g., we can find ''EXIT'' signs in buildings even though we have not explicitly learned their locations). Our research reveals important similarities in these abilities between persons with and without ID. While it is likely this basic similarity does not indicate that persons with and without ID perform implicit learning tasks in an identical manner, the fact that they are functional may provide an avenue for transmitting important information to persons with ID that they can use in everyday activities.

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