

**Title:** Spatial and identity cues differentially affect implicit learning of children with autism in the contextual cueing task with human characters stimuli

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**Introduction:** Contextual cueing is a classical paradigm that has been used to indicate possible impairments in implicit learning of individuals with autism spectrum disorder (ASD). Earlier studies in ASD using tasks similar to Chun and Jiang (1998), i.e., letters as stimuli, indicated that individuals with ASD demonstrated similar amounts of implicit learning as typically developing (TD) participants (Barnes et al., 2008; Brown et al., 2010; Kourkoulou et al., 2012). Chun and Jiang's (1998) contextual cueing task was designed to mainly rely on spatial contextual cues embedded in both global and local contexts. However, contextual cueing tasks also offer stimulus-identity cues (i.e., the identification features of the target and surrounding distractor stimuli). Spatial cues and stimulus-identity cues are thought to rely on distinct neural networks (Huang & Grossberg, 2010). Travers et al. (2013) used a contextual cueing task with cartoon characters stimuli and found that when only stimulus-identity cues were provided, adolescents and adults with ASD had difficulty with implicit contextual cueing, but when both stimulus-identity and spatial cues were provided, participants with ASD demonstrated the same rate of learning as TD participants. However, children with ASD show different visual attention to the social stimuli of static cartoons vs. people (Sedeyn, 2017). Given that children with ASD need to interact with people in the real world, the present studies examined how spatial and identity cues differentially affect the implicit learning performance of children with ASD in a revised version of the contextual cueing task, using photos of people.

**Method:** There are two studies. In study 1, 26 children with ASD and 28 IQ- and age-matched TD children completed a revised version of contextual cueing task in which the overall spatial configuration of human characters stimuli remains constant across trials. This task emphasizes the individual identities of the distractors in predicting the location of the target character. Participants were shown the picture of the target and instructed to find the target as quickly and as accurately as possible and press the keyboard key corresponding to the quadrant in which the target was located. For each trial, a fixation cross was displayed in the middle of the screen for 1.667 ms, followed by a matrix of 20 child characters arranged into four quadrants. Each matrix was presented until participants responded by pressing the correct response button indicating the target location. Participants completed 8 blocks (48 trials/block) of these visual search trials (6 predictable blocks, followed by a 7th unpredictable block, and an 8th predictable block). For each predictable block, 16 different predictable stimuli were presented three times each in a random order. Similarly, 16 unpredictable stimuli were presented three times each in a random order in the unpredictable block. After the contextual cueing task was completed, participants completed an explicit awareness test. Study 2 included 27 children with ASD and 29 TD children matched for age and IQ. The procedure for study 2 was the same as in study 1, except that this paradigm provided both spatial-configuration cues and stimulus-identity cues.

**Results:** Reaction times were used as the dependent variable. Prior to analyses, we did reaction time trimming based on extreme outliers. For the study 1 learning phase (predictable blocks 1-5), we conducted a 2 (group)  $\times$  5 (block) mixed ANOVA, and found significant main effects for group and block,  $F(1,52) = 6.537, p < .050, \eta^2 = .112, F(4,208) = 29.706, p < .000, \eta^2 = .364$ . The ASD group performed the predictable visual search task more slowly than the TD group, and both groups of participants were faster in later vs. earlier blocks. There was no significant interaction between group and block,  $F(4,208) = 0.743, p = .564, \eta^2 = .014$ , suggesting the rate of learning across the 5 blocks was similar in both groups. To examine implicit contextual learning, we calculated the percent decrease in reaction time that occurred in the predictable trial blocks (blocks 6 and 8) compared to the unpredictable trial block 7. We found no significant group difference in the percent of decrease in reaction time,  $t(52) = 1.155, p = .253$ , Cohen's  $d = 0.311$ ; further analysis found reliable contextual cueing effects in the ASD group,  $t(25) = 2.383, p < .050, r^2 = .185$ , and also robust contextual cueing effects in the TD group,  $t(27) = 5.249, p < .000, r^2 = .505$ .

For study 2, we used the same analytic approach. During the learning phase, there was a significant main effect for group,  $F(1,54) = 9.476, p < .010, \eta^2 = .149$ , as well as for block,  $F(4,216) = 13.349, p < .000, \eta^2 = .198$ , with no significant interaction between

group and block,  $F(4,216) = 0.656$ ,  $p = .623$ ,  $\eta^2 = .012$ . Examining implicit contextual learning, we found a marginally significant group difference in the percent decrease in reaction time,  $t(54) = 1.874$ ,  $p = .066$ , Cohen's  $d = 0.50$ , with no reliable contextual cueing effects in the ASD group,  $t(26) = 0.773$ ,  $p = .446$ ,  $r^2 = .022$ , but robust contextual cueing effects in the TD group,  $t(28) = 3.878$ ,  $p < .010$ ,  $r^2 = .349$ . In addition, the groups did not differ on accuracy for the memory test, and accuracy was not significantly better than chance (25%) for either group.

**Discussion:** The current studies found that children with ASD are able to implicitly learn the relation between the location of the target and the context (the surrounding human characters) as well as TD participants, using only stimulus-identity contextual cues. But when both stimulus-identity and spatial cues were provided, the ASD group demonstrated decreased implicit contextual learning compared to the TD group. These findings contrast with those of Travers et al. (2013), who found participants with ASD performed poorly with only stimulus-identity cues, but showed similar implicit contextual learning compared to TD peers with both spatial and stimulus-identity cues. A small but growing body of research suggests ASD children process cartoon stimuli in more configural, gestalt or holistic styles and photos of people in more local and piecemeal styles (Brosnan et al., 2015; Rosset et al., 2007). Because we used photos of people, children with ASD may have processed the contextual cues in a local, item- to- item manner. With only stimulus-identity cues, this style allowed similar implicit contextual learning for ASD children as those in the TD group, although with overall slower responses. Adding spatial cues to stimulus-identity cues potentially led to task overload, with children with ASD unable to effectively process both cue types simultaneously. The current results are consistent with weak central coherence theory (Frith, 1989) that predicts individuals with ASD will excel in tasks where attention to local information is advantageous, but do poorly in tasks requiring integration of features to derive the configuration and meaning of a stimulus. In daily life, if children with ASD cannot dynamically adjust their behavior according to environmental requirements, they may have difficulty in implicit learning of associations or probabilities in natural contexts.

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