Intact selective attention supports context memory in adults with autism spectrum disorder

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Abstract

Research on memory in autism spectrum disorder (ASD) finds increased difficulty encoding contextual associations in episodic memory and suggests executive dysfunction and deficient metacognitive monitoring as potential contributing factors. Using an aging framework, we tested the effects of selective attention on context memory in ASD. We evaluated memory performance, hyper-binding, and metamemory performance in a novel context memory task. Results showed that adults with ASD performed similarly to typically developed adults on all measures. We conclude that context memory performance is not disrupted in adults with ASD, even when demands on selective attention are high, and discuss the need for continued research to evaluate well-known neurotypical aging effects on episodic memory and further investigate the metacognitive profile in ASD.

Keywords: autism, attention, context memory, metamemory

Research Highlights

- Adults with autism perform similarly to typically developing adults on tests of item and context memory
- Adults with autism show no evidence for hyper-binding which may suggest intact selective attention
- Adults with autism show similar metacognitive performance for context judgments to neurotypical adults

Intact selective attention supports context memory in adults with autism spectrum disorder

Autism spectrum disorder (ASD) is characterized by both socio-communicative impairments and restricted or stereotypical patterns of interests and behavior[1]. It is becoming increasingly clear that memory deficits may be present in populations with neurodevelopmental disorders, including adults with ASD[2]. The memory profile of individuals with ASD suggests that deficits are not homogenous across all memory subsystems[3] or uniform across individuals with ASD[4]. However, episodic memory is one area where research has predominantly found evidence for mild impairment in individuals with high-functioning autism (HFA) or Asperger's syndrome[5,6].

Episodic memory is long-term memory for our daily life experiences. Episodic memory includes encoding of contextual features (location, time of event) associated with the event itself, which allow us to distinguish events from one another at retrieval. A number of studies have demonstrated intact item memory among adults with ASD, but deficits in memory for contextual details associated with those items or events[7–9]. For example, some studies using "remember/know" procedures in individuals with ASD show that they may *know* that they have seen or heard something before but are less able to *remember* the contextual details of those memories[10–12]. Consistent with the executive dysfunction hypothesis of symptomatology in ASD[13], episodic memory impairments tend to be greater when tasks are highly complex and/or minimal support is provided to facilitate encoding or retrieval[14]. For example, episodic memory is particularly poor for individuals with ASD compared to participants with typical development (TD) on tests of free recall[15–17], and often intact in tests of cued recall or recognition[2,7,18–20].

Numerous parallels between the memory profiles of ASD and that of typical aging and ASD have led researchers to utilize an "aging analogy" to explain memory impairments sometimes seen in ASD[11]. For example, typical aging features increased relational memory difficulties[21] similar to that seen in ASD[3,7] compared to item memory. Furthermore, similar difficulties in free recall but intact recognition and increased reliance on task support are seen in typical aging literature[22]. Relative to memory for items, episodic memory for item features is disproportionately dependent upon frontally-mediated executive control processes[23]. Emergent research has suggested that context memory accuracy can be improved in typical aging when orienting instructions or tasks are presented during encoding and direct attention to task-relevant associations [e.g., "Is this color (context) likely for this object (item)?"] compared to when attention is directed to a single item or non-contextual features[24–29]. However, daily life involves multiple context features and our ability to remember certain details likely depends on how well we ignore others. Thus, deficits in inhibitory control would likely impede context memory performance in the presence of task-irrelevant distractors. Consistent with this idea, and the age-related inhibitory control hypothesis[30], we[31] have shown that TD older adults, compared to young adults, show reduced context memory accuracy and increased binding of distracting contextual information (i.e., 'hyper-binding')[32]. Inhibitory control deficits, including difficulties with distractor interference and prepotent response inhibition, are also common in ASD[33].

Poorer episodic memory performance in ASD may also be at least partly accounted for by metacognitive monitoring or metamemory difficulties[34–36]. Well-known tests of metacognitive ability involve asking participants to not only answer questions about recently studied material or stored knowledge but also to report confidence in answers provided [e.g., judgment of confidence (JOC), feeling of knowing (FOK), or judgment of learning (JOL) tasks]. If metacognitive monitoring is good, performance judgments should accurately discriminate between correct and incorrect answers (indicating confidence-accuracy correspondence). Results from ASD metamemory studies remain scarce and inconclusive with some finding no differences compared to TD in metacognitive accuracy (Ref.[37–39], but see Ref.[40]). In contrast, others find differences but only in certain age groups (e.g., children but not adults[41], but see Ref.[42]), or certain types of memory judgments (e.g., episodic not semantic)[43]. The few studies that have found differences between ASD and TD suggest potential impairments in metacognition for ASD[40,42,44–46]. For example, Grainger et al.[42] found less accurate FOK judgments in adults with ASD but greater self-reported metacognitive abilities than TD adults. These findings suggest the potential for diminished correspondence between metacognitive monitoring and memory accuracy despite high self-confidence in metacognition in ASD. However, ASD metamemory studies frequently use correlation coefficients between accuracy and confidence (e.g., Gamma coefficient)[47], which risks confounding confidence judgment sensitivity with response biases[48]. Specifically, differences in participants' confidence-accuracy correlation coefficients could result from an overall likelihood to give high confidence endorsements for their responses, rather than a true reflection of a difference in sensitivity. Maniscalco and Lau's[48] metadprime (*metad'*) is grounded in signal detection theory (SDT)[49]. It allows for separation of sensitivity (i.e., how well confidence ratings discriminate between a participant's correct/incorrect responses) and response bias (i.e., how likely a participant is to endorse responses with high vs. low confidence) of metacognitive performance.

Taken together, existing literature suggests that episodic memory may be particularly impaired in ASD when demands on executive function and/or metamemory are high. In our lab, we have designed a novel selective attention context memory task that places heavy demands on executive function and has been previously used to evaluate item and contextual memory in neurotypical aging[31,50,51]. To our knowledge, no studies have investigated hyper-binding in ASD.

Using an aging framework to investigate episodic memory in ASD, we would predict increased hyper-binding in ASD compared to TD. Further, our task asks participants to make judgments of confidence (JOC) at retrieval for both attended and unattended contexts. Metamemory is still an understudied area in ASD research and, to our knowledge, this is only the second to explore retrospective memory confidence for contextual-level details in adults with ASD[52] and the first that uses *metad'* which separates response biases from sensitivity unlike commonly used Gamma correlations. When metacognitive differences have been seen in ASD compared to neurotypical controls, results suggest diminished confidence-accuracy correspondence[40–42,44,46] which has also been seen in healthy aging[53–55]. However, mixed results and minimal preliminary findings from adult samples make it currently unclear whether difficulties observed in contextual metamemory performance would be seen in adults with ASD in the present study.

To our knowledge, no other studies have explored context memory, hyper-binding, and metamemory for contextual details in the same sample of adults with ASD compared to TD adults. We aimed to establish whether these abilities are impaired in ASD in a way that aligns with an aging analogy. In order to do so, we compared context memory performance in a sample of adults with ASD (ages 18 to 58 years) to a sample of age, gender, and education matched typically developing adults. Specifically, we use a complex context memory task which we have previously employed in younger and older adults without ASD[31,50,51] to investigate whether adults with ASD demonstrate 1) impaired item or context memory, 2) increased patterns of hyper-binding, and 3) less retrospective confidence-accuracy correspondence compared to adults without ASD. If ASD involves impairments similar to that seen in neurotypical aging, we would expect to see significant decreases in episodic memory performance and increased hyper-binding among adults with ASD compared to TD controls. ASD metamemory performance may also show less confidence-accuracy correspondence similar to that seen in neurotypical aging, but this was not assumed a priori based on existing literature.

Methods

Participants

Twenty-three participants with ASD (18-58 years, $M = 30.2$, $SD = 12.3$) and 23 TD participants (18-61 years, $M = 29.5$, $SD = 14.6$) were included in this study. A subset of the data from the TD sample was included in prior publications[31,50,51]. Participants were right-handed, native English speakers with normal or corrected-to-normal visual acuity and normal color vision. No participants reported psychiatric or neurological disorders, vascular disease, or use of medications affecting the nervous system. All participants were recruited through the Georgia Institute of Technology Psychology participant pool, advertisements on public transportation, newspapers, word of mouth, and referrals from programs in the greater metro-Atlanta area serving adults with ASD. All participants were compensated either $15/hour or with extra credit for their psychology courses. Study protocols were approved by the Georgia Institute of Technology Institutional Review Board (IRB) and were carried out in accordance with the approved guidelines and regulations. We obtained written consent from all participants on IRB-approved consent form prior to participation in our study.

Participants completed a standardized neuropsychological battery to rule out clinically significant cognitive impairments (e.g., mild cognitive impairment) and were excluded if their scores fell two standard deviations above or below that of the TD group mean (see **Table 1**). The neuropsychological battery included subtest from the Memory Assessment Scale (MAS)[56] and the Halsted-Reitan Neuropsychological Test Battery (HRNB)[57]. MAS included letter fluency and immediate and delayed list recall, HRNB included Trails A (processing speed) and B (processing speed + cognitive flexibility). ASD diagnosis was confirmed by clinical interview using the Autism Diagnostic Observation Schedule-2 (ADOS-2)[58] using the following inclusion criteria: 1) prior diagnosis of ASD and 2) met the ADOS-2 diagnostic cut-off score (>7) and Social Responsiveness Scale-2 (SRS-2)[59] diagnostic cut-off (>60). For this study, we initially considered all available ASD participants' data (n = 25). Two participants were excluded from the ASD sample, one for not meeting criteria based on the ADOS-2 and one for neuropsychological tests. Each participant with ASD (n = 23) was then matched to a TD control with regard to age, gender, and education. The groups did not significantly differ on these three demographics.

Materials & Design

The task utilized a pool of 432 grayscale images of objects collected from the Hemera Technologies Photo-Object DVDs and Google Images. Each image featured a single, nameable object centrally fixed on a white background. On opposite sides (left/right) of the object were 1 of 3 possible colored squares (red, brown, or green) and 1 of 3 possible scenes (studio, city, or island). The positions of these flanking contexts (color/scene) were counterbalanced so that they were presented an equal number of times on the right and left side of the central object. Object and context images spanned a maximum horizontal and vertical visual angle of approximately 3°. During encoding, 288 objects were presented, and participants were instructed to direct their attention to one of the two attended contexts (either the colored square or the scene) on each trial. At retrieval, all 288 previously presented objects (i.e., "old trials") were presented along with 144 new objects that had not been previously studied. Old/new status for objects was also counterbalanced across subjects.

Procedure

Participants were informed about study purposes and procedures and written consent was obtained. The procedure was split into four study blocks (288 trials, 72 trials per block) and four test blocks (432 trials, 108 trials per block). Younger adults completed all four study then all four test blocks. Older adults (ages 60+) studied and tested on half and then repeated this procedure (study-study-test-test-study-study-test-test) to halve the memory load. For this study, only two TD participants were ages 60+ and were afforded this memory load adjustment. All participants were given instructions and a brief practice of study and test blocks before beginning the experiment. Practice was repeated (average ~5 min. for all participants) until participants demonstrated understanding of the procedure.

The upper portion of **Figure 1** illustrates the structure and timing for study trials. On each trial during study blocks, participants were asked to make subjective (yes/no) judgments about the relationship between the grayscale object and *either* the scene (i.e., "Is this object likely to appear in this scene?") *or* the colored square (i.e., "Is this color likely for the object?"). Both verbal and written instructions instructed participants to orient their attention to one context and ignore the other context for each trial. Participants responded with one of two keypresses to indicate "yes" or "no." Study blocks were each divided into four mini-blocks of 18 trials, each for a total of 72 trials per block. These mini-blocks were designed to both orient the participant to which context they should pay attention to on the subsequent trials, but also to reduce the task demands of having to switch back-and-forth between judging the two different contexts (color, scene) which previous evidence has suggested disrupts memory performance in older adults[60]. Piloting determined that the blocking procedure was necessary to ensure suitable performance across participants of all ages in this study. Prior to beginning each mini-block, participants were prompted with a question, "Likely color?" or "Likely scene?" to inform them of which judgment to make. These prompts remained on the screen underneath the images on each trial. The order of which context judgment was prompted first (i.e., object-color or object-scene) was counterbalanced across participants.

Figure 1

Experimental Design.

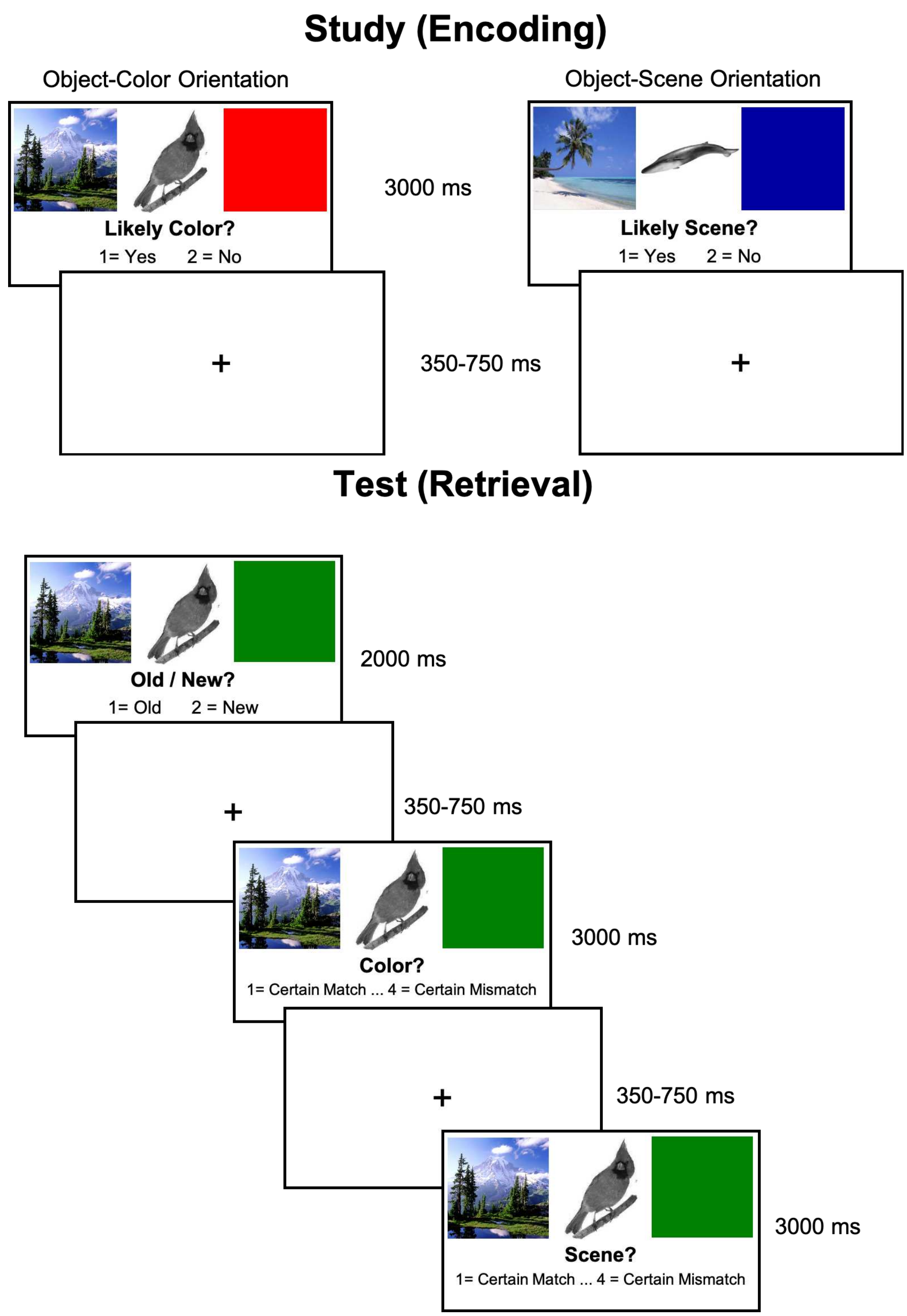
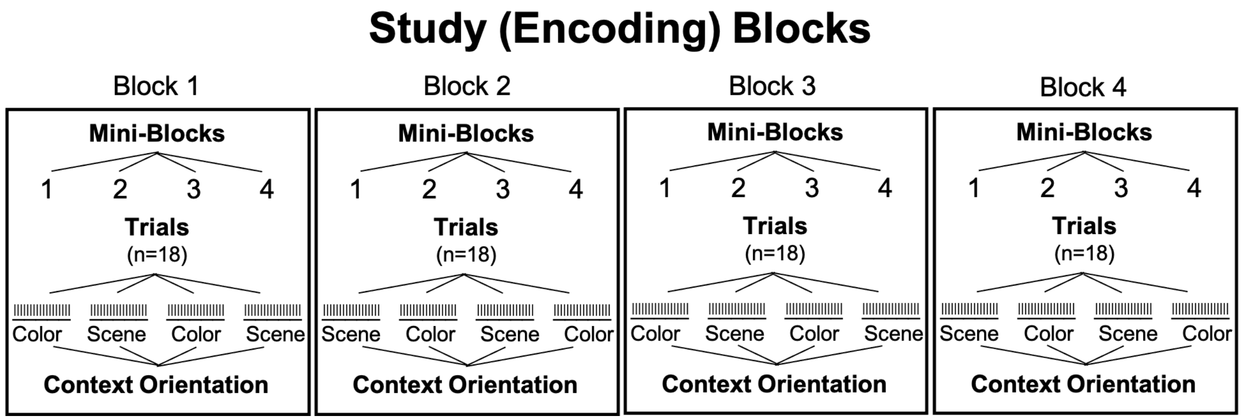


Figure 2

Mini-block design of study phase. Four mini-blocks per study block, 18 trials per mini-block.



The lower portion of **Figure 1** illustrates the structure and timing for test trials. On each trial during test blocks, participants were presented with both old and new objects. Similar to the study blocks, each object was flanked on opposite sides (left/right) by a scene and colored square. For old objects, the color/scene contexts were located on the same side of the object as they had been during study. Participants were first asked to respond via keypress whether the object was “old” or “new.” If they responded “new”, the next trial began after 2000 ms. If they responded “old,” they were then asked to make two additional judgments about the context features (i.e., one about the scene, one about the colored square). For these judgments, participants decided whether the context presented with the object matched the context that had been presented with that object during encoding. Participants responded using 1 of 4 keypresses to indicate scaled context match confidence judgments ranging from 1 (certain match) to 4 (certain mismatch). Again, the order of which context judgment was prompted first (i.e., object-color match, object-scene match) was counterbalanced across participants. Trials were designed that for “old” trials, objects were presented equally with 1) both color and scene matching those presented during study, 2) only scene matching, 3) only color matching, and 4) neither color nor scene matching.

Analysis

Statistical analyses were performed using IBM SPSS 27 software. Where analyses of variance (ANOVAs) were used, effect sizes were calculated using partial eta-squared (η^2_p), where $\eta^2_p = .01$, $\eta^2_p = .06$, $\eta^2_p = .14$ is considered small, moderate, or large effect size, respectively[61]. Where *t* tests were used, effect sizes were calculated using *Cohen's d*, where d = .2, d = .5, d = .8 is considered small, medium, or large effect size, respectively[61]. Where non-significant main effects or interactions with Group (TD vs. ASD) were observed, Bayes Factor[62] (null/alternative; BF_{01}) were computed where < .33 or > 3 are considered noteworthy.

Results

Group demographics and neuropsychological test results are shown in **Table 1**. Scores for the MAS and HRNB neuropsychological battery subtests were missing for one ASD participant due to failure to complete and were replaced with the ASD group mean for each subtest. Adults with ASD exhibited significantly lower performance as compared to matched TD controls on Delayed List Recall [$t(31) = 2.88$, $p = .006$, *Cohen's d* = 0.85, equal variances not assumed, Levene's test was significant]. There were no other significant group differences.

Table 1

Participant demographics.

Measure	ASD (*n* = 23)	TD (*n* = 23)
Age	30.2 (25.2, 35.2)	29.5 (23.5, 35.4)
Gender (M/F)	16/6	15/7
Education	14.4 (13.7, 15.1)	14.5 (13.8, 15.2)
Letter Fluency	14.0 (12.3, 15.7)	14.0 (12.2, 15.8)
List Recall (Immediate)	9.3 (8.3, 10.3)	10.1 (9.6, 10.6)
List Recall (Delayed)	9.8 (8.8, 10.8)	11.2 (10.7, 11.7)*
Trails A (in seconds)	32.2 (23.3, 41.1)	25.5 (22.2, 28.9)
Trails B (in seconds)	83.0 (58, 108.0)	56.4 (44, 68.8)
ADOS-2 module 4[a]		
Communication	3.8 (3.3, 4.4)	--
Reciprocal Social Interaction	8.2 (7.3, 9.2)	--
Combined Total	12.1 (10.6, 13.5)	--

SRS-2 (T-score)		
Social Awareness	60.6 (56.9, 64.2)	--
Social Cognition	66.0 (62.4, 69.5)	--
Social Communication	70.7 (67.5, 73.9)	--
Social Motivation	68.9 (64.6, 73.1)	--
Restricted Interests Behavior	73.7 (69.9, 77.5)	--
Combined Total	71.0 (67.8, 74.3)	--

Note. Mean (95% Confidence Interval). *significant group difference (p < .05). [a]Autism diagnostic observation schedule-2 (ADOS-2), module 4. [b]Social responsiveness scale-2, adult form self-report (SRS-2)

Object and context memory performance

Item recognition accuracy was estimated using Signal Detection Theory (*d'prime*) measure of discriminability: z (hit rate) – z (false alarm rate) and are shown in **Table 2**. Both groups showed above chance (0) performance for item recognition [$t(22)$'s > 7.52, p's < .001, *Cohen's d*'s > 1.57]. Item recognition did not differ between groups, [$t(38) = 0.93$, $p = .18$, *Cohen's d* = 0.27, equal variances were not assumed, as Levene's test was significant], suggesting comparable item memory performance between the adults with and without ASD Given the data, there is weak evidence in favor of an absence of a Group effect ($BF_{01} = 2.41$).

Context memory accuracy was also computed as *d'prime* for attended and unattended context features separately using the following formula: d' = z (proportion of "match" responses to contexts that matched those presented at encoding) – z (proportion of "match" responses to contexts that mismatched those shown at encoding). These discriminability scores are presented in **Table 2**. Both groups showed above chance (0) performance for both attended [$t(22)$'s > 3.98, p's < .001, *Cohen's d*'s > 0.83] and unattended [$t(22)$'s > 3.12, p's < .005, *Cohen's d*'s > 0.65] contexts. A Context (Attended vs. Unattended) x Group (TD vs. ASD) ANOVA revealed a main effect of Context, [$F(1, 44) = 28.66$, $p < .001$, $\eta^2_p = .39$], but no main effect of Group, [$F(1, 44) = 0.09$, $p = .76$, $\eta^2_p = .002$] or interaction between these factors, [$F(1, 44) = 0.11$, $p = 0.74$, η^2_p =

.003]. This suggests that the manipulation of attention during encoding was effective at enhancing context memory accuracy for the target context. Given the data, there is moderate evidence in favor of an absence of a main effect of Group ($BF_{01} = 3.95$) and an interaction between Group and Context ($BF_{01} = 3.90$). This pattern of effects remained when controlling for age: ANCOVA again revealed a main effect of Context, [$F(1, 43) = 27.28$, $p < .001$, $\eta^2_p = .39$], no main effect of Group [$F(1, 43) = .18$, $p = .68$, $\eta^2_p = .004$], and no Context x Group interaction [$F(1, 43) = 0.08$, $p = .78$, $\eta^2_p = .002$].

Table 2

Group averages in discriminability (d') for item and context memory

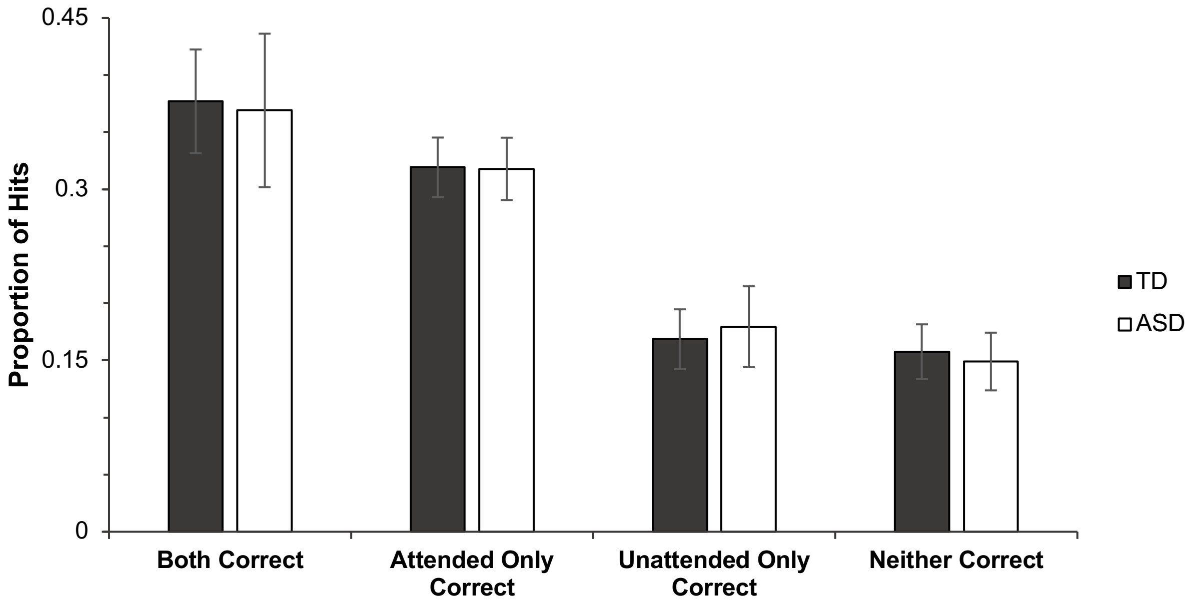
	ASD ($n = 23$)	TD ($n = 23$)
Item recognition	1.78 (1.32, 2.25)	2.04 (1.74, 2.35)
Attended Context Accuracy	0.96 (0.49, 1.43)	0.97 (0.66, 1.28)
Unattended Context Accuracy	0.20 (0.12, 0.29)	0.11 (0.04, 0.18)

Note. Mean (95% Confidence Interval).

Figure 3 depicts the mean proportion of correctly recognized objects (hits) for which the participant correctly judged both contexts (*Both correct* trials), only the target context (*Attended only correct)*, only the distractor context (*Unattended only correct*), or only the item (i.e., neither context correctly judged; *Neither correct* trials). Consistent with the previous analyses, there were no group differences in performance [$t(44)$'s < 0.57, p's > .57, *Cohen's d*'s < 0.17]. Given the data, there is moderate evidence in favor of an absence of an effect of Group (BF_{01}'s > 3).

Figure 3

Proportions of hits associated with correct and incorrect judgments for both attended and unattended contexts.



Note. Error bars depict 95% CI for mean.

Hyper-binding

In order to directly examine hyper-binding of attended and unattended context features in each group, we calculated conditional probabilities similar to Uncapher et al.[63] using proportions in **Figure 2**. Specifically, the probability of correctly endorsing the attended context given that the unattended context was correctly endorsed was calculated as (p(Both correct)/[p(Both correct) + p(Unattended only correct)]. The probability of correctly endorsing the attended context given the unattended context was incorrect was calculated as (p(Attended only correct)/[p(Attended only correct) + p(Neither correct)]. Likewise, the probability of correctly endorsing the unattended context given that the attended context was correct was calculated as (p(Both correct)/[p(Both correct) + p(Attended only correct)]. Finally, the probability of correctly endorsing the unattended context given that the attended context was incorrect was calculated as (p(Unattended only correct)/[p(Unattended only correct) + p(Neither correct)]. All conditional probabilities are shown in **Table 3.**

Table 3

Probabilities of correct context features conditionalized on accuracy for the other context feature.

	Attended correct if unattended correct	Unattended correct if attended correct	Attended correct if unattended incorrect	Unattended correct if attended incorrect
ASD (n = 23)	0.65 (0.58, 0.71)	0.52 (0.48, 0.56)	0.68 (0.63, 0.73)	0.54 (0.51, 0.57)
TD (n = 23)	0.68 (0.63, 0.73)	0.53 (0.51, 0.56)	0.67 (0.62, 0.72)	0.51 (0.48, 0.55)

Note. Mean (95% Confidence Interval).

If either group is hyper-binding, they should show greater context accuracy for one feature if the other feature was also correctly recognized than if it was not recognized. If ASD adults are more likely to show hyper-binding, similar to that seen in older adults, they should show greater conditional dependence between attended and unattended context accuracy. To examine these possibilities, we conducted a Context (Attended vs. Unattended) x Accuracy of the other feature (Correct vs. Incorrect) x Group (TD vs. ASD) ANOVA which revealed a main effect of Context, [$F(1, 44) = 55.79$, $p < .001$, $\eta^2_p = .56$] but no other significant main effects or interactions, [$F(1, 44)$'s < 3.94, p's > .053]. Given the data, there is moderate evidence in favor of an absence of a main effect of Group ($BF_{01} = 4.68$) and the Context*Group interaction ($BF_{01} = 3.69$) and weak evidence in favor of the absence of the Accuracy of the other Feature*Group interaction ($BF_{01} = 1.49$). Participants were more likely to judge attended than unattended contexts correctly, but the lack of Context x Accuracy interaction suggests there was no evidence of hyper-binding in either group. This pattern of effects remained when controlling for age: ANCOVA again revealed a main effect of Context, [$F(1, 43) = 38.54$, $p < .001$, $\eta^2_p = .47$], but no other significant main effects or interactions, [$F(1, 43)$'s < 1.95, p's > .17].

Metamemory performance

In the present study, for each trial that participants responded ‘old’ (item recognition), they then decided whether each context (attended, unattended) matched or mismatched the context presented with the object at encoding. Embedded within this second decision was also a decision regarding confidence (high/low) in context memory judgments (i.e., participants chose either high confidence context match, low confidence context match, low confidence context mismatch, high confidence context mismatch). Metamemory performance was estimated using Signal Detection Theory (*meta-d'prime*)[48] measure of discriminability: z (high confidence hit rate) – z (high confidence false alarm rate) and are shown in **Table 4**.

Table 4

Group averages in metamemory performance (metad') for context memory

	ASD (n = 23)	TD (n = 23)
Attended Context	0.99 (0.57, 1.41)	1.10 (0.75, 1.45)
Unattended Context	0.25 (0.04, 0.47)	0.11 (-0.52, 2.69)

Note. Mean (95% Confidence Interval).

We conducted a Context (Attended vs. Unattended) x Group (TD vs. ASD) ANOVA to evaluate differences in metacognitive performance (*metad'*). Results revealed a significant main effect of Context, [$F(1, 44) = 41.02, p < .001, \eta^2_p = .48$] but no main effect of Group, [$F(1, 44) = 0.01, p = .91, \eta^2_p = .00$] or interaction between these factors, [$F(1, 44) = 0.89, p = 0.35, \eta^2_p = .02$]. Metacognitive performance was greater for attended than unattended contexts for all participants. Given the data, there is moderate evidence in favor of an absence of a main effect of Group ($BF_{01} = 4.01$) and weak evidence in favor of an absence of the Context*Group interaction ($BF_{01} = 2.35$). This pattern of effects remained when controlling for age: ANCOVA again revealed a main effect of Context, [$F(1, 43) = 27.27, p < .001, \eta^2_p = .39$], no main effect of Group, [$F(1, 43) = 0.18, p = .68, \eta^2_p = .004$] or interaction between these factors, [$F(1, 43) = 0.08, p = 0.78, \eta^2_p = .002$].

Metacognitive efficiency is calculated by observing the discrepancy between *d'* (accuracy) and *metad'* (metacognition) where $metad'/d' = 1$ indicates an ideal metacognition-performance relationship and the degree to which $metad'/d' < 1$ indicates the degree to which a participant is metacognitively inefficient[48]. We conducted a Context (Attended vs. Unattended) x Group (TD vs. ASD) ANOVA to evaluate differences in the ratio of *metad'/d'*. Results revealed no significant main effects or an interaction [$F(1, 44)$'s < 0.96, p's > .33, η^2_p's < .02]. This suggests that the confidence/accuracy relationship (metacognitive efficiency) does not significantly differ across contexts or group. Given the data, there is moderate evidence in favor of an absence of a main effect of Group ($BF_{01} = 3.06$) and weak evidence in favor of an absence of the Context*Group interaction ($BF_{01} = 2.36$). This pattern of effects remained when controlling for age: ANCOVA again revealed no significant main effects or interactions, [$F(1, 43)$'s < 2.1, p's > .15, η^2_p's < .05].

Discussion

The goal of the present study was to investigate whether adults with ASD differed from typically developing adults in context memory accuracy, hyper-binding, or metamemory in a novel context memory task. Results revealed no significant group effects. Consistent with previous studies[4], adults with and without ASD exhibited similar item-memory performance. However, the hypothesis that ASD would show decreased context memory performance despite intact item-level performance was not supported. For both groups, memory for contextual features was greater for the attended context compared to unattended contexts. Further, both groups were more likely to correctly judge attended contexts compared to unattended contexts, and this was not conditionally dependent on accuracy of the other context, suggesting neither group was hyper-binding in this sample. Hyper-binding is thought to result from problems with inhibitory control, which are seen in ASD[33], and led us to hypothesize increased hyper-binding similar to that previously seen in typical aging[31] on this task. Deficient context memory performance as a result of selective attention and inhibitory control deficits may be attenuated by adulthood through the development of compensatory strategies that support behavioral performance. Research in ASD remains predominately focused on early childhood and adolescence and only recently has shifted to include studies of adults[64–66]. Future studies involving larger samples of younger and older adults with ASD adults will be important for better understanding age-related versus ASD-related differences in episodic memory and hyper-binding[31,32].

These results are perhaps surprising given the literature documenting episodic memory impairments in ASD[2,4,5]. However, it is also possible that environmental support in this task attenuated context memory deficits that would have been seen in ASD. This present task directed participants' attention to the focal item-context relationship during encoding (i.e., "is this object likely for this scene?"). Research has suggested that context memory accuracy can be improved when attention is directed to task-relevant associations compared to when attention is directed to a single item or non-contextual features[24–26,28,29]. It is possible that if given no direction on which object-context relationship to focus on that we might have seen effects more so aligned with theories of autism (e.g., executive dysfunction), suggesting that individuals with ASD have problems inhibiting distraction, which may lead to overlooking contextually significant relationships and paying too much attention to extraneous stimuli. Also, participants in the present study are re-presented with the previously seen pairs (e.g., object-context match) at test which may allow for reliance on familiarity-based recognition. Bowler et al.'s Task Support Hypothesis[7] suggests that memory in ASD will be better on any task where test procedures include information about encoded material. Individuals with ASD show the greatest difficulties on tests of free recall compared to controls and group differences diminish on cued recall or recognition tasks[15,19]. However, recognition tasks with high demands on relational binding have found diminished recognition of object-context combinations despite intact recognition of individual context elements[9] though findings on recognition tasks have been mixed (e.g., Ref.[7,67], but see Ref. but see[10,20,68]). Future studies could vary or remove orienting instructions or require participants to choose from all possible options the appropriate contexts (both attended and unattended) at test for items previously seen during encoding. Such methodological manipulations to minimize task support would allow for further exploration of the nuances of context memory impairments and potential for hyper-binding in ASD.

Further, it should be noted that the neuropsychological test data (**Table 1**) data suggest that some memory impairments are observed in the ASD group in this study, in contrast to what we observed in our context memory task. Specifically, ASD adults' delayed list recall performance was lower than that of TD adults in this study. This discrepancy could be explained by the nature of these assessments and our task. As discussed earlier, one possibility is that the task support provided at both encoding and retrieval in our task may have attenuated episodic memory differences that would have otherwise been observed in this sample. It is also worth noting that these neuropsychological tests assess memory for words while our task assessed memory for pictures and associated colors and scenes. It is possible that the pictorial stimulus materials that we used resulted in enhanced memory, demonstrating a "picture superiority effect," whereas pictures are remembered better than other types of stimuli[69]. This effect is suggested to result from faster activation of semantic associations for pictures versus words, allowing for generation of more robust and elaborative associations between stimuli[70]. A direct comparison of the object-scene and object-color pairs used in this study to word pairs would be needed to fully test this hypothesis.

Adults with ASD also did not significantly differ from TD in a measure of metacognitive performance (*metad'*) or in the *metad'/d'* ratio which investigates confidence-accuracy correspondence. Metacognitive abilities are still understudied in ASD and findings to date have been inconclusive. Existing studies feature mostly child and adolescent samples[37,38,40,41,43]. Studies that report group differences suggest diminished confidence-accuracy correspondence for ASD, although this has not been conclusive in the literature (Ref.[40,41,43,45], but see [37–39]). Only one adult study[52] had evaluated retrospective confidence for episodic memory finding no group differences. Other existing adult studies suggesting no group differences had methodological concerns (see Ref.[40] for detailed evaluation) including inadequate age-matchings[39] and incomplete reporting and interpretation of results (Ref.[41] (exp. 2)). This variability in the existing literature prevented us from making firm a priori predictions regarding metamemory differences between adults with and without ASD. The null findings in our study perhaps further highlight the need for continued research on metacognitive abilities in ASD. The existing literature to date varies significantly in how metamemory is defined and assessed in ASD. Different metamemory judgment tasks (JOC, FOK, JOL) used throughout the literature show only modest correlations with one another and may be tapping different processes[71,72] which could explain inconclusive evidence regarding ASD metacognitive impairment. A few studies have begun distinguishing metacognitive accuracy and control[39,40,52] but continued research into these separable processes is needed. Lastly, existing ASD metamemory studies utilize correlation coefficients (e.g., Gamma coefficient[47]) to assess metacognitive performance, which risks confounding the sensitivity and response biases. SDT Measures such as *metad-prime*[48] used in the present study allow for separation of bias and sensitivity and should be widely utilized in future studies for investigations of metacognitive monitoring in ASD. Lastly, further investigations should investigate how the task support hypothesis may apply not only to episodic memory performance but also to underlying metamemory processes. It is possible that individuals with ASD are better able to monitor and regulate performance when environmental support aids memory performance, as in the current study.

It is important to acknowledge the present study's limitations. One limitation is that we did not include a direct measure of inhibition. Though our hypothesis that adults with ASD would show increased hyper-binding compared to TD adults was not supported, increased hyper-binding is thought to stem from reduced selective attention due to underlying problems with inhibiting distractors[30]. In the future, a direct measure of inhibition such as the Stroop task should be included. Further, we cannot truly know from this experiment what aspects of the items and contexts shown were focused on by participants. Research has shown individuals with ASD to exhibit atypical local/global processing compared to neurotypical controls. For example, individuals with ASD have been hypothesized to have enhanced local processing[73], impaired global processing[74,75], and/or a preference or bias towards local versus global information when given a choice[76]. In the future, an Embedded Figures test[77], Block Design test[78], or a Navon[79] figure test could be used to evaluate local and global processing in all participants. Further, while we cannot truly know in our task if local aspects of the stimuli presented (e.g., a leaf on a palm tree in the island scene) were perceived more so than the Gestalt of the stimulus (i.e., island vs. city scene), future research could incorporate eye-tracking technology to investigate this possibility. Another minor limitation of the present study to acknowledge is that we did not match on verbal IQ, which is commonly seen in ASD literature, as this data was not collected for the sample. However, we performed one-to-one matching considering age, education, and gender which resulted in similar average and distributions (**Table 1**). Our ASD sample did vary considerably on the SRS-2 (total T-score range of 60-85 with 73% of sample scoring 66+ which indicates moderate to severe symptoms). This suggests that null group differences are unlikely to be due to the fact that the adults in our ASD group were predominately those with mild or sub-clinical ASD symptomology. Autism symptomatology lies on a continuum and a larger sample with the ability to examine severity as related to memory could be illuminating. Future studies including larger lifespan samples with diverse ASD symptomatology could better address questions regarding 'aging in autism' by investigating if onset of changes in episodic memory performance seen in neurotypical aging are mirrored in ASD. It is also possible that the null effects including lack of group differences were due to a smaller sample size yielding insufficient power to detect smaller effects. However, as mentioned above, it is possible that our task provided sufficient support, diminishing group differences in context memory performance[7].

Conclusion

To conclude, the present study, to our knowledge is the first to assess context memory, hyper-binding, and metacognitive performance for contextual details in a community sample of adults with ASD on a novel episodic memory task. Results show no evidence of differences in episodic memory or metacognitive performance between adults with and without ASD. It is possible that individuals with ASD show only minimal episodic memory or metamemory impairments compared to TD. It is also possible that impairments do exist but that the present task offered enough support to overcome them or that deficient performance would not be seen until later adulthood due to age-related cognitive decline. Future research should extend these findings to larger, older adult samples utilizing paradigms that minimize task-relevant support in order to tease apart the nuances of context memory and metamemory performance.

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Author Contributions

S.A.J.: Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **P.S.P.:** Conceptualization, Methodology, Investigation, Writing – review & editing. **A.D.:** Conceptualization, Methodology, Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition.

Figures

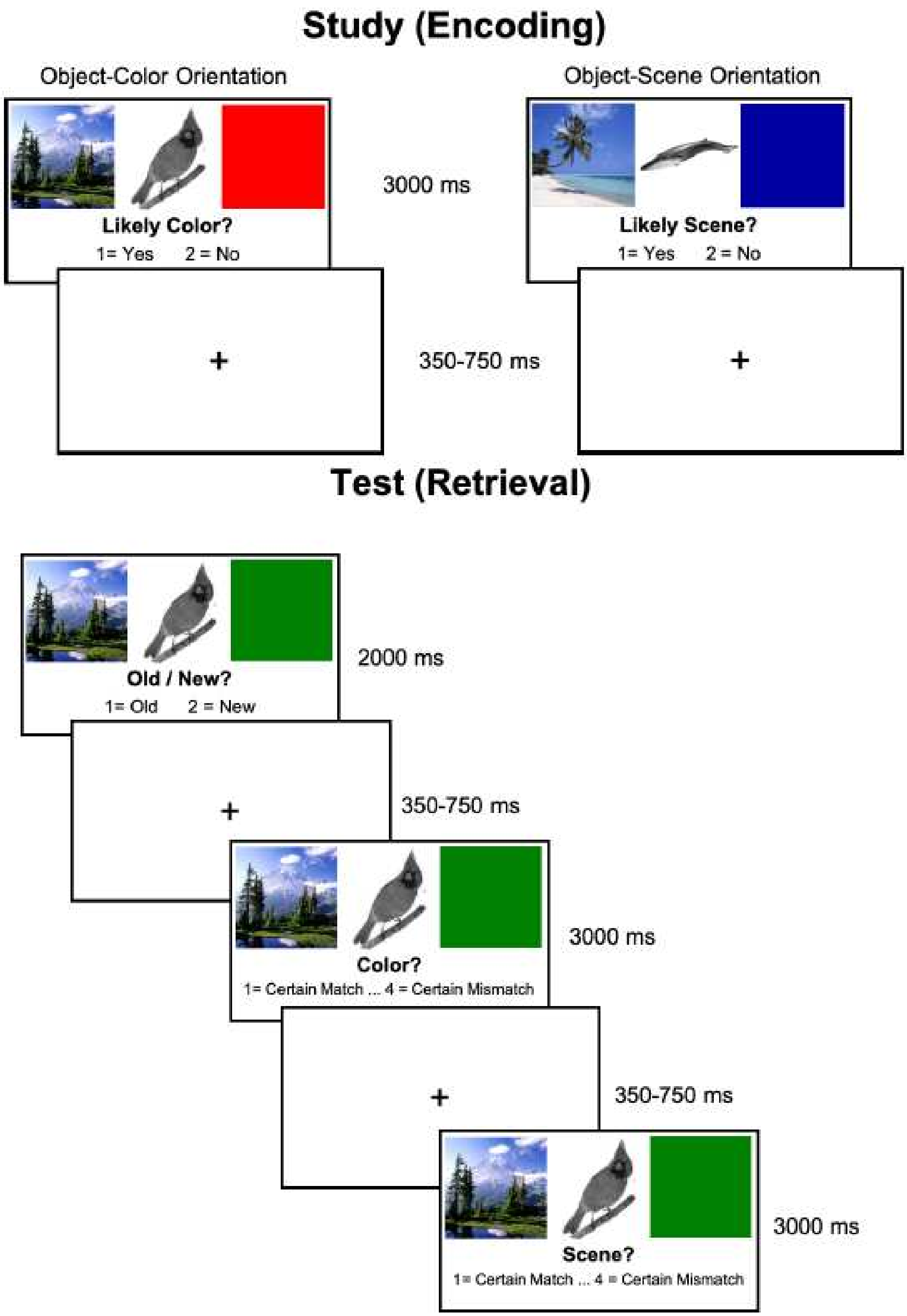

Figure 1

Experimental Design.

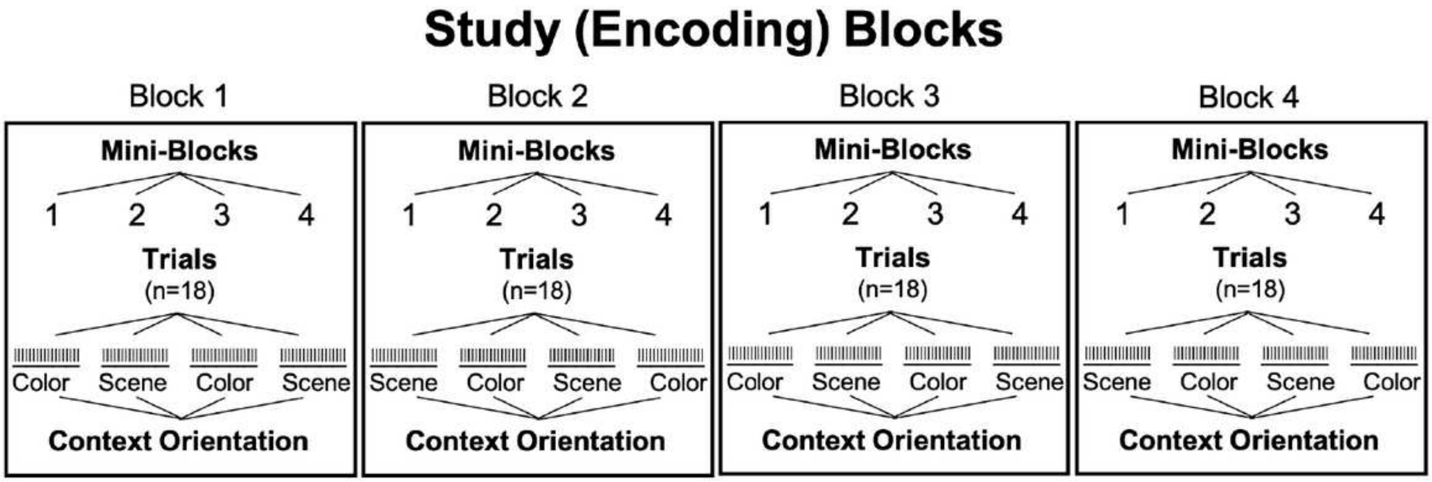

Figure 2

Mini-block design of study phase. Four mini-blocks per study block, 18 trials per mini-block.

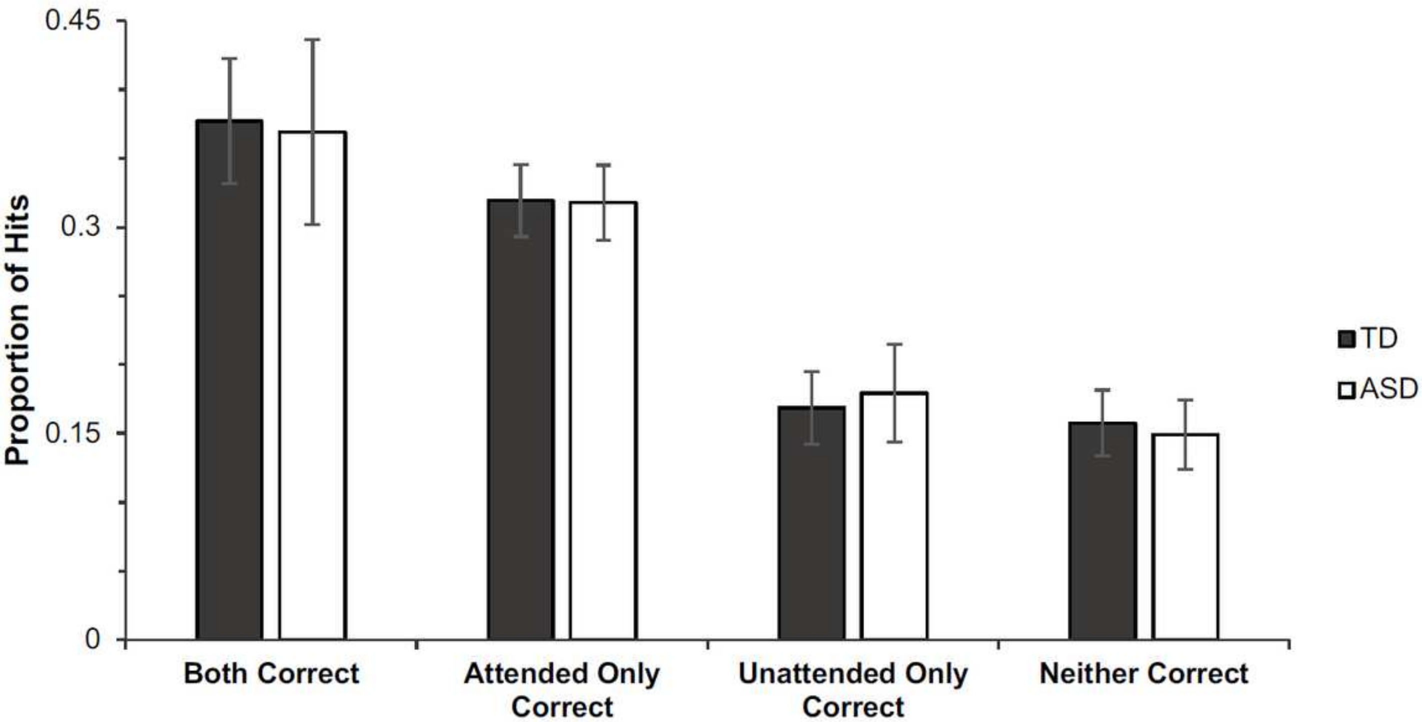

Figure 3

Proportions of hits associated with correct and incorrect judgments for both attended and unattended contexts. Note. Error bars depict 95% CI for mean.