Contextual effects on visual short-term memory in high-functioning autism spectrum disorders

Citation for published version:
Souza, C, Coco, MI, Pinho, S, Filipe, CN & Carmo, JC 2016, 'Contextual effects on visual short-term memory in high-functioning autism spectrum disorders', *Research in autism spectrum disorders*, vol. 32, pp. 64-69. https://doi.org/10.1016/j.rasd.2016.09.003

Digital Object Identifier (DOI):
10.1016/j.rasd.2016.09.003

Published In:
Research in autism spectrum disorders

Contextual effects on visual short-term memory in high-functioning autism spectrum disorders.

Abstract

Background: According to the context blindness hypothesis (Vermeulen, 2012) individuals with autism spectrum disorders (ASD) experience difficulties in processing contextual information. This study re-evaluates this hypothesis by examining the influence exerted by contextual information on visual short-term memory.

Method: In a visual short-term memory task, we test high-functioning individuals with ASD (N = 21) and a typically developed (TD) group (N = 25) matched on age, education and IQ. In this task, participants are exposed to scenes (e.g., the photo of a *restaurant*), then shown a target-object that is manipulated according to its contextual *Consistency* with the scene (e.g., *a loaf of bread* versus an *iron*) and finally asked whether they saw the target-object or not.

Results: The response accuracy was differentially mediated by the *Consistency* of the target-object for both the ASD and TD groups. In particular, individuals with ASD experienced more difficulty in identifying an inconsistent target when it was present in the scene. Moreover, when a consistent object was absent from the scene, individuals with ASD were more likely to wrongly state its presence than TD individuals.

Conclusions: Our results challenge a strict interpretation of the context blindness hypothesis by demonstrating that individuals with ASD are as sensitive as TD individuals to contextual information. Individuals with ASD, however, appear to use contextual information differently than TD individuals, as they seem to rely more on consolidated contextual expectations than the TD group. These findings could drive the development of novel expectancy-based teaching strategies.

Keywords: visual short-term memory; contextual expectations; autism spectrum disorder.

Introduction

Since the first descriptions of autism (Kanner, 1943) differences in perceptual processing has been frequently reported in the literature. These differences were first formalised in the Weak Central Coherence (WCC) account (Frith, 1989), which argued that Autism Spectrum Disorder (ASD) was characterised by reduced global processing whereby, for instance, there is no advantage from perceptual grouping of visual stimuli (Scherf, Luna, Kimchi, Minshew, & Behrmann, 2008). Instead, individuals with ASD were argued to rely more heavily on detail-focused processing, which conferred advantages on tasks such as the Wechsler block-design or embedded figures tasks (e.g., Shah and Frith, 1993). The Enhanced Perceptual Functioning (EFP) model (e.g., Mottron, Dawson, Soulières, Hubert, & Burack, 2006), later suggested that ASD was not necessarily characterised by reduced global processing but that enhanced perceptual processing could interfere with the processing of global information. Vermeulen (2012) recently argued that this unusual perceptual processing in ASD seems to lead to difficulties in the processing of contextual information and this 'context blindness hypothesis' is the focus of the current study.

The context blindness hypothesis may be considered a stronger formulation of the WCC stating that individuals with ASD are 'blind' to contextual information (Vermeulen, 2012). Central coherence is based on the idea that healthy individuals can form a coherent global representation of multiple stimuli, and use such representation flexibly across contexts. For example, it has been shown that contextual information facilitates object recognition (e.g., Palmer, 1975), especially when there are other related objects in the scenario (Davenport, 2007), or when the object is present in the scenario as opposed to the object being absent (Hollingwoth, 2005). In individuals with ASD, however, this coherence mechanism is weaker, as they tend to focus on specific details of the stimuli (Frith, 1989). According to Vermeulen (2012), individuals with ASD are unable to distinguish important from unimportant details, rather than suffer from a generalized deficit in processing details. Vermeulen (2012) refers to this as *context blindness*, as context is what helps in disambiguating between relevant and irrelevant stimulus information.

Working memory is one of the cognitive domains in which difficulties in contextual processing have been argued to play an important role in ASD (Joseph, Steele & Tager-Flusberg, 2005; Bowler, Gaigg & Gardiner, 2008; Loth, Gómez & Happé, 2011; Mammarella, Giofrè, Caviola, Cornoldi & Hamilton, 2014). Research in this area has shown inconsistencies between studies (e.g., Bennetto, Pennington & Rogers, 1996; Ozonoff & Strayer, 2001, Williams, Goldstein, Carpenter & Minshew, 2005), which has more recently stimulated work closely examining the contextual factors that could underlie difficulties in this domain. Mammarella, et al. (2014) demonstrated that participants with ASD, in contrast to TD individuals who performed better in high-semantic conditions (i.e., patterns more amenable to global configuration), did not exploit the semantic regularities to detect changes in abstract matrices (see also Joseph et al., 2005, for similar results on a self-ordering pointing task of pictures of concrete objects vs. abstract patterns). These findings suggest that ASD individuals might have a reduced ability to utilize contextual information to perform visual short-term memory tasks. However, not all research agrees on this point. Other studies using visual recognition tasks have shown that individuals with ASD can perform as well as TD individuals when presented with consistent objects that are appropriate to a given context. Lopez and Leekam (2003, Exp. 1), for example, demonstrated that an ASD group was as fast and accurate as a TD group in recognizing objects, especially when such objects were preceded by a contextually consistent scene.

Yet, on the other hand, Loth, Gómez and Happé (2011), observed that individuals with ASD did not show the same ability to selectively recall objects from a complex scene that were consistent with a particular narrative (e.g., recalling objects consistent with a birthday party) as TD individuals.

Difficulties in using semantic relatedness to aid memory has been shown in verbal tasks as well (e.g., Tager-Flusberg, 1991), particularly in free recall tasks (but see Carmo et al., 2016). According to some authors (e.g., Bowler, Matthews, & Gardiner, 1997; Bowler, Gardiner, & Berthollier, 2004), recognition tasks (i.e., support-based tasks), in contrast to free recall tasks (i.e., unsupported tasks), lead to a differential pattern of preserved vs. impaired performance in individuals with ASD, respectively. Moreover, Bowler and colleagues (2008) observed that semantic relatedness boosted memory only for recognition tasks and not for recall tasks (see also Hillier, Campbell, Keillor, Phillips, & Beversdorf, 2007 for a similar result on a study on false memories).

The present study sought to re-evaluate the role played by contextual knowledge in visual scenes among individuals with ASD. In particular, we aimed to provide evidence for or against the context blindness hypothesis (Vermeulen, 2012). Moreover, by testing individuals with ASD on a visual recognition short-term memory task, we aim to better understand the disparate findings in the literature regarding contextual effects on memory (e.g., Bowler et al., 2008; Loth et al., 2011; Mammarela et al, 2014). In this study, participants are initially presented with a naturalistic scene that contains or not a target object. The scene is then removed, and participants are shown an image of the target object and then asked whether they saw the object or not. Note that this task is different from tasks included in previous research on ASD in two substantial ways: (1) the stimuli are visual materials depicting largely naturalistic settings and objects and (2) the participants' memories are tested while the specific target is shown to them (i.e., supported retrieval/recognition).

According to the contextual blindness hypothesis and the findings of Mammarella et al. (2014) and Joseph et al. (2005), we should expect no difference in correct recall accuracy for ASD individuals in this visual task based on the consistency of the object. If, however, contextual processing is also at work in individuals with ASD (e.g., Lopez & Leekam, 2003; Bowler et al., 2008) who are performing a supported task, then we should observe variations in their performance according to the contextual consistency of the target object. Moreover, if individuals in the ASD group strongly rely on consolidated prior-expectations and therefore have a reduced capacity to identify objects that violate the context, then we would expect significantly fewer correct detections of inconsistent objects when the target is present in the scene, or an increase in false alarms for consistent objects that are absent from the scene.

Methods

Participants

Twenty-one individuals (2 females) diagnosed with ASD and 25 control individuals (3 females) participated in the study. The diagnoses of ASD were made by two expert clinicians using the DSM-IV protocol (APA, 1994). The Autism Diagnostic Observation Schedule (ADOS) (Lord et al., 1999) and/or the Asperger's Syndrome Diagnostic Scale (ASDS) (Myles et al., 2001) were used to confirm the diagnoses. Additional inclusion criteria for the ASD group were > 9^{th} grade of formal education, > 18 years old, and > 80 points on the Wechsler adult intelligence verbal subscale (M = 102.28, SD = 8.96) (WAIS-III, 1996). Independent sample t-tests were used to compare the two populations (TD and ASD) and showed no difference for age [$t(44) = -.68$, $p > .5$] (ASD: M = 27.24, SD = 8.3, [range: 19 - 52]; TD: M = 29.2, SD = 10.89, [range:

18,52], Cohen's d = -0.20); education as number of school years [$t(44) = .86$, $p > .8$] (ASD: $M = 13.05$, $SD = 2.10$, [range: 9 - 17]; TD: $M = 12.48$, $SD = 2.3$, [range: 9 - 17], Cohen's d = 0.26); and IQ (Raven progressive matrices, raw score) [$t(44) = -.29$, $p > .7$)] (ASD: $M = 47.19$, $SD = 8.58$, [range: 30 - 60]; TD: $M = 47.84$, $SD = 6.76$, [range: 31 - 56], Cohen's d = -0.08).

Materials and Procedure

We utilized 64 photographic scenes taken from an extensively normed set by Borges and Coco (2015), which were divided into 32 object-consistent scenes (e.g., a loaf of bread in a kitchen scene) and 32 object-inconsistent scenes (e.g., a corkscrew in a bathroom scene) drawn from 7 indoor environments (e.g., kitchen, waiting room). Each environment comprised a varying number of consistent objects in addition to the target object, and the objects tested were not identical to the target objects present in the scenes (see Figure 1). We re-tested the consistency between the target objects and scene contexts with 12 adult participants on a 5-point Likert scale, and observed that consistent objects are judged as significantly more likely to appear in the scene context, than inconsistent objects ($t = -24{,}08$, $p < .001$, Cohen's d= -3.69).

Each trial began with a scene (18.5 cm x 15 cm) that was presented on a 13'' screen for 2000 ms (as in Lopez & Leekam, 2003), followed by a 500 ms retention interval (see Figure 2). Then, the image of the target object (13.5 cm x 9 cm) appeared in the centre of the screen together with the question "Did you see a…?" Participants were instructed to tell whether they noticed the presence of that object or not in the scene by pressing response keys. Participants' responses were self-paced. In half of the trials the object was present, in the other half it was absent. Each participant completed

64 randomized trials, and four practice trials with feedback were run before the task started.

The study was approved by the Ethical Committee of the Faculty of Psychology of the University of Lisbon (Portugal), and each participant gave written informed consent.

Results

Accuracy (see Figure 3) was analysed by repeated measures ANOVAs, where Group (ASD, TD) was the between-subjects variable and Context (Consistent, Inconsistent) and Presence (Present, Absent) were the within-subjects factors.

We found main effects of: (a) *Group* (F (1, 44) = 13.67, p = 0.001, $\eta_p^2 = 0.24$), with the ASD group performing worse (M = 0.72, SD = 0.71) than the TD group (M = 0.80, SD = 0.21); (b) *Context* (F (1, 44) = 40.57, $p < 0.001$, $\eta_p^2 = 0.48$), with Inconsistent trials recalled better (M = 0.80, SD = 0.09) than Consistent trials (M = 0.71, SD = 0.09); and (c) *Presence* (F(1, 44) = 17.80, p < 0.001, $\eta_p^2 = 0.29$), with the Absent condition (M = 0.82, SD = 0.13) leading to better performance than the Present condition (M = 0.70, SD = 0.12). We also found a significant *Presence* * *Context* interaction (F(1, 44) = 42.66, $p < 0.001$, $\eta_p^2 = 0.49$), with a considerably better recall for inconsistent-absent trials (vs. inconsistent-present) (t(45) = 12.47, $p < 0.001$, Cohen's d = 3.72), but we found no significant difference for consistent items (t (45) = - 0.90, p = 0.37, Cohen's d = -0.27). Crucially, we also found a significant *Context* * *Presence* * *Group* interaction (F(1, 44) = 7.79, p = 0.008, $\eta_p^2 = 0.15$). In particular, post-hoc analysis showed significantly poorer performance among individuals with ASD than among TD individuals on inconsistent-present trials[1] ($F(1,44) = 9.87$, $p = 0.003$, $\eta_p^2 = 0.18$), consistent-absent trials ($F(1,44) = 6.84$, $p = 0.012$, $\eta_p^2 = 0.13$), and inconsistent-absent trials ($F(1,44) = 6.86$, $p = 0.012$, $\eta_p^2 = 0.13$) but not for consistent-present trials ($F(1,44) = 0.50$, $p > 0.48$, $\eta_p^2 = 0.01$. No other effects were found to be significant (all *p*s > 0.30). Because some of the conditions showed problems with the normality assumption, we tested the accuracy of the data with non-parametric statistics as well. The same pattern of results was found, with differences between the groups (Mann-Whitney U test, $p < 0.05$) for all conditions except for the consistent-present condition (Mann-Whitney U test, $p = 0.46$).

Discussion

The results suggest that both populations (ASD and TD) are influenced by contextual information when recalling visual information from memory. This finding is seemingly at odds with the contextual blindness hypothesis, which states that individuals with ASD are insensitive to contextual information (Vermeulen, 2012). In particular, we observed that both groups are better at recognizing inconsistent than consistent objects. However, we also found that individuals with ASD display disadvantages for inconsistent objects when they were present in the scene, and for consistent objects when they were absent. This result suggests that the ASD group relies more heavily than the TD group on consolidated contextual expectations when parsing a scene, and therefore this group misses objects that deviate from such expectations, or incorrectly recalls expectation-consistent target objects even when such targets are not present. This finding could explain the tendency in the literature to assume contextual blindness (e.g.,

[1] The observed accuracy in the ASD group for the Absent-Consistent condition is 60%, for Present-Inconsistent condition is 58%, for Absent-Inconsistent condition is 93% and for Present-Consistent condition is 76%. In all cases, the accuracy is above chance (i.e., 50%, *p*s < .001).

Vermeulen, 2012) among this population because individuals with ASD seem to be differentially aware of contextual information and this contextual modulation seems to not always be an advantage.

Although we still observe overall poorer performance among individuals with ASD in recall accuracy, it might be an overstatement to consider this as a general indicator of short-term memory deficits. Rather, such deficits seem to be more subtly characterized by interactions between the contextual fit of the target object in the scene and its visual presence in the scene. In fact, clear differences between the two groups emerged only for specific interactions between such factors. Consequently, these results are consistent with the findings of Joseph et al. (2005) and Mammarella et al. (2014), which indicate that the poor performance observed in visuo-spatial memory tasks is not widespread; however, in our study, individuals with ASD relied extensively on contextual information to recognize a specific item.

Some of the contradicting results in the literature (e.g., Joseph et al., 2005; Bowler et al., 2008; Mammarella et al., 2014) may stem from the supported vs. unsupported nature of the task, as claimed by the Task Support Hypothesis (TSH) (Bowler et al., 1997, 2004). Despite the fact that we did not directly compare the performance on a free recall task against a recognition task, our data supports and extends the TSH modulation of contextual effects on short-term memory (as in Bowler et al., 2008) because the advantage of contextual information was also observed in a visual recognition task. In particular, our study fosters more support than the free recall tasks used by, for example, Joseph et al., (2005). The preserved contextual processing of the ASD group on a recognition task agrees with the findings from Lopez & Leekam (2003) and reinforces the view that support-based task performance is preserved in individuals with ASD and is modulated by contextual information. Along the same lines, in Loth and colleagues (2011), individuals with ASD showed no facilitation of contextual information in a free-recall task even if they could recognize consistent objects in the scene. The contrasting findings of Mammarella et al., (2014) were obtained using *similar-different* tasks, in which the two visual arrays to be compared were separated by a short time interval, and performance is therefore less supported than in recognition tasks.

Admittedly, we did not control for the number of objects in each scene, which could be an important limitation of the current study because the co-occurrence of objects in a scene may facilitate object recognition (Davenport, 2007). Another limitation of the current study is the fact that the objects displayed were slightly different than the ones present in the scenarios; however, this fact does not seem to explain the differences found between experimental conditions.

In summary, in contrast to the context blindness hypothesis (Vermeulen, 2012), we found that ASD participants are actually as sensitive to contextual information as TD participants, even though the ASD group displays a differential pattern of access and use. In particular, we found the ASD group to be strongly biased by contextual expectations. In fact, the poor performance observed in individuals with ASD is confined to the scenarios where there are violations of contextual expectancies. Our research provides evidence that contextual information modulates visual recognition tasks in individuals with ASD and extends the findings of Bowler et al. (2008), which used verbal material.

Implications

We show that individuals with ASD have access to contextual information and are somehow biased by it. This finding could drive the development of novel teaching strategies and the organization of daily life settings where expectancies are systematically manipulated (e.g., by taking advantage of the consistency among objects and their context and avoid the violation of expectancies) with the aim of improving learning by boosting memory recall.

Acknowledgements

JCC is supported through a post-doctoral fellowships awarded by the *Fundação para a Ciência e a Tecnologia* (Portugal) (SFHR/BPD/79485/2011) and the POPH/FSE (European Union). MIC is supported by a Leverhulme Early Career Fellowship (ECF-2014-205).

References

American Psychiatric Association -APA. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Arlington, VA: American Psychiatric Publishing.

Bennetto, L., Pennington, B. F., & Rogers, S. J. (1996). Intact and impaired memory functions in autism. *Child Development*, 67(4), 1816-1835.

Borges, M., & Coco, M.I. (2015). Access and Use of Contextual Expectations in Visual Search during Aging *in Proceedings of the EuroAsianPacific Joint Conference in Cognitive Science* (*EAP CogSci 2015*), Torino, Italy, *in press*.

Bowler, D. M., Matthews, N. J., & Gardiner, J. M. (1997). Asperger's syndrome and memory: Similarity to autism but not amnesia. Neuropsychologia, 35, 65–70.

Bowler, D. M., Gardiner, J. M., & Berthollier, N. (2004). Source memory in Asperger's syndrome. Journal of Autism and Developmental Disorders, 34, 533–542.

Bowler, D. M., Gaigg, S. B., & Gardiner, J. M. (2008). Subjective organisation in the free recall of adults with Asperger's syndrome. Journal of Autism and Developmental Disorders, 38, 104–113.

Carmo, J. C., Duarte, E., Pinho, S. Filipe, C & Marques, J. F. (2016) Preserved proactive interference in autism spectrum disorders. *Journal of Autism and Developmental Disorders. 46*(1), 53-63.

Davenport, J.L. (2007). Consistency effects between objects in scenes. Memory and Cognition. 2007 Apr;35(3):393-401.

Frith, Uta (1989). *Autism: Explaining the enigma*. Oxford, UK: Blackwell.

Hillier, A., Campbell, H., Keillor, J., Phillips, N., & Beversdorf, Q. (2007). Decreased false memory for visually presented shapes and symbols among adults on the autism spectrum. *Journal of Clinical and experimental Neuropsychology*, 29:6, 610-616.

Hollingwoth, Andrew (2005). Memory for object position in natural scenes. *Visual Cognition, 12*(6), 1003-1016.

Joseph, R.M., Steele, S.D., Meyer, E., & Tager-Flusberg, H. (2005). Self-ordered pointing in children with autism: failure to use verbal mediation in the service of working memory? *Neuropsychologia*, 43, 1400-1411.

Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child,* 2, 217-250.

Lopez, B., & Leekam, S.R. (2003). Do children with autism fail to process information in context? *Journal of Children Psychology and Psychiatry*, 44, 285-300.

Lord, C., Rutter, M., DiLavore, P. C., & Risi, S. (1999). *Autism Diagnostic Observation Schedule – WPS (ADOS-WPS)*, Los Angeles, CA: Western Psychological Services.

Loth, E.; Gómez, J.C.; Happé, F. (2011). Do High-Functioning People with Autism Spectrum Disorder Spontaneously Use Event Knowledge to Selectively Attend to and Remember Context-Relevant Aspects in Scene? Journal of Autism and Developmental Disorders, Vol. 41, issue 7, pp. 945-961.

Mammarella, I.C., Giofrè, D., Caviola, S., & Cornoldi, C.; Hamilton, C. (2014). Visuospatial working memory in children with autism: the effect of a semantic global organization. *Research in Developmental Disabilities*, 35(6), 1349-1356.

Myles, B. S., Bock, S. J., & Simpson, R. L. (2001). *Asperger Syndrome Diagnostic Scale (ASDS)*, Austin, TX: Pro-Ed.

Mottron L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. A. (2006). Enhanced perceptual functioning in autism: an update, and eight principle of autistic perception. *Journal of Autism and Developmental Disorders*, 2,1-17.

Ozonoff, S., & Strayer, D. L. (2001). Further evidence of intact working memory in autism. *Journal of Autism and Developmental Disorders,* 31(3), 257-612.

Palmer, Stephen E. (1975). The effects of contextual scenes on the identification of objects. Memory & Cognition, 3(5), 519-526.

Shah, A., & Frith, U. (1993). Why do autistic individuals show superior performance on the block design task? *Journal of Child Psychology and Psychiatry*, 34(8),1351-64.

Scherf, K. S., Luna, B., Kimchi, R., Minshew, N., & Behrmann, M. (2008). Missing the Big Picture: Impaired Development of Global Shape Processing in Autism. Autism Research, 1, 114–129.

Tager-Flusberg, H. (1991). Semantic processing in the free recall of autistic children: Further evidence for a cognitive deficit. *British Journal of Developmental Psychology, 9(3)*, 417-430.

Vermeulen, P. (2012) *Autism as context blindness*. AAPC PUBLISHING: Kansas.

Weschsler, D. (1996) *Escala de Inteligência Weschler para adultos – 3th Edition (WAIS-III)*. CEGOC-TEA Investigação e Publicações Psicológicas: Lisboa, Portugal.

Williams, D.L., Goldstein, G., Carpenter, P.A., & Minshew, N.J. (2005). Verbal and spacial working memory in autism. *Journal of Autism Developmental Disorders*, 35(6), 747-756.

Figures

Figure 1

Figure 2

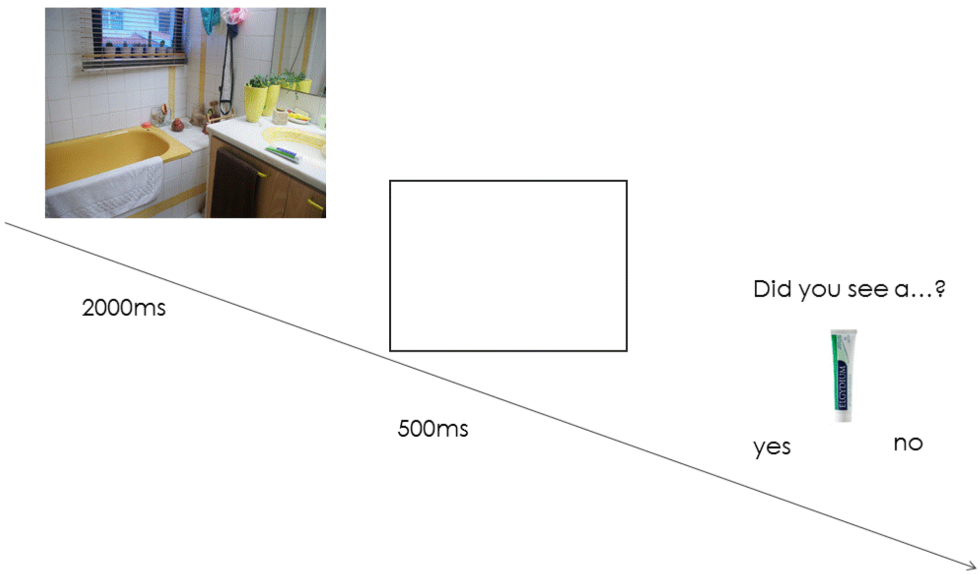

Figure 3

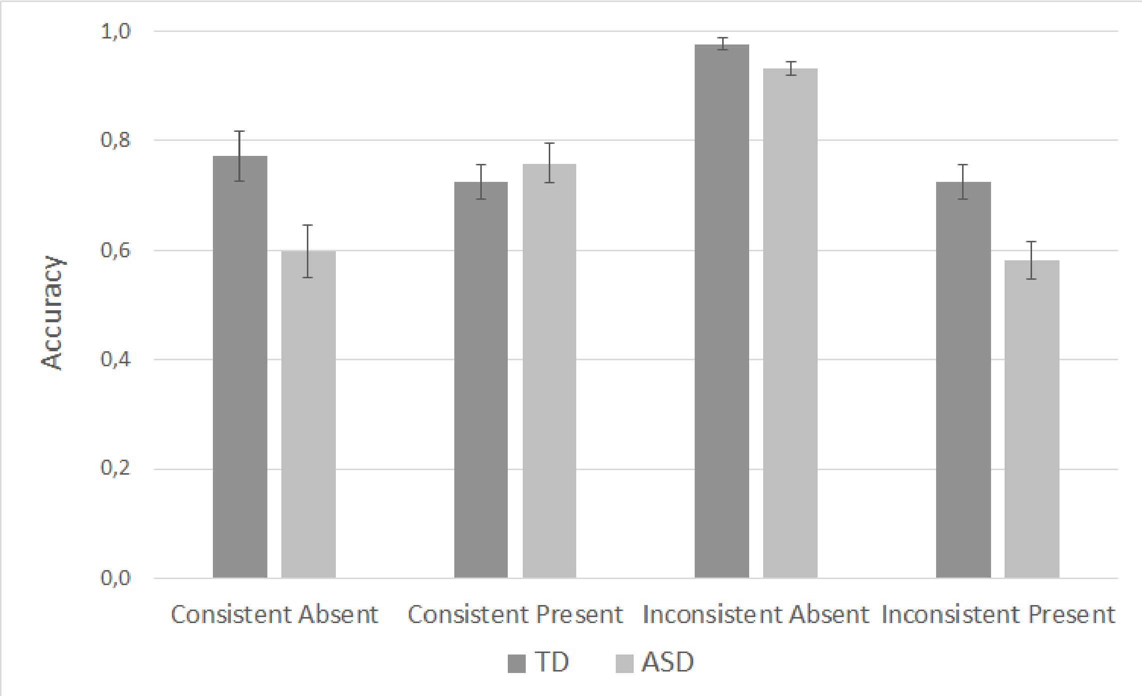
Accuracy
1,0
0,8
0,6
0,4
0,2
0,0
Consistent Absent
Consistent Present
Inconsistent Absent
Inconsistent Present
TD
ASD

Figure Captions

Figure 1. Examples of the stimuli used in the four conditions.

Figure 2. Schematic drawing of the trial design.

Figure 3. Average of correct recall over trials for both the ASD group and the TD group, for the four experimental conditions crossing Object (Absent, Present) and Context (Consistent, Inconsistent). Error bars represent standard error from the mean.

.