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Emotional false memory in autism spectrum disorder: More than spared

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Abstract

To advance what is known about how emotions affect memory in autism spectrum disorder, we examined emotional false memory for negative, positive, and neutrally-valenced photographs comprising scripts of everyday events in a verbal IQ-case matched sample of youth ages 8-14 with autism spectrum disorder (ASD, $N = 38$) and typical development (TYP, $N = 38$). The groups exhibited many similarities. Their task performance during a recognition task including previously seen and unseen photographs was largely comparable. They evidenced high hit rates for previously viewed photographs, and low false alarm rates for lure photographs that were inconsistent with the scripts. Both groups showed relatively higher false alarms for lure photographs depicting previously unseen causes of scenario outcomes (causal errors) compared to errors for script-consistent lure photographs that showed extra potentially related events (gap-filling errors). In both groups, task performance was associated with verbal working memory, but not attention deficit hyperactivity, anxiety, or depression symptoms. However, the ASD group made more causal and gap-filling errors on negative and positive, but not neutral, lures compared to TYP, indicating that viewing emotionally-valenced stimuli made it harder to discriminate previously seen and unseen photographs. For the ASD group, task performance was associated with compulsive, ritualistic, and sameness behaviors and stereotypic and restricted interests. Findings suggest that the integration of cognition and emotion in ASD is altered, and associated with the presence of

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repetitive behaviors. The impact of these results on the lives of individuals with ASD, and implications for psychosocial interventions are discussed.

General Scientific Summary:

The current study shows that youth with ASD are able to remember many aspects of scripts of common everyday events similarly to those with TYP. However, when emotional versus neutral materials are presented as lures, youth with ASD perform more poorly than TYP, suggesting that the presence of emotional materials may distort memory for emotional everyday events in those with ASD.

Keywords

false memory; emotion; memory; backward causal inference; gist; autism

Introduction

Memories for emotion-laden events are important for the human experience. Most people vividly remember the joy associated with experiencing love, winning prizes or seeing new beautiful places, as well as the pain associated with loss, loneliness, and disappointment. These emotional memories help organize our sense of who we are, and are critical determinants of our approach and avoidance behaviors as we navigate the world (Eaton & Anderson, 2018).

A considerable body of research has examined the interplay between emotions and memory throughout the life span in typically developing individuals (TYP). Perhaps the most consistent finding from these studies is that emotional events are better remembered than ones without an emotional valence (Cahill & McGaugh, 1995; Heuer & Reisberg, 1990; Kensinger & Corkin, 2003), especially if they are described using negative words (Kensinger, Garoff-Eaton, & Schacter, 2007) or displayed in negative scenes (Anderson, Yamaguchi, Grabski, & Lacka, 2006).

Interestingly, emotion can distort an individual's recollection of words or events and produce gist-based memory illusions, which are known as emotional false memories (Bookbinder & Brainerd, 2017; Koutstaal & Schacter, 1997; Roediger & Mcdermott, 1995). Individuals tend to make more errors when asked to remember fictitious causes of previously-experienced events (e.g., remembering erroneously that a motorist hit a biker after seeing an ambulance take the biker, who in fact simply fell of her bike, to the hospital) which are referred to as causal emotional memory errors, than errors that are related to simply filling in non-casual emotional details related to scenes (e.g., remembering that the biker on the way to the hospital was accompanied by a police escourt, when in fact they were not), which are known as gap-filling errors (Mirandola, Toffalini, Grassano, Cornoldi, & Melinder, 2014).

Cognitive and psychological characteristics have been associated with the propensity to have emotional false memories. Higher levels of depression (Howe & Malone, 2011; Joormann, Teachman, & Gotlib, 2009) and anxiety symptoms (Toffalini, Mirandola, Drabik, Melinder,

& Cornoldi, 2014) can enhance the illicitation of negative false memories. Strength of cognitive processes such as working memory, attention, and language can influence the depth and quality of stimulus encoding, which then produces more accurate memories (Fox, Russo, Bowles, & Dutton, 2001; Mirandola, Toffalini, Ciriello, & Cornoldi, 2017; Ohman, Flykt, & Esteves, 2001; Toffalini, Mirandola, Coli, & Cornoldi, 2015).

Emotions and memory in autism spectrum disorder (ASD)

There have been relatively few studies of false memory, the impact of emotional materials on memory, and emotional false memory in persons with ASD. Writing about general false memory in ASD, Beversdorf et al. (Beversdorf et al., 2000) used the Deese, Roediger, McDermott paradigm or “DRM” (Roediger & Mcdermott, 1995), where participants are asked to encode lists of words, pictures, or word-picture pairs, and then are asked to remember them when presented with a list including semantically and/or emotionally related lures. In this very small study that included 8 adults with ASD and 16 with TYP, they found that individuals with ASD were less likely to show false memories than TYP, and concluded that high functioning adults with ASD had restricted associative memory networks, resulting in reduced ability to encode the gist of a category of similar items. However, a second similarly sized study with the same design failed to replicate these initial findings (Bowler, Gardiner, Grice, & Saavalainen, 2000). Studies using perceptually-related versus sematically-related materials confirm the absence of group differences in adults with ASD and TYP in the tendency to produce false memories. For example, Gaigg & Bowler (Gaigg & Bowler, 2009), found similar rates of recognition using orthographically similar stimuli and lures in 22 adults with ASD and 22 adults with TYP. Also writing about visual stimuli, Molesworth and colleagues (Molesworth, Bowler, & Hampton, 2005) showed that the prototype effect (recognizing pictoral best exemplars of a category of stimuli without having actually seen them) was comparable in 15 preadolescents with Asperger’s Disorder and 15 with TYP. The most recent study using a non-emotional DRM paradigm included three difficulty-graded conditions with words (most difficult), pictures (intermediate difficulty), and word/picture pairs (least difficult) and was implemented in 15 late adolescents with ASD and 15 with TYP (Parra et al., 2016). False alarms on both gist-consistent and gist-inconsistent lures, declined from the word only, to the picture, to the word-picture condition in the TYP group. Although the ASD group scored more poorly than TYP on most measures, they showed the same general pattern of performance as TYP. In sum, although studies of false memory in ASD have been small and have utilized different task paradigms, they have found that the pattern of false memories errors for perceptual and semantic materials is similar in ASD and TYP.

Writing about the potential facilitation effects of emotion on memory in another small study, Beversdorf and colleagues (1998) showed that benefits of recalling emotional materials were less pronounced in adults with ASD compared to healthy controls. Deruelle and colleagues (Deruelle, Hubert, Santos, & Wicker, 2008) investigated the impact of negative emotion on memory for neutral and emotional pictures in 15 adults ages 17-55 years with average or better IQs versus age and IQ-matched TYP. All were shown two sets of emotional stimuli with equal numbers of positive, negative, and neutrally-valenced pictures, and then were tested on a second set of pictures consisting of both previously-viewed and new photos.

Overall, both groups performed comparably, although the TYP group better recalled negative versus neutral and positive pictures, while the ASD group did not show this facilitation. There were no effects of age or IQ in either group. South and colleagues (South et al., 2008) conducted a relevant study attempting to probe the role of amygdala functioning and emotional memory in ASD in a larger (n=37/group) and relatively younger group (mean age of 19). Participants in this study completed several tasks including one related to fear-inducing stimuli, one related to the recognized preference for previously viewed words, one which involved discriminating studied versus unstudied emotional words, and a gambling task. The authors found a few performance differences between the groups across the tasks, but no diagnostic group by condition interactions in the ability to remember emotional versus neutral material in adolescents and young adults.

In the only study of emotional false memory in ASD, affected individuals made more false-alarms than TYP when remembering stimuli consisting of sexual and swear words (Gaigg & Bowler, 2009), which may have been arousing, but did not represent simple or complex emotions. Overall, research is in the early stages, and has relied on small samples, a wide range of task paradigms, and mostly adult participants. While false memories appear to occur equally often in ASD, there appear to be subtle group differences in the ways in which emotion enhances memory and promotes false memories in individuals with ASD versus TYP– findings that are consistent with the proposition that ASD involves atypical integration of cognition and emotion (Gaigg, 2012).

To advance what is known about how emotional false memory impacts the lives of individuals with ASD, we implemented a backward causal inference paradigm where participants are shown scenarios/scripts consisting of photographs of common everyday events which children would have experienced, or could understand, during an encoding phase. These have positive, negative, and neutral valences. Participants are then tested on previously seen and unseen emotional photographs that may cause them to make causal or gap-filling errors. Participants included 8 to 14 year-old children with ASD or TYP; these samples were well matched on verbal IQ. Matching on verbal IQ is important because the studies that reported more substantial memory differences between TYP and ASD tested verbal materials and did not always case match for verbal skills.

In light of recent studies which have documented comparable false memory for words and pictures that do not involve emotions in those with ASD and TYP (Parra et al., 2016), we predicted that there would be no group differences in task performance for both gist-consistent (i.e., those that were consistent with a given event) and gist-inconsistent photographs (i.e. those that were unrelated to a given event) which contained matched numbers of positive, negative, and neutral scenarios. However, given findings that, compared to TYP, emotionally-valenced stimuli affect memory at least subtly differently in adults (Deruelle et al., 2008) and older adolescents with ASD (South et al., 2008), and may cause those with ASD to have false memories (Gaigg & Bowler, 2009), we anticipated that there would be differences between ASD and TYP in their tendency to remember emotionally valenced versus neutral materials and to generate false memories when positive and negative versus neutral materials were the focus of analyses. To constrain this prediction and to make it more specific to ASD, we additionally hypothesized that the presence of social communication and social interaction, and repetitive behavior autism symptoms and their would be associated with the propensity to experience emotional false memories in the ASD group. Based on the literature on TYP reviewed above, which suggests that cognitive and psychological factors may be associated with emotional false memory, we also examined whether there were differences in working memory, and attention deficit hyperactivity disorder (ADHD), anxiety, and depression (Howe & Malone, 2011; Joormann et al., 2009; Toffalini et al., 2014) symptoms related to task performance in adolescents with ASD as there are in TYP adults, but offered no hypothesis given the lack of relevant studies.

Method

Participants

The present study examined a case-matched sample of 38 individuals with ASD (6 females) and 38 individuals with TYP (9 females), drawn from the UC Davis MIND Institute Autism Phenome Project (APP) and the Predictors of Cognitive Development Studies (Predictors). The APP sample was originally recruited beginning in 2006, including children between 23 and 44 months of age both with and without ASD. These children all met NIH Collaborative Programs of Excellence in Autism standards for an ASD diagnosis. These included having received a best estimate diagnosis of autism, PDD-NOS, or Asperger syndrome from a licensed site clinician; and having met the Autism Diagnostic Observation Schedule (ADOS-2) (Lord et al., 2000) cutoff score for either autism or ASD, or the Autism Diagnostic Interview-revised (ADI-R (Lord, Rutter, & Le Couteur, 1994)) cut-off for autism on either the Social or Communication subscale while being within two points of this criterion on the other subscale. Participants from the Predictors Study were recruited starting in 2015 from the UC Davis MIND Institute's Subject Tracking System, fliers posted at local schools, and the surrounding Sacramento community. The individuals range in age from 8-14 years old (M=11.0, SD=1.4). All participants from the Predictors sample had a community diagnosis of ASD, met DSM-5 criteria for ASD, scored in the ASD range on the ADOS-2, and had scores of greater than 15 on the Social Communication Questionnaire (Berument, Rutter, Lord, Pickles, & Bailey, 1999). Based on available clinical cutoff scores of 70 on the parent-report Child Behavior Checklist (CBCL) (Achenbach, 2001), 19% of participants in this study with ASD met criteria for depression, 27% for anxiety, and 32% for ADHD. These same percentages were 3%, 0%, and 3% in the participants with TYP.

Given the potential importance of verbal abilities to memory, we created a well-matched sample from the larger samples of APP and Predictors participants using the SAS %matchcc macro (http://support.sas.com/resources/papers/proceedings10/061-2010.pdf). This allowed verbal ability to be matched within an acceptable range (8 points) between each ASD case and a TYP control. This produced two groups with IQs between 80 and 140, with mean IQs that did not differ more than 2 points for any IQ component. All of these participants were able to complete the task at better than chance levels of performance on a sensitivity index (d'). Demographic and clinical characteristics of the participants can be found in Table 1. This study was approved by the UC Davis Institutional Review Board, Clinical Committee B (Protocol #: 686644-7) and informed consent was obtained from the parent or guardian of each participant.

Measures

Emotional false-memory recognition task—(Mirandola, Losito, Ghetti, & Cornoldi, 2014; Mirandola et al., 2017). This task is a version of the backward causal inference paradigm that has been used with children (Melinder, Toffalini, Geccherle, & Cornoldi, 2017).

Study/encoding phase: The task begins with a study/encoding phase where partipants are shown a series/episode of photographs depicting 9 everyday events/scenarios (waking up in the morning, going for a bike ride, grocery shopping, playing a slot manchine, going hiking, running on a track, having a birthday party, returning home from a trip, and going on a date) in a continuous randomized sequence. Each event consists of 13 photographs, which are presented for 2 seconds each, followed by a 2 second delay. Embedded within each series of photographs, are consequences (referred to as effects) of unseen actions (i.e., causes) that are related to the series of photographs. These effects can be either positive (n=3 events), negative (n=3 events), or neutral (n=3 events). Participants receive one of 6 set orders of photographs which contain equal numbers of valenced events to ensure that target-distractor photographs are counterbalanced across participants. Examples of positive events/*effects* include a picture of the couple kissing during the dating episode or the hiker making it to the top of the mountain in the hiking series. Examples of negative effects include a photograph of the girl rejecting the boy during the dating scenario or the hiker falling during the mountain climbing scenario. The neutral outcome for the dating scenario is the boy giving the girl a book, whereas a neutral outcome in the mountain climbing scene is driving home from the mountain. As reported in (Mirandola et al., 2017), the valence and arousal levels of the photographs chosen to represent the effects were rated by 18 independent judges and found to be consistent with their assignment to the negative, positive, and neutral categories.

Test phase of the task: The study phase of the task is followed by an untimed surprise recognition test 15 minutes later, where participants are asked, "Have you seen this picture before?" in a yes/no format. With this task, 3 types of false memory-related errors can be studied -- gap-filling errors, inferential causal errors -- both of which are also referred to as false alarms -- and errors committed for pictures that are inconsistent with the episodes. Gap-filling errors are committed when one incorrectly endorses having previously seen photographs containing peripheral details consistent with the episode. For example, a person might erroneously remember a girl brushing her teeth when in fact she was combing her hair in the waking up in the morning scenario. A second type of error -- causal errors -- involves remembering a non-presented but plausibly hypothesised, *cause* of a viewed action's effects. Thus, causal errors relate to crucial aspects of the episode but represent the erroneous acceptance of an unseen action cause (e.g., viewing an injured girl on the street with a car nearby might lead to the false recognition of the car hitting the girl who was crossing the street, even if this scene was not experienced). Finally, it is possible to make errors on inconsistent lures that are photographs unrelated to the presented events (i.e. endorsing having seen a park bench that was not previously presented or related to any of the episodes). During the recognition task, participants are shown 45 previously viewed and 45 new (i.e., lure) photographs. There are 3 potential gap-filling lures per episode where the lure photographs depict potential peripheral details of the episode that were not presented during encoding; 1 causal lure per episode where the lure photograph depicts an erroneous *cause* of an *effect* scene (e.g., a newly presented car hitting the biker, when the studied episode only included an ambulance taking the biker to the hospital although the original scene did not contain an explicit cause for the trip); and 9 total inconsistent lures that present photographs that are not related to the episodes..

Dependent variables investigated, which all are based on performance during the test phase of the task, include hit rates (correctly remembering previously seen photographs) for total and emotional versus neutral scenarios, false alarm rates on photographs that are scene-consistent, error rates on photographs that are scene-inconsistent, and a sensitivity index (d'), which is calculated as *Z*(hit rate) – Z(false alarm rate) for scene-inconsistent photographs. We refer to this d' as a measure of task performance. Scene-inconsistent photographs are used to calculate this measure of task performance in order to assess a general memory ability to discriminate old from familiar apart from the influence of stimuli predisposing participants to make false alarms. False alarm rates on gist-consistent gap-filling, and causal lures also are computed for positive, negative, and neutral episodes to assess the relative probability of forming memory illusions as a function of event valence and error type. See Figure 1 for a schematic depiction of the task.

Participants also completed common ASD cognitive and diagnostic measurements as outlined below. All diagnostic assessments were completed by licensed clinical psychologists who specialize in ASD and were trained to research standards for these measures.

Autism Diagnostic Observation Schedule-2 (ADOS-2) (Lord et al., 2000).—The ADOS-2 is a semi-structured standardized observation to diagnose ASD. To meet criteria for classification, individuals must exceed a threshold of a combined Social Affect and Repetitive Behavior score. This calibrated severity score (CSS) allows for comparison across ADOS-2 modules by estimating the ASD symptom severity. CSS range from 1-10 (1-3 Non-ASD; 4-5 Autism Spectrum; 6-10 Autism).

Social Communication Questionnaire, Lifetime Version (SCQ)(Rutter, Bailey, & Lord, 2003).—The SCQ is a parent-report questionnaire exploring children's social and communicative behaviors over their lifetime. Through 40 yes/no items, a total score of 15 or more indicates the presence of ASD.

Differential Ability Scales (DAS-II) (Elliot, 2007).—The DAS-II is a standardized measure of children's cognitive abilities. Participants in the present study completed the DAS-II School Age form, which includes verbal, nonverbal, and spatial subscales to create a General Conceptual Ability (GCA) composite score.

Wide Range Assessment of Memory and Learning, Second Edition (WRAML2) (Sheslow & Adams, 2003).—The WRAML2 is a standardized measure of children's memory. Varying Memory Indexes are calculated using verbal and symbolic memory subtests. These scores can be converted to percentiles to make age-based performance comparisons. The Verbal Working Memory index was used.

Child Behavior Checklist (CBCL) (Achenbach, 2001).—The CBCL, which is a part of the broader Achenbach System of Empirical Behavioral Assessment (ASEBA), is a caregiver report questionnaire that identifies behavioral, social and emotional problems in children. Participants in the present study completed the CBCL School Age form, which includes standardized symptom, syndrome, and composite t-scores. The depression, anxiety, and ADHD syndrome scales were used. For the syndrome scales, t-scores less than 65 are considered in the normal range, t-scores ranging from 65 to 70 are considered to be in the borderline clinical range, and t-scores above 70 are in the clinical range (Achenbach, 1991).

Repetitive Behavior Scale- Revised (RBS-R) (Bodfish, Symons, & Lewis, 1999).—The RBS-R is a parent-report questionnaire measuring a range of repetitive behaviors of children with ASD. The 44-items provide a continuous measure of the entire spectrum of repetitive behaviors. It is divided into six subscales including stereotyped behavior (sum of 9 items), self-injurious behavior (sum of 8 items), compulsive behavior (sum of 6 items), routine behavior (sum of six items) sameness behavior (sum of 12 items), and restricted interests (sum of 3 items). Behaviors are rated on a 4-point scale. In a factor analysis of the RBS-R, a three factor solution including self-injurious behavior; compulsive, ritualistic, and sameness behavior; and stereotypic and restricted interests has been recommended as most parsimonious (Mirenda, Smith, Vaillancourt, Georgiades, Duku, Szatmari, Bryson, Fombonne, Roberts, Volden, Waddell, & Zwaigenbaum, 2010; Mirenda, Smith, Vaillancourt, Georgiades, Duku, Szatmari, Bryson, Fombonne, Roberts, Volden, Waddell, Zwaigenbaum, et al., 2010). Scores for these three factors were used in analyses.

Statistical Analysis

Statistical analysis was conducted within a general linear mixed models framework that can accommodate traditional general linear models (e.g., ANOVA and multiple linear regression) for data that were assumed independent across individuals, as well as mixed-effects linear models (Laird & Ware, 1982) for data that was collected repeatedly for an individual, across multiple conditions. An advantage of this approach is the ability to directly model heterogeneous variances (across groups or conditions). This framework was used both to assess group differences between ASD and TYP and to examine associations involving specific predictors (age, working memory, psychopathology, etc) and the variables of interest. Hits and false alarm rates were collected for consistent photographs and errors were collected for inconsistent photographs. False alarm rates were calculated for positive, negative, and neutrally-valenced photographs, for both causal and gap-filling lures. D' was calculated for consistent and consistent photographs and for emotional (positive and negative versus neutral) and scenarios. Thus, linear mixed-effect models were used to analyze these variables that were collected repeatedly over different conditions. In these analyses, we started with a full factorial model and sequentially removed the interaction terms that were not significant. Following any significant interaction, we examined pairwise comparisons of interest.

Linear regression with a fixed effect for group was used to examine d' for inconsistent photographs. In secondary analyses, we examined associations between d' and measures of working memory and psychopathology (ADHD, anxiety, and depression) by adding these measures (one at a time) to the regression model for d'. Finally, within the ASD group, we also examined correlations between performance as measured by d' and autism severity and repetitive behavior symptoms. These additional analyses used false discovery rate (FDR) to correct for multiple comparisons. All tests were two-sided, with $\alpha = 0.05$ and estimates are reported with 95% confidence intervals (CI). All analyses were conducted in SAS version 9.4. (SAS Institute Inc., Cary, NC).

Results

Performance on non-emotion related aspects of the false memories task

Repeated measures models with fixed effects for group (ASD versus TYP), type (consistent vs. inconsistent), and their interaction, as well as a random effect for person (to account for the within-person dependence) was used to examine how error rates, hits, and recognition test performance (d') differed by group. For the error rate model, separate variances were assumed for consistent and inconsistent errors. Table 2a presents summaries for the error rates and hits for the ASD and TYP groups. For hits, the interaction between group and type of hit was not significant and was not retained in the final model (estimate = 0.03, 95% CI −0.04 to 0.11, $F_{1,76} = 0.14$, $p = 0.39$). In the final model (see Table 3a), there was no significant difference between the ASD and TD groups in hit rates (estimate = −0.04, 95% CI −0.10 to 0.02, $F_{1,76} = 1.50$, $p = 0.22$), but the main effect of trial type was significant, with hit rate on script-consistent photographs about 12% lower than in script-inconsistent photographs for both groups (estimate = −0.12, 95% CI −0.16 to −0.08, $F_{1,76} = 35.78$, $p < 0.001$). See Figure 2a. For error rates, the interaction between group and error type was significant (estimate = 0.11, 95% CI 0.05 to 0.18, $F_{1,76} = 10.98$, $p = 0.001$), suggesting that the pattern of group differences varied across types of photographs (see Table 3a). The ASD group made about 12% more false alarm errors for scene-consistent photographs (e.g., preparing ones ropes to go mountain climbing during the mountain climbing scene, even if this part of the episode was not presented during the study phase of the task) than the TYP group (estimated difference in false alarm rates = 0.12, 95% CI 0.05 to 0.19, $t_{76} = 3.52$, $p < 0.001$), although they did not show the same pattern for inconsistent photographs (e.g., sitting on a park bench during the mountain climbing scene) (estimated difference = 0.01, 95% CI −0.01 to 0.03, $t_{76} = 0.76$, $p = 0.45$) (Figure 2b). Both groups made more false alarms for the consistent versus errors on inconsistent photographs (estimated error rate difference = 0.32, 95% CI −0.27 to 0.37, for ASD, 0.21, 95% CI 0.16 to 0.26, for TYP, $t_{76} = 13.24$ and 8.55, respectively, both $p < 0.001$). This indicated that the ASD group was more likely to remember incorrectly in the face of gist-consistent lures, but were not simply responding to every lure. There was no group difference on sensitivity (d') for inconsistent trials (estimated difference between TYP and ASD = 0.12, 95% CI −0.14 to 0.38, $t_{74} = 0.92$, $p = 0.36$).

Do individuals with ASD and TYP better remember scenes that involve emotional materials?

We next examined group differences in d' and whether recognition accuracy was better for emotional compared to neutral scenarios using a repeated measures model with fixed effects for group (ASD versus TYP), scenario valence (positive/negative versus neutral) and their interaction, as well as a random effect for person. The interaction between group and valence was significant (estimate = −0.37, 95% CI −0.70 to −0.05, $F_{1,76}$ = 4.88, p = 0.03), suggesting that the pattern of group differences varied across stimulus valences (see Table 3b). The ASD group performed more poorly than the TYP group for the emotional images (estimated difference in d' = −0.56, 95% CI −0.84 to −0.27, t_{137} = −3.83, p < 0.001), but did not show the same pattern for neutral photographs (estimated difference = −0.19, 95% CI −0.47 to 0.10, t_{137} = −1.28, p = 0.20) (Figure 3, Table 2b). We further examined within group differences between the emotional and neutral scenarios. Performance on emotional scenes versus neutral ones was not significantly better for either the ASD (estimated difference = −0.20, 95% CI −0.44 to 0.03, t_{76} = −1.72, p = 0.09) or the TYP group (estimated difference = 0.17, 95% CI −0.07 to 0.40, t_{76} = 1.40, p = 0.16).

Does stimulus valence affect the propensity to make causal versus gap-filling errors?

A repeated measures model with fixed effects for group (ASD versus TYP), error type (causal vs. gap-filling), and valence (positive, negative, neutral), as well as a random effect for person was used to examine group differences in errors and whether this differed by stimulus valence. Separate variances were assumed for causal vs. gap-filling errors. We started with a full factorial model and sequentially removed the interaction terms that were not significant. The final model (see Table 3c) included all three main effects and the interactions between error type and valence ($F_{2,319}$ = 11.90, p < 0.001) and between group and valence ($F_{2,373}$ = 3.05, p = 0.049). The significant error type by valence interaction in the absence of a three-way interaction with diagnosis indicates that the ASD and TYP groups had similar patterns of errors; both groups evidenced more causal than gap-filling errors for all three valences (estimated difference in error rates = 0.25, 95% CI 0.19 to 0.31 for negative, 0.32, 95% CI 0.26 to 0.39 for neutral, 0.11, 95% CI 0.05 to 0.17 for positive, t_{319} = 8.08, 10.43, and 3.64, respectively, all p < 0.001). The significant group by valence interaction in the absence of a three-way interaction with error type indicates that the pattern of group differences across valences was similar for the two types of errors; for both causal and gap-filling, the ASD group evidenced more errors than the TYP group for negative (estimated difference = 0.14, 95% CI 0.06 to 0.21, t_{152} = 3.48, p < 0.001) and positive (estimated difference = 0.14, 95% CI 0.06 to 0.21, t_{152} = 3.51, p < 0.001), but not neutral valences (estimated difference = 0.05, 95% CI −0.02 to 0.13, t_{152} = 1.40, p = 0.16). See Figure 4, Table 2c.

Working memory, psychopathology (ADHD, anxiety, and depression), ASD symptoms, and emotional false memory

We also examined whether working memory and symptoms of psychopathology related to anxiety, ADHD, and depression, were associated with task performance as measured by d', and whether these associations differed by diagnosis. To do so, we added these cognitive and psychopathology-related variables, one at the time, as fixed effects in the regression model fitted for d'. After controlling for multiple comparisons, we found a positive association between working memory and d' (estimated coefficient = 0.01, 95% CI 0.004 to 0.02, t_{70} = 2.92, adjusted p = 0.02). To test whether this association differed by group, we added an interaction between working memory and group to the model. The estimated effect was small (−0.0004, 95% CI −0.02 to 0.02, t_{69} = −0.04, p = 0.97, respectively).

Some autism measures (ADOS-2 severity) were only collected for the ASD group and other autism symptoms (the three factor scores from the RBS-R) had a very narrow range in the TYP group. Thus, we examined correlations between these measures and d’ only in the ASD group. After controlling for multiple comparisons, for the ASD group, d’ was associated with scores on the stereotypic and restricted interests ($r = 0.45$, adjusted $p = 0.02$) and the compulsive, ritualistic, and sameness factors ($r = 0.39$, $p = 0.04$) of the RBS-R 3 factor solution, but not the ADOS-2 severity score or the self-injurious behavior RBS-R factor score (both adjusted p-values > 0.85).

Discussion

We examined emotional false memory in a task involving photographs depicting positive, negative, and neutrally-valenced everyday scenes in a large verbal IQ-case matched sample of children ages 8-14 with ASD and TYP. There were many similarities in performance between the groups including high hit rates, low false alarm rates for gist-inconsistent photographs, and comparable d’s for gist-inconsistent photographs. Both groups made significantly more causal than gap-filling errors across stimuli of all emotional valences. They also showed positive associations between verbal working memory strength and task performance; and a lack of significant associations between ADHD, anxiety, and depression symptoms and task performance. Notable differences between the groups included that individuals with ASD showed less overall emotional facilitation in their task performance for emotional compared to neutral scenes, made significantly more false alarms on causal and gap-filling gist-consistent lures than TYP, with more emotional (positive and negative) than neutral false alarms for both types of lures. For the ASD group, d’ was related to compulsive, ritualistic, and sameness behaviors and stereotypic and restricted interests.

Perhaps the most striking finding of the current study was that individuals with ASD had higher false alarm rates for emotional gist-consistent versus neutral lures than those with TYP, which could be seen as somewhat surprising in light of the general beliefs that individuals with ASD are less aware of semantic context and less able to extract gist (Beversdorf et al., 2000; Klin & Jones, 2006). Theories about processes that govern lexical-sematic networks can help explain the tendency to make false alarms. Associative-activation theory (ATT) (Howe, 2008) suggests that, paradoxically, false memories develop over time as one’s knowledge base expands and enables more efficient and automatic activation of concepts that are related to stimulus materials. Fuzzy-trace theory (FTT) (Brainerd & Reyna, 2002, 2005) takes this notion a step further and proposes that there are two distinct types of traces involved in memory -- verbatim traces that encode item-specific information and reduce false memories, and gist traces, which promote false memories by emphasizing meaning-based connections between pieces of information. Negative words also are thought to have the densest and most interconnected associative networks, thus limiting the search space, and enhancing both encoding and retrieval efficiency (Bookbinder & Brainerd, 2017; Knott, Howe, Toffalini, Shah, & Humphreys, 2018; Talmi & Moscovitch, 2004; Tulving & Pearlstone, 1966).

If interpreted according to this framework, one could argue that we found that when stimuli had an emotional valence, the ASD group evidenced well-elaborated contextual association networks, that became activated during encoding, and then were more difficult to inhibit during retrieval (Cann, McRae, & Katz, 2011). This was true despite the fact that the ASD group showed no impairments relative to TYP in correctly identifying gist-inconsistent lures, were from a verbal-IQ case-matched sample, and did not show differences from the TYP group in the relationship between their task performance and factors like working memory, anxiety, and depression, which could have driven group differences. In essence, it could be argued that presenting participants with emotionally-valenced stimuli resulted in greater associative network activation in the ASD group, which had sufficiently mature and developed networks to encode the scenes. Negative (and positive) emotion made them more likely to endorse lures.

However, an alternative explanation also is possible. Rather than attributing enhanced memory to greater associative network activation in the ASD group, another rationale for these findings is that individuals in the ASD group experienced less memory benefit from the presence of emotional materials than those in the TYP group because they may not have prioritized them, and/or traded speed for accuracy when responding (Worsham, Gray, Larson, & South, 2015), and were thus was not able to comparably encode the specific item details which might have boosted their ability to recollect the events. This interpretation is consistent with our findings of reduced facilitation by positive and negative versus neutral valence in the recognition of scenes for the ASD versus the TYP group, although it should also be noted that neither group showed the better performance overall on the positive and negative versus neutral scenes, which might have been predicted by the literature (Cahill & McGaugh, 1995; Heuer & Reisberg, 1990; Kensinger & Corkin, 2003). If this memory enhancement did not occur in indivduals with ASD, then they might be less confident in their recollection of individual images and more likely to rely on the event gist and semantic details to remember the event. Future studies of recollection vs. familiarity that include measures of memory confidence and strength, would enable the field to better adjudicate between these two interpretive frameworks.

Our work represents an extension of Gaigg & Bowler (2009) and Parra et al. (2016), who also documented higher false alarm rates in the ASD group under emotional and false memory conditions, respectively. However, it bears mention that the emotional swear words used by Gaigg & Bowler were different than the emotional stimuli we used. They may have prevented false alarms in the TYP but not the ASD group, not because of their emotional valence, but because the latter did not posess the social knowledge to realize the full meaning and impact of such words. It is interesting that the participants in the Parra et al. (2016) study also committed more false alarms on gist-consistent stimuli in their word-picture condition which is most similar to our complex scenes, suggesting that the tendency to false alarm may actually be more common when conditions are easier, not just emotional, and instead of facilitating task performance, make the inhibition of semantic networks more difficult. This notion that the difficulty is with accurate retrieval is consistent with recent suggestions that memory problems in ASD are more a matter of problems with retrieval than encoding (Cooper et al., 2017).

Another interesting and somewhat unexpected finding of the current study was that, although we predicted that difficulties with the integration of cognition and emotion would be associated with ASD symptoms for those with the disorders, they were related to repetitive behaviors, but not to the severity of social interaction and social communication symptoms. In a recent study of dual processes of familiarity (a sense of knowing based on the strength of a memory trace) and recollection (the experience of retrieving qualitative information about items and related aspects of the context in which they were encoded) in episodic memory in adolescents with ASD, our group unexpectedly found that individuals with ASD used less familiarity than TYP when recalling stimuli encoded in an associative context. This suggested that persons with ASD might use these two memory processes differently than TYP, and that the semantic networks of persons with ASD might thus in fact be more elaborated and densely connected than is typical (Solomon, McCauley, Iosif, Carter, & Ragland, 2016). We hypothesized that such networks might be associated with restricted interests and repetitive behaviors, as has been suggested previously (Cohen, 2007; McClelland, 2000). Findings of the current study also are consistent with this premise given that it appears that well connected and elaborated networks are activated during encoding and retrieval in those with ASD, thereby increasing the probability of producing false memories and failing to inhibit them. Cognitive mechanisms similar to those that govern the creation of false memories, and overly conjuction memories in general, may be related to the tendency of those with ASD to exhibit compulsive, stereotyped, narrow, and rigid behavioral repertoires.

In addition to the strength of the semantic networks in which emotional stimuli are encoded, it has been suggested that arousal levels during encoding have a comparable (Buchanan, Etzel, Adolphs, & Tranel, 2006) or even greater (Mirandola & Toffalini, 2016) effect on the ability to remember them. It could be argued that the arousal occasioned by the emotional task stimuli had a greater influence on the ASD group’s propensity to false alarm during the recall phase of the task, although the only study of the impact of arousal, emotion, and memory in ASD did not find group differences (Maras, Gaigg, & Bowler, 2012). Similarly, mood at encoding and retrieval has been shown to affect information processing such that positive moods support relational or gist-based processing with broader activation of more remote and weakly associated information, whereas negative moods are associated with item-specific and smaller and more strongly associated networks (Storbeck & Clore, 2005, 2011; Zhang, Gross, & Hayne, 2017). The role of arousal and mood on encoding and retrieval have not yet been well studied in ASD, but represent potentially interesting leads to pursue, especially given their potentially opposing effects on false memory (Bookbinder & Brainerd, 2016).

Our finding of increased false memories for negatively valenced stimuli is similar to that of Mirandola and colleagues (Mirandola, Losito, et al., 2014), who conducted a study of memory for scenes using the same task, in preadolescents with learning disabilities (LD). The disabilities studied including non-verbal learning disability (NVLD), which is thought to be similar to the Asperger’s Disorder (Klin, Volkmar, Sparrow, Cicchetti, & Rourke, 1995). Mirandola et al. found that compared to participants with TYP and dyslexia, the 14 preadolescents in their study with NVLD were more likely to falsely recognize photograhs that depicted unseen causes of a negative emotional scenes. Although there were no significant associations between depression symptoms in our findings, children with ASD, like those with LD, likely possess well-developed networks of negative experiences like bullying and social isolation that can become activated when viewing negative scenes (Zablotsky, Bradshaw, Anderson, & Law, 2013).

As detailed in the first paragraph of this manuscript, recollections of emotional events color the experience of being human, and propel us toward future action. Based on our findings, it would appear that preadolescents with ASD have qualitatively different memories of emotional material. They filled in more gaps, made more assumptions about associations between events, and jumped to conclusions based on causal stimuli. The tendencies revealed in the current study may help explain the at times idiosyncratic social perceptions (Byrge, Dubois, Tyszka, Adolphs, & Kennedy, 2015; Loveland, Pearson, Tunali-Kotoski, Ortegon, & Gibbs, 2001) and atypical patterns of motivation in the form of social and non-social reward processing (Clements et al., 2018) found in affected individuals. Furthermore it suggests that mental health professionals working with individuals with ASD need to be aware of theses tendencies when implementing supportive and cognitive behavior therapy (CBT), which are both premised on helping clients to reframe inaccurate negative thinking. Our results suggest that modifying patterns of thoughts may be particularly difficult for persons with ASD, given their tendency to falsely remember emotional materials. CBT therapists also will need to take care that their clients with ASD actually are actively engaged in processing the stimuli that they themselves perceive to be threatening, versus those that may be expected by the therapist, when conducting the exposures required for successful therapy (Foa & Kozak, 1986).

The current study had several limitations. First, although ours is the largest and most cognitively diverse study of emotional false memory in ASD to date, we elected to match on verbal IQ to prevent confounding effects of verbal abilities; we were thus unable to include individuals with ASD and intellectual disability who could not complete the task at better than chance levels of performance, and those for whom we had relatively few matched control participants. This makes our results less generalizable to all persons with ASD. Second, since we were focused on investigating the relationship between emotional false memory and ASD symptoms, we used a repetitive behavior measure that was very specific to ASD. Future studies could better tease apart this association trans-diagnostically if a more general repetitive behavior measure was selected. Third, although we selected a backward causal inference paradigm that has been widely published, it is a relatively new experimental paradigm with psychometric properties that have not yet been rigorously evaluated. Finally, it could be argued that the use of script-inconsistent lures, which were more novel and less perceptually similar to previously viewed photographs, might have supported participants’ abilities to identify as novel thereby reducing group differences in performance. However, given that the ASD group also performed comparably to TYP on the emotionally neutral gist-consistent lures, we do not believe that the fact that gist-inconsistent lures were less perceptually similar to gist-consistent ones represents a true confound.

In conclusion, in this implementation of a child-compatible version of the backward causal inference paradigm, we found that 8-14 year olds with ASD made more gap-filling and causal false alarms on emotionally-valenced versus neutral stimuli. This patterns suggests that they do in fact possessed well-developed semantic networks related to the everyday scenes shown in the photographs that may have been triggered by the emotional valence of the stimuli. Interestingly, the tendency to make such errors was related to compulsive, ritualistic, and sameness behaviors and restricted interests, raising the possibility that having such established semantic networks that can be triggered and retrieved when coupled with emotionally-valenced materials is behaviorally and/or neurobiologically associated with exhibiting symptoms from the poorly understood second ASD symptom domain.

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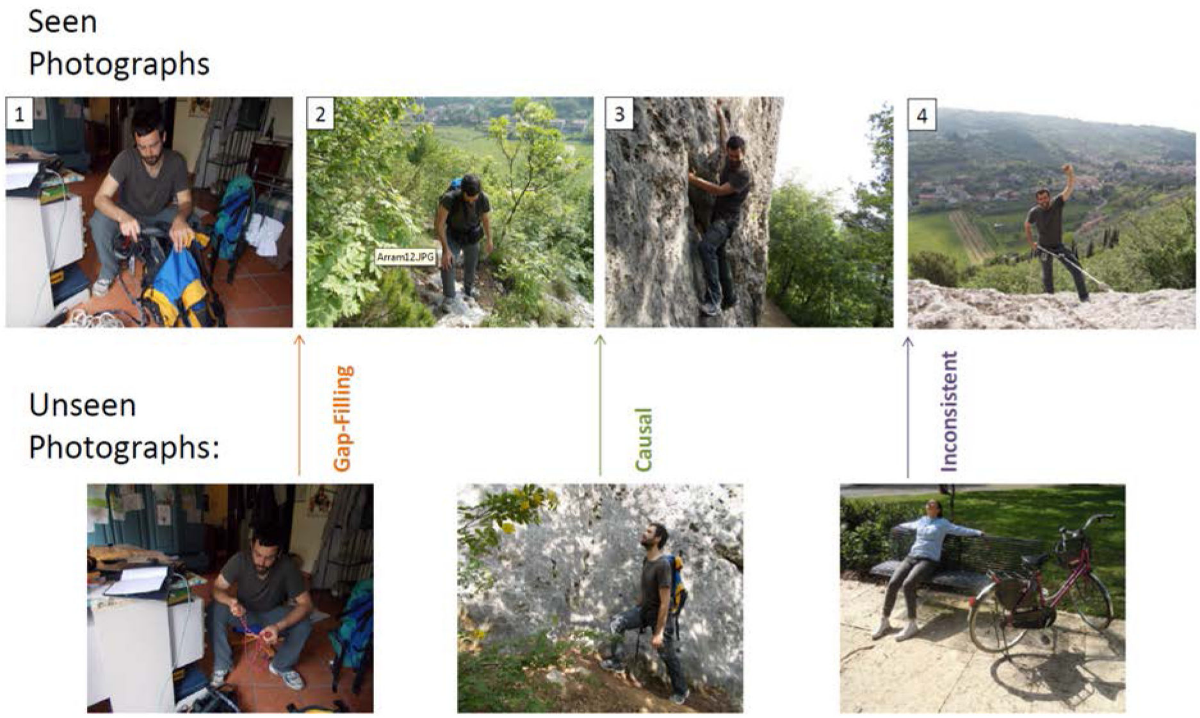

Figure 1. Schematic depiction of the Emotional False Memory task.

The seen photographs show an emotionally-valenced scripted series of events. The unseen photographs depict lure scenes not included in the encoding phase, but included in the recognition task. Gap-filling errors are those in which the unseen photograph lures are script-consistent, but never have been viewed. For example, as shown here, this includes a photograph of the man from the mountain climbing scene adjusting some ropes, although this script-consistent action was not shown during the encoding phase of the task. Causal errors are those in which the unseen photograph lures are script-consistent but have not been shown as causal of the other photographs. For example, as shown here, this includes a photograph of the man from the mountain climbing scene moving into position to climb the rocks that will cause him to reach the top of the mountain. Inconsistent photograph are those that have not been seen before and are not script-consistent. For example, as shown here, this includes a woman sitting on a park bench next to her bike, which is not part of this or any other scene.

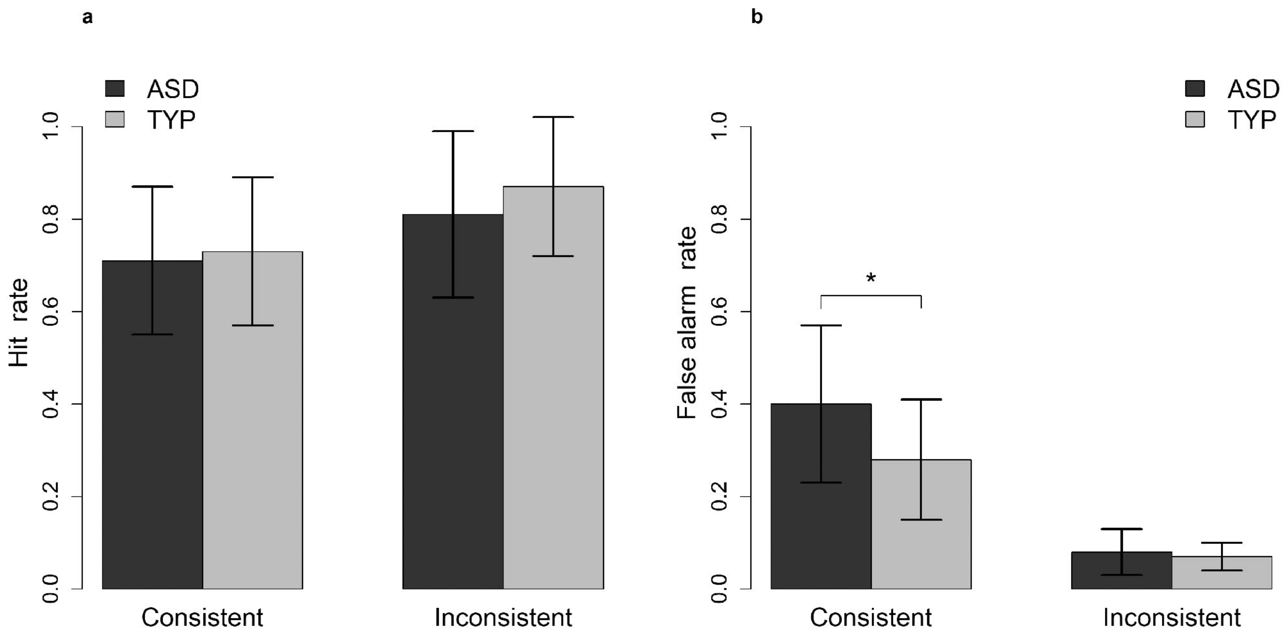

Figure 2.

Hits and false alarm rates for both scene-consistent and scene inconsistent lures during the test phase. Bars represent means and lines represent standard deviations. * represent group differences that are statistically significant ($p < .05$). ASD = Autism Spectrum Disorder; TYP = Typical Development

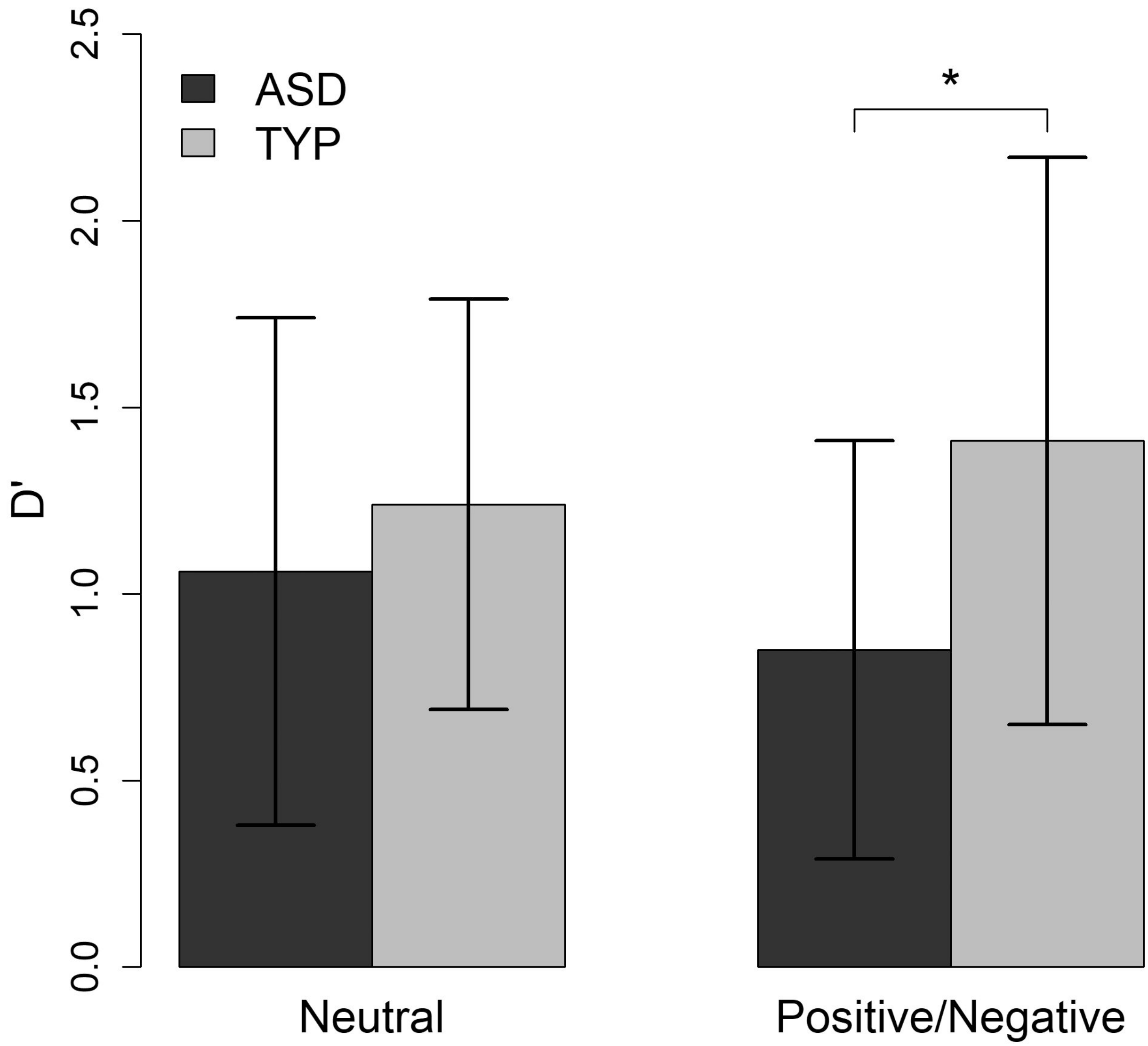

Figure 3.

Causal and gap filling error rates for negative, positive and neutral trials. Bars represent means and lines represent standard deviations. * represent group differences that are statistically significant ($p < .05$). ASD = Autism Spectrum Disorder; TYP = Typical Development. For both causal and gap filling, ASD group made significantly more negative and positive, but not neutral, than the TYP group.

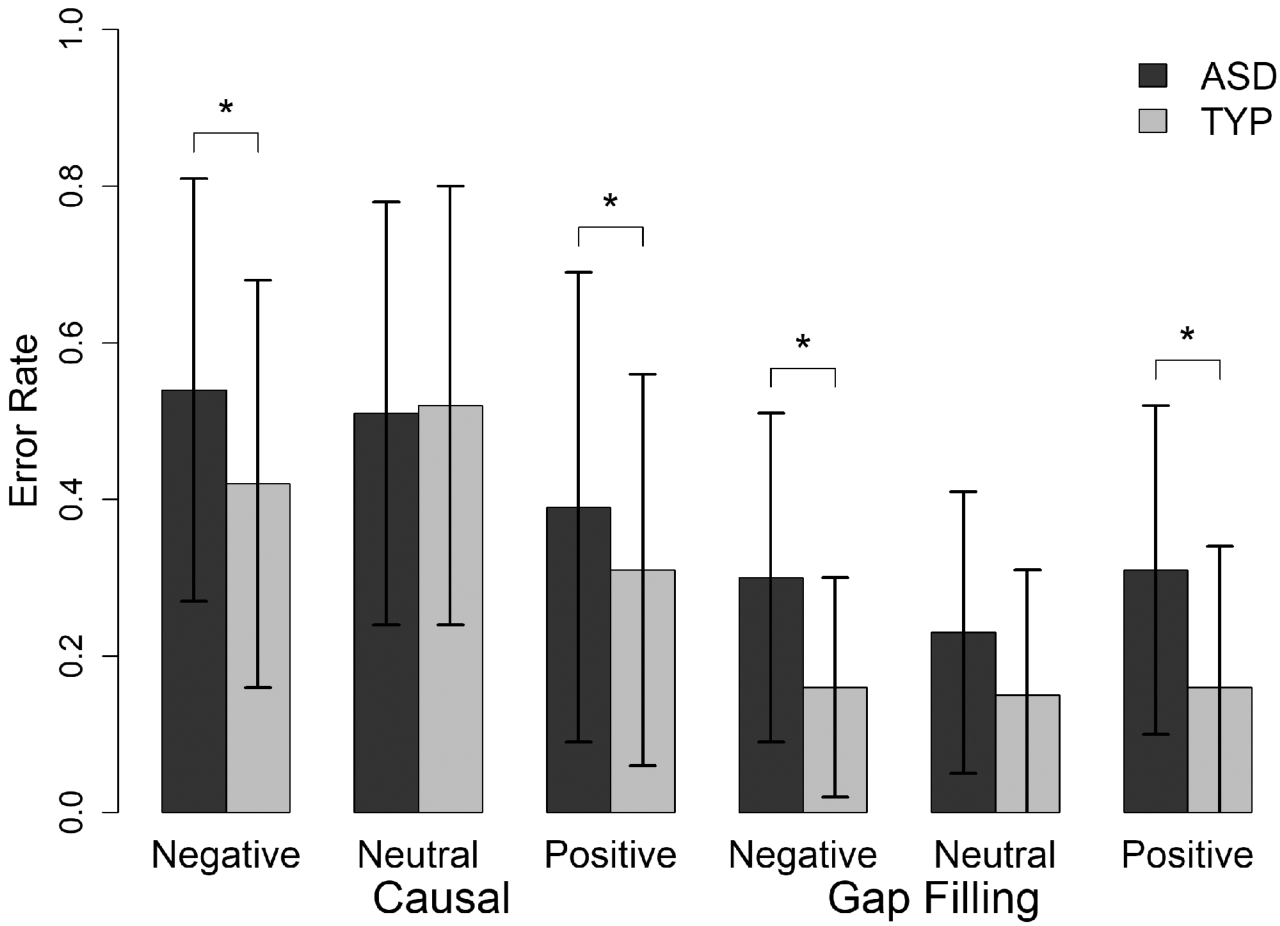

Figure 4.

Causal and gap filling error rates for negative, positive and neutral trials. Bars represent means and lines represent standard deviations. * Group differences that are statistically significant ($p < .05$). ASD = autism spectrum disorder; TYP typical development. For both causal and gap filling, ASD group made significantly more negative and positive, but not neutral, than the TYP group.

Table 1.

Demographic and clinical characteristics for the participants

	ASD (*n* = 38)	TYP (*n* = 38)
Gender, *n* (%)		
Males	32 (84%)	29 (76%)
Females	6 (16%)	9 (24%)
Race[1], *n* (%)		
African American	1 (3%)	2 (6%)
Asian	4 (12%)	3 (9%)
Caucasian	27 (79%)	20 (61%)
More than one race	2 (6%)	8 (24%)
Hispanic[2], *n* (%)	5 (14%)	5 (14%)
Age (years), mean (*SD*)	10.77 (1.31)	11.18 (1.45)
Verbal IQ, mean (*SD*)	106.61 (13.39)	108.37 (12.09)
Nonverbal IQ, mean (*SD*)	103.34 (17.22)	102.26 (11.69)
Spatial IQ, mean (*SD*)	108.50 (15.64)	107.74 (12.23)
Full-Scale IQ, mean (*SD*)	107.39 (15.41)	107.21 (11.98)
ADOS-2 Comparison, mean (*SD*)	6.56 (1.35)	

Note. ASD = autism spectrum disorder; TYP = typical development; ADOS = Autism Diagnostic Observation Schedule.

[1]Frequency missing=4 in ASD and 5 in TYP group.

[2]Frequency missing=3 in ASD and 4 in TYP group.

Table 2.

Summary (mean, SD) of the Performance for Participants with Autism Spectrum Disorder (ASD) and Typical Development (TYP)

a). Performance on non-emotion related aspects of the false memories task						
	ASD		**TYP**		**Cohen's *d***	
	Consistent	**Inconsistent**	**Consistent**	**Inconsistent**	d_C	d_I
Variable						
Hit Rate	0.71 (0.16)	0.81 (0.18)	0.73 (0.16)	0.87 (0.15)	−0.13	−0.33
False Alarms	0.40 (0.17)	0.08 (0.05)	0.28 (0.13)	0.07 (0.03)	0.80	0.17
b). Performance on scenes that involve emotional materials						
	ASD		**TYP**		**Cohen's *d***	
	Emotion	**Neutral**	**Emotion**	**Neutral**	d_E	d_N
d'	1.06 (0.68)	0.85 (0.56)	1.24 (0.55)	1.41 (0.76)	−0.30	−0.83
c) Stimulus valence and the propensity to make causal versus gap-filling errors						
	ASD		**TYP**		**Cohen's *d***	
	Causal	**Gap-Filling**	**Causal**	**Gap-Filling**	d_{Ca}	d_G
Negative Errors	0.54 (0.27)	0.30 (0.21)	0.42 (0.26)	0.16 (0.14)	0.47	0.77
Neutral Errors	0.51 (0.27)	0.23 (0.18)	0.52 (0.28)	0.15 (0.16)	−0.04	0.45
Positive Errors	0.39 (0.30)	0.31 (0.21)	0.31 (0.25)	0.16 (0.18)	0.29	0.80

Note: Descriptive measures of effect sizes for differences between the ASD and TYP groups were calculated by computing Cohen's *d* separately for each task condition.

Abbreviations: d_C, Cohen's d for Consistent; d_I, Cohen's *d* for Inconsistent; d_E, Cohen's d for Emotion Valence; d_N, Cohen's *d* for Neutral Valence; d_{Ca}, Cohen's d for Causal Errors; d_G, Cohen's *d* for Gap-Filling Errors.

Table 3.

Summary of the final mixed-effects linear models predicting performance

a). Final mixed-effects linear models predicting hit rates and false alarms

	False alarm rates[a]			Hit Rates[b]		
Model term	**Estimate (*SE*)**	**95% CI**	***P*-value**	**Estimate (*SE*)**	**95% CI**	***P*-value**
Intercept	0.07 (0.01)	0.06; 0.09	< 0.001	0.86 (0.02)	0.81; 0.91	< 0.001
ASD Group	0.007 (0.01)	−0.01; 0.03	0.45	−0.04 (0.03)	−0.10; 0.02	0.22
Type Consistent	0.21 (0.02)	0.16; 0.26	< 0.001	−0.12 (0.02)	−0.16; −0.08	< 0.001
ASD*Consistent	0.11 (0.03)	0.05; 0.18	0.001	-	-	-

b). Final mixed-effects linear model predicting d'

Model term[c]	**Estimate (*SE*)**	**95% CI**	***P*-value**
Intercept	1.24 (0.10)	1.04; 1.44	< 0.001
ASD Group	−0.19 (0.15)	−0.47; 0.10	0.20
Emotion	0.17 (0.12)	−0.07; 0.40	0.16
ASD*Emotion	−0.37 (0.17)	−0.70; −0.04	0.03

c). Final mixed-effects linear model predicting errors

Model term[d]	**Estimate (*SE*)**	**95% CI**	***P*-value**
Intercept	0.17 (0.03)	0.11; 0.22	< 0.001
ASD Group	0.14 (0.04)	0.06; 0.21	< 0.001
Type Causal	0.11 (0.03)	0.05; 0.17	< 0.001
Negative	−0.01 (0.03)	−0.06; 0.05	0.84
Neutral Valence	−0.01 (0.03)	−0.06; 0.05	0.84
ASD*Negative	0.14 (0.04)	0.05; 0.22	0.002
ASD*Neutral	0.21 (0.04)	0.12; 0.30	< 0.001
Causal*Negative	−0.001 (0.04)	−0.08; 0.07	0.97
Causal*Neutral	−0.08 (0.04)	−0.16; −0.01	0.03

Abbreviations: ASD, Autism Spectrum Disorder; SE, standard error; CI, confidence interval.

[a]Reference was TYP for group and Inconsistent for type. Due to reference coding, the intercept can be interpreted as the expected Inconsistent false alarm rate for TYP participants. The ASD fixed effect represents the difference between ASD and TYP for Inconsistent false alarms. Type Consistent fixed effect represents the difference between Consistent and Inconsistent false alarms for TYP participants, and ASD*Consistent represents the difference in differences between Consistent and Inconsistent false alarms for ASD participants versus the TYP participants.

[b]Reference was Typically Developing (TYP) for group and Inconsistent for type. Due to reference coding, the intercept can be interpreted as the expected Inconsistent hits for TYP participants. The ASD fixed effect represents the difference between ASD and TYP and the Type Consistent fixed effect represents the difference between Consistent and Inconsistent hits.

[c]Reference was TYP for group and Neutral for valence. Due to reference coding, the intercept can be interpreted as the expected neutral d' for TYP participants. The ASD fixed effect represents the difference between ASD and TYP for neutral images. Emotion Valence fixed effect represents the difference between Emotional and Neutral d' for TYP participants, and ASD* Emotion represents the difference in differences between Emotional and Neutral d' for ASD participants versus the TYP participants.

[d]Reference was TYP for group, Gap for type, and Positive for valence. Due to reference coding, the intercept can be interpreted as the expected errors for positive gap-filling images for TYP participants. The ASD fixed effect represents the difference between ASD and TYP for positive images. Negative and Neutral Valence fixed effects represents the differences between Negative and Positive and Neutral and Negative error rates, respectively for TYP participants and gap-filling images.