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ORIGINAL PAPER

Impaired Social Processing in Autism and its Reflections in Memory: A Deeper View of Encoding and Retrieval Processes

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Abstract Previous studies of memory in autism spectrum conditions (ASC) have consistently shown that persons with ASC have reduced memories for social information, relative to a spared memory for non-social facts. The current study aims to reproduce these findings, while examining the possible causes leading to this difference. Participants' memory for trait-words was tested after they had viewed the words in three study contexts: visuo-motor, letter-detection, and social judgment. While participants with ASC showed a levels-of-processing effect, such that their memory for words viewed in the social judgment context was greater than their memory for words viewed in the letter-detection context, their memory for socially-processed words was reduced relative to comparison participants. This interaction effect could not be explained by a speed/accuracy trade-off, nor could it be explained solely by differences in encoding. These results suggest that social memory deficits in ASC arise from difficulties both in orienting towards and encoding social content, as well as retaining and retrieving it. Implications for theory and clinical practice are discussed.

Keywords Social memory · Autism · Encoding · Retrieval · Levels of processing

Introduction

Studies of memory in autism spectrum conditions (ASC) have consistently shown that persons with ASC have a poor memory for social information, relative to a spared memory for non-social facts (Boucher and Bowler 2008; Crane and

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Goddard 2008; Lind 2010; Losh and Capps 2003). As the crucible of learning, memory patterns may simultaneously contribute to the pervasive social difficulties exhibited by persons with ASC, while at the same time affording a window for future intervention. However, it is unclear at which stage, or stages, of the memory process, memory for socially-encoded information becomes impeded.

Decades of research have shown that persons with ASC are specifically impaired both in orienting towards social stimuli (Klin et al. 2009) and further perceiving and interpreting the social stimuli around them (Baron-Cohen et al. 1999; Hobson 1986; Piggot et al. 2004). Thus, reduced memory for social, or socially-encoded, content could easily be attributed to deficits at the encoding stage (Ben-Shalom 2003). Yet some memory studies suggest that persons with ASC have difficulty not only in encoding social information, but also in spontaneously retrieving it (Bowler et al. 2004; Whitehouse et al. 2007). In their Task Support Hypothesis, Bowler et al. (2004) argue that persons with ASC have a deficit in memory retrieval, and that given the right amount of structured external support their retrieval levels will increase. The current study aims to address this question by employing a levels of processing paradigm, expressly manipulating participants' attention to the social or non-social properties of a word, and testing their recognition memory 30 min later.

Previous studies employing the levels-of-processing paradigm in ASC have shown that persons with ASC have a reduced memory for words attributed to particular social actors (self, best friend, or Harry Potter), relative to a spared memory for phonologically- or orthographically-processed words (Henderson et al. 2009; Lombardo et al. 2007; Toichi and Kamio 2002). Importantly, however, the social processing conditions employed in these studies differed from the phonological and orthographic conditions not only in their social content, but also in their greater degree of complexity and lesser support; i.e., rather than relying on the concrete phonological or orthographic properties of a word, participants had to retrieve the abstract meaning of a word, and then relate it with their view of a particular social actor.

While it is difficult to equate the level of complexity and support for social and non-social encoding tasks, in the current experiment we employed a simpler social task, wherein participants rated the social valence of a word ('is this a nice word to say about someone'?) without the added challenge of attributing the word to a particular social actor. If children and adolescents with ASC are capable of performing accurate social judgments, and processing words for their social content further enhances their memory for these words to a degree comparable to comparison participants, we would conclude that persons with ASC have no difficulty performing abstract social judgments. In this case, memory patterns found in previous studies would be explained by ASC participants' difficulty attributing trait-words to particular social actors, alongside a spared ability to perform abstract social judgments (Blair 1996; Takeda et al. 2007). On the other hand, if participants with ASC recognize fewer words viewed in the 'social judgment' context than comparison participants, we would conclude that persons with ASC have a more basic difficulty processing words with regards to their social content—which may then affect difficulties with real-life attribution downstream.

A further unresolved debate regards ASC participants' memory during non-social processing. While some studies have shown that a focus on the physical properties of the word (phonological or orthographic) leads to enhanced memory in persons with ASC relative to comparison participants (Mottron et al. 2001; Toichi and Kamio 2002), others have found that memory for orthographically-processed words is no greater in ASC participants than in comparison participants (Henderson et al. 2009; Lombardo et al. 2007). The present study aims to further test ASC participants' memory during low-level processing. If ASC participants have an enhanced processing of low-level perceptual information, we would find that their memory for orthographically-processed words (i.e., having detected the letter 'e' in a word) is greater than comparison participants' (in line with Mottron et al. 2001; Toichi and Kamio 2002).

A third aim of the study was to examine the relative contribution of encoding and retrieval to social memory impairments in ASC. Given that participants' social evaluations of words could be compared with objective valence ratings (in contrast with the social actor attributions, employed by Henderson et al. 2009 and Lombardo et al. 2007, which are more subjective), accuracy rates can be obtained both at the study and recognition phases. Specifically, we hypothesize that if social memory deficits in ASC are due to difficulties at encoding, participants with ASC would be less accurate than comparison participants at the study phase (judging a word for its social valence); but when performance at study is equated across groups (i.e., only accurately processed words are examined), participants with ASC may be no less accurate at recognizing words than comparison participants. Alternatively, if social memory deficits in ASC are primarily due to difficulties in retention or retrieval, we would expect no difference in participants' initial social processing of words, but words processed for their social content would nonetheless be recognized less frequently by participants with ASC than comparison participants. Finally, if both encoding and retrieval processes of social stimuli are affected in participants with ASC, we would expect reduced accuracy both when they are initially judging a word for its social valence, and later, when they are recognizing the word from amidst distractors.

A final, under-explored aspect of memory processing is the possibility that reduced social memory in ASC is associated with faster, inaccurate processing (i.e., a speed/accuracy trade-off), given findings that impulsivity and hyperactivity affect social processing in children with ASC (Sinzig et al. 2008). Such a possibility may have important clinical implications: if children with ASC are taught to slow their processing, they may show increased social memory. In order to test this possibility, we will compare the participants' speed of response to accurately and inaccurately recognized words. If accurate responses are associated with longer response times, this would suggest a speed/accuracy trade-off.

Methods

Participants

Recruitment

Forty-three participants with ASC and 35 comparison participants were recruited for the study. ASC participants were recruited through the UCLA Center for Autism Research and Treatment and through the Help Group network of schools. Comparison participants were recruited through internet advertisements and by word of mouth. ASC participants completed the study in two parts: a diagnostic component conducted at the UCLA lab, and an experimental component conducted either at home (4 participants) or in the lab (39 participants). Comparison participants completed only the experimental component, which was conducted either at home (20 participants) or in the lab (15 participants). Of the ASC participants, five participants completed only the diagnostic component, but were unable to return for the experimental component. Three additional ASC participants were excluded from the study as their IQ did not meet cut-off criteria (FSIQ above 70); and data from three ASC participants was excluded from the analyses, as they had misunderstood the task. Thus a total of 32 ASC participants and 35 comparison participants participated in the experiment.

Eligibility Criteria

All of the ASC participants met diagnostic criteria on the Autism Diagnostic Interview—Revised (Rutter et al. 2003), a 3-h parental interview, and the Autism Diagnostic Observation Scale—Generic (Lord et al. 1999); a 1-h play observation adapted to the child's level of functioning. Comparison participants' parents completed the Social Responsiveness Scale (Constantino 2005) and the Social Communication Questionnaire (Rutter et al. 2003). All of the comparison participants scored below cut-off scores for autism on both scales (50 on the SRS and 14 on the SCQ). All of the participants scored above 70 in Full-Scale IQ, as measured by the Wechsler Abbreviated Scale of Intelligence (Wechsler 1999).

Participants' Characteristics and Group Matching

In order to match the comparison group with the ASC sample, 30 comparison participants were selected, who were well-matched on age, VIQ, PIQ and FSIQ with the ASC sample, at the group level. The groups were matched in VIQ, PIQ, FSIQ, and age, while the comparison group had significantly greater social skills than the ASC group, as measured by the SCQ and SRS (see Table 1).

Study Measures

Clinical Measures

Participants' degree of autism symptoms were measured by the SCQ and SRS. Participants' verbal and non-verbal intelligence was measured by the WASI.

Word Recognition Test: Materials

The stimuli for the Word Recognition Test included 120 trait-words, such as "adventurous", "shy", or "mad". To generate a list of trait-words known by children, an initial list of 257 trait-words was chosen from a common resource of 555 trait-words (Anderson 1968), and augmented by 37 additional trait-words generated from an online children's thesaurus (Merriam-Webster 2009), for a total of 294 words. This list was then presented to a group of nine typically developing 8-year-old children who crossed out the words they did not understand, and a list of 240 commonly known words was extracted. The average age of acquisition for the 240 selected words, based on Kuperman et al. (2012), ranged from 3.2 to 8.2 years (*mean* = 7.29).

The valence of the words was determined primarily by reference to the 'likableness' scores given by 100 college students in Anderson (1968). To verify these valence ratings, and provide novel ratings to the newly generated words, the list of 240 words was given to 5 adult blind raters, who rated the words as positive, negative, or neutral. Only clearly positive or negative words were chosen to serve in the study, and 60 words were divided into three different lists of 20 words, equated for mean length of words, average age of acquisition, presence of the letter 'e', and valence. An additional 60 words were used as distractors at the recognition phase; the remaining 120 words were used in a separate study (Brezis et al., in review).

Table 1 Participants' background characteristics range (mean ± SEM)

	Comparison participants ($n = 30$)	ASC ($n = 32$)	Statistic	p value
Age	8–18 (13.5 ± .5)	8–18 (12.4 ± .5)	$t = -1.49$	.141
Gender	77 % male	88 % male	$\chi^2 = 1.24$	.264
Full-Scale IQ (FSIQ)	81–137 (110.4 ± 2.8)	82–140 (110.4 ± 2.3)	$t = .002$	.999
Performance IQ (PIQ)	61–128 (101.9 ± 2.5)	70–132 (107.1 ± 2.5)	$t = -1.46$	.149
Verbal IQ (VIQ)	96–137 (116.8 ± 2.3)	84–151 (111.0 ± 3.2)	$t = -1.48$	.146
Social Communication Questionnaire (SCQ)	1–13 (4.8 ± .6)	9–32 (22.5 ± 1.2)	$t = -13.41$	<.001
Social Responsiveness Scale (SRS)	5–46 (21.8 ± 2.0)	27–142 (77.8 ± 4.7)	$t = -10.57$	<.001

Study Protocol

General Procedures

A Parental informed consent and child assent were collected at the beginning of the visit, and participants were given an overview of the procedures. While the parents were completing the ADI-R, SCQ and SRS, children were taken to a testing room where the remaining procedures were administered by the first author. Visits to the lab (or home visits) lasted approximately 4 h, including the IQ test and other experimental procedures.

Word Recognition Test

Task Overview: Participants were presented with a computerized word evaluation and recognition task on E-Prime 2.0. At the study phase, participants were presented with 60 different trait-words under three types of study contexts intended to manipulate their depth of encoding (20 words per condition). 25–30 min later, they were requested to recognize the words they had seen from a list of 120 words (recognition phase). The words were presented at the center of a 15″ laptop screen, in Courier New point size 30. Since the words were presented on a laptop, participants' viewing distance from the screen varied between 12 and 24″. The three study contexts were:

a. Visuo-motor: "Press a button as soon as a word appears"
b. Letter-detection: "Does this word have a letter 'e'?"
c. Social-judgment: "Is this a nice word to say about someone?"

Study Phase: In order to ensure the participants' understanding of the different study contexts, a reduced version of the study phase was practiced prior to the experiment. At the start of the practice run, a prompt appeared on the screen for 4 s—'Press a button as soon as a word appears'—followed by 4 different trait-words, each presented one by one for 4 s (for a total of 16 s). Then a blank screen appeared for 4 s, and the next prompt appeared—'Does the word have the letter 'e'? Press 1 for Yes and 2 for No'—followed again by 4 different words presented one by one for 4 s each. The length of word presentation did not vary with the participant's response, but was kept at a constant 4 s for all words, and participants were not given explicit instructions to respond during the given time frame. Finally, after another 4-s blank screen, the last prompt appeared—'Is this a nice word to say about someone?'—and the participant was again requested to press 1 for Yes and 2 for No when viewing the following 4 words. The participants were then encouraged to ask questions about the task, and if participants did not respond correctly, or had doubts about their performance, the practice task was run again. These words were not included in the main experiment.

In the experimental run of the study phase, participants were presented with repeated blocks consisting of one of the 3 prompts, followed by 4 new trait-words and a blank screen (each block lasted a total of 24 s). Each of the three prompts—visuo-motor, letter-detection, social judgment—appeared 5 times in randomized order, so that a total of 20 different words were evaluated under each processing condition, for a grand total of 60 words evaluated altogether. Response times were recorded for each response, though the presentation time remained at a constant 4 s per word.

Recognition Phase: Following a 25–30 min interval (during which sub-tests of the WASI were administered), participants were presented with a surprise recognition test to the words they had previously seen at the study phase. At the recognition test phase, participants were presented with 60 of the words they had previously seen (targets), along with 60 new words (distractors). At the start of the phase, the question 'Have you seen this word before?' appeared on the screen, and participants were instructed to press a button for 'Yes' if they had just seen the word today, on the computer, and a button for 'No' if they had not. All 60 words they had previously seen, along with 60 new words (distractors) were then presented one by one in randomized

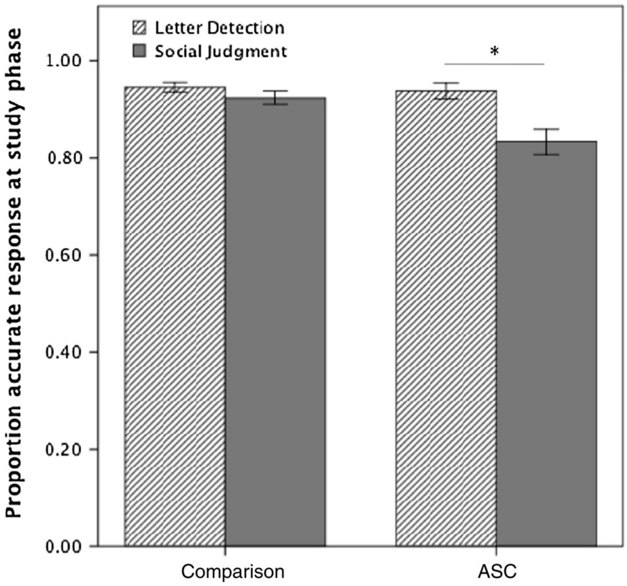

Fig. 1 Participants' proportion of accurate responses to the Letter-Detection and Social-Judgment prompts at the word study phase. All participants were significantly more accurate at detecting whether a word had a letter 'e' (letter-detection) than whether it was a nice word to say about someone (social judgment), yet this decrease in accuracy for social judgment was particularly pronounced in the ASC participants. *Error bars* represent mean ± SEM

order for 4 s at a time. Response times were recorded for each response, though the presentation time remained at a constant 4 s per word regardless of the participants' response.

Statistical Analyses

Preliminary Analyses

The analysis used multi-way and repeated-measures ANOVA, *t* tests and pearson's correlation measures, as needed. When required, proportion variables were transformed using the arcsine function, in order to have a more normal distribution. Prior to conducting parametric statistics, assumptions of normality and equality of variance were ascertained using distribution plots, Levene's and Kolmogorov–Smirnov tests. Preliminary analyses were aimed at ascertaining the potential confounding effects of age and gender on performance, and the possibility of an interaction of age, gender and diagnosis, if the two groups had different developmental trajectories. No interaction effects of age, gender and diagnosis were found at any stage of the experiment. Further, since the ASC and comparison participants were well-matched for age and gender, age and gender were not included as factors in the analyses. All analyses were conducted in SPSS v. 21.0.

Results

Study Phase

Accuracy

To determine whether the ASC participants were capable of performing a baseline computerized task at the same rate as comparison participants, and were not impeded by visual or motor abilities, the proportion of responses to visuo-motor prompts was compared between groups. Participants' responsiveness was computed as the proportion of responses given within 4,000 ms of the prompt, and all proportional scores were transformed by arcsine prior to conducting statistical tests. (Note that the proportion scores reported below and in Fig. 1 pertain to the pre-transformed data, while the analyses were conducted on the transformed data). Comparison participants responded to 97.7 % (±SE = 1.4 %) of the visuo-motor prompts, and ASC participants responded at a similar rate, 96.1 % (±SE = 1.2 %) ($t(60) = 1.118$, $p = .268$).

To test whether participants could respond equally well in making a social judgment or detecting a letter in a word, or whether the ASC participants had a particular difficulty with social judgments, a repeated-measures 2 × 2 ANOVA was computed, with study context as a within-subjects variable (letter-detection, social judgment) and Group as a between-subjects variable (ASC, comparison group) (see Fig. 1). All participants were more accurate at letter-detection than at social judgment (letter-detection: comparison group: 94.5 % (±SE = 1.0 %), ASC: 93.8 % (±SE = 1.6 %); social judgment: comparison group: 92.3 % (±SE = 1.4 %), ASC: 83.3 % (±SE = 2.6 %); main effect of Context: $F(1,60) = 9.821$, $p = .003$, $\eta^2 = .141$), and the ASC participants were no less accurate overall than comparison participants (no main effect of Group: $F(1,60) = 2.693$, $p = .106$, $\eta^2 = .043$). However, the effect of study context on performance was significantly more pronounced in the ASC participants than the comparison participants (Interaction effect: $F(1,60) = 5.481$, $p = .023$, $\eta^2 = .084$). Specifically, post hoc Bonferroni-corrected *t* test analyses indicated that comparison participants were significantly more accurate than ASC participants in making Social Judgments (Comparison group: $t(60) = 2.441$, $p = .018$), but not in detecting the letter 'e' ($t(60) = .258$, $p = .797$); and while there was no significant difference in accuracy rates by condition in the comparison participants ($t(29) = .726$, $p = .474$), the ASC participants were significantly more accurate at detecting the letter 'e' than making a social judgment ($t(31) = 3.332$, $p = .002$).

Table 2 Participants' rate of accurately recognizing words (mean ± SEM) they had previously evaluated in the visuo-motor, letter-detection, and social judgment contexts (hits), and in falsely recognizing novel words which served as distractors (false alarms) at the recognition phase

	Visuo-motor	Letter-detection	Social judgment	False alarm
Comparison participants				
Hits (%)	.408 (±.034)	.465 (±.030)	.721 (±.034)	.254 (±.023)
d′	.464 (±.092)	.627 (±.072)	1.429 (±.142)	
ASC				
Hits (%)	.496 (±.040)	.579 (±.040)	.702 (±.036)	.414 (±.046)
d′	.217 (±.149)	.436 (±.135)	.839 (±.174)	

Recognition rates were computed as $d' = \Phi^{-1}(hits) - \Phi^{-1}(false\ alarms)$

Response Speed

To test whether participants responded more slowly as the task increased in difficulty, and whether the ASC participants responded more slowly than comparisons, response times were compared across the three study contexts in the two diagnostic groups. Response times were computed as each participant's median response time to accurate trials in each study context. A repeated-measures 3 × 2 ANOVA was conducted, with study context as the within-subjects variable (visuo-motor, letter-detection, social judgment) and Group as the between-subjects variable (ASC, comparison group).

Participants were quickest to respond to a visuo-motor prompt (comparison group: *mean* = 598 ms, *SE* = 68 ms; ASC: *mean* = 807 ms, *SE* = 66 ms), slower to respond to a letter-detection prompt (comparison group: *mean* = 1,141 ms, *SE* = 64 ms; ASC: *mean* = 1,385 ms, *SE* = 62 ms), and slowest to respond to a social judgment prompt (comparison group: *mean* = 1,415 ms, *SE* = 76 ms; ASC: *mean* = 1,546 ms, *SE* = 73 ms), demonstrating a main effect of context ($F(2,120) = 112.096, p < .000, \eta^2 = .651$). ASC participants were overall slower than comparison participants to respond to all types of prompts (main effect of group: $F(1, 50) = 6.87, p = .011, \eta^2 = .103$), and the type of prompt did not mediate this difference (interaction effect not significant: $F(2, 120) = .573, p = .565, \eta^2 = .009$). Since ASC participants were both slower and less accurate in their responses at the Study phase, the possibility of a speed-accuracy trade-off was ruled out.

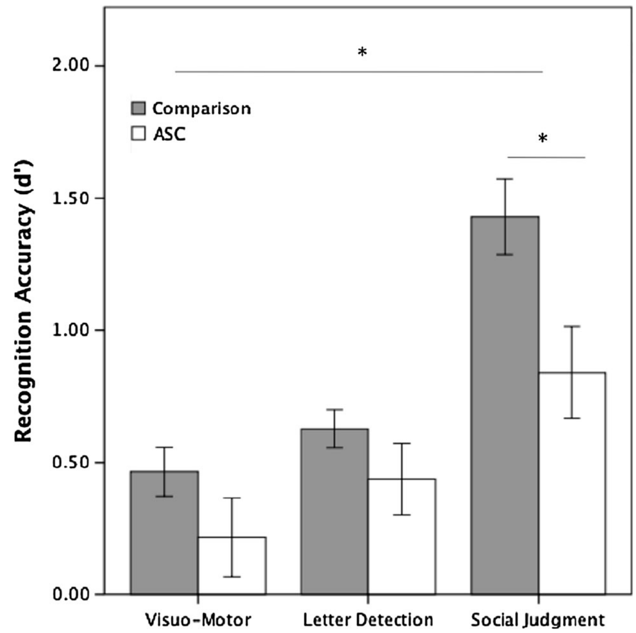

Fig. 2 Participants' accuracy at recognizing words viewed in the Visuo-Motor, Letter-Detection and Social-Judgment contexts 20–30 min earlier (d'). Both ASC and comparison participants were increasingly better at recognizing words as the study complexity increased from the visuo-motor, to letter-detection to social judgment contexts (levels of processing effect), yet the ASC participants' recognition memory was specifically reduced relative to comparison participants for words viewed in the social judgment context. *Error bars* represent mean ± SEM

Recognition Phase

Recognition Accuracy

To determine whether and how the study contexts and participants' performance affected their memory for words 25–30 min later, a series of analyses was conducted. First, we sought to determine whether a social study context improved participants' recognition memory of a non-social context, and whether this improvement was less pronounced in ASC participants. Recognition accuracy scores were computed for each participant, for words from each study context, defined as $d' = \Phi^{-1}(Hits) - \Phi^{-1}(false\ alarms)$ (Stanislaw and Todorov 1999); where Hits are defined as the percent of correctly endorsed targets that the subjects had previously seen in the study phase, and false alarms defined as the percent of incorrectly endorsed distractors, that the subjects had not previously seen (see Table 2; Fig. 2).

A repeated-measures 2 × 3 ANOVA was computed to compare participants' recognition accuracy for words from different study contexts (visuo-motor, letter-detection, social judgment), and across diagnostic categorization (ASC, comparison). All participants were most likely to recognize a word that had been viewed in the social judgment context, less likely to recognize a word that had been viewed in the letter-detection context, and least likely to recognize a word that had been viewed in the visuo-motor context (main effect of context: $F(2,120) = 52.326$, $p < .001$, $\eta^2 = .466$; see Fig. 2). The comparison participants recognized more words than the ASC participants (group effect: $F(1,60) = 4.361$, $p = .041$, $\eta^2 = .068$), while their increased recognition was significantly affected by the type of study context (interaction effect of Context $\times$ Group: $F(2,120) = 3.556$, $p = .032$, $\eta^2 = .056$). Post-hoc Bonferroni-corrected t tests indicated that the comparison participants' relative advantage in recognition accuracy over the ASC participants was driven primarily by their advantage in recognizing words that had been viewed in the social judgment context ($t(60) = 2.61$, $p = .011$); as the comparison participants were no more likely than ASC participants to recognize words that had been viewed in the non-social contexts, letter-recognition ($t(60) = 1.22$, $p = .226$) and visuo-motor processing ($t(60) = 1.391$, $p = .169$).

Second, to determine whether participants' different degree of accuracy of recognition for words from the letter-detection and social judgment contexts may be explained by their accuracy at encoding, we selectively analyzed recognition accuracy for words that were correctly judged at study (no accuracy score was given during visuo-motor processing, and it was therefore not included in this analysis). A repeated-measures 2×2 ANOVA for recognition accuracy with Group as between-subjects factor (ASC, comparison) and study context as within-subjects factor (letter-detection, social judgment) was then computed only for words participants had correctly identified at the study phase. This analysis revealed that the comparison participants were significantly more likely than ASC participants to recognize words they had previously seen (main effect of group: $F(1,60) = 5.134$, $p = .027$, $\eta^2 = .079$). All participants recognized words from the social judgment context better than words from the letter-detection context (main effect of context: $F(1,60) = 68.526$, $p < .001$, $\eta^2 = .533$), and group differences were more pronounced in the social than the non-social study context (Interaction effect: $F(1,60) = 11.659$, $p = .001$, $\eta^2 = .163$). Specifically, while both ASC and comparison participants recognized more words if they had been judged for their social valence than for the presence of the letter 'e' (comparison group: letter-detection: *mean* = .619, *SEM* = .074; social judgment: *mean* = 1.464, *SEM* = .140; $t(29) = 7.530$, $p < .001$; ASC: letter-detection: *mean* = .482, *SEM* = .127; social judgment: *mean* = .833, *SEM* = .159; $t(31) = 3.808$, $p = .001$), comparison participants recalled significantly more words than ASC participants if the words had been judged for their social valence ($t(60) = 2.955$, $p = .004$), but not if they had been judged for the presence of the letter 'e' ($t(60) = .917$, $p = .363$). Thus, given that participants had correctly identified the words at the study phase, comparison participants maintained a relative advantage over ASC participants in later recognizing socially-encoded words.

Recognition Response Latencies

In order to test whether participants responded more quickly to words they had processed more deeply, and whether the ASC participants responded more slowly than comparison participants, response times were compared across the three study contexts in the two diagnostic groups. Response times were computed as each participant's median response time to accurate trials in each study context. A repeated-measures 3×2 ANOVA was conducted, with study context as the within-subjects variable (visuo-motor, letter-detection, social judgment) and Group as the between-subjects variable (ASC, comparison).

Though participants were responding to the same prompt—determining whether they had seen a word before or not—their response-times differed according to the type of context the word was viewed under 25–30 min prior. Participants were quickest to recognize words seen in the social judgment context, slower to recognize words seen in the letter-detection context, and slowest to recognize words seen in the visuo-motor context (visuo-motor: *mean* = 1,616 ms, *SEM* = 66 ms; letter-detection: *mean* = 1,548 ms, *SEM* = 53 ms; social judgment: *mean* = 1,452 ms, *SEM* = 54 ms; main effect of context: $F(2,120) = 4.718$, $p = .011$, $\eta^2 = .073$). Diagnosis was not predictive of the recognition speed, as comparison participants were not significantly quicker than ASC participants at recognizing words (comparison group: *mean* = 1,568 ms, *SEM* = 71 ms; ASC: *mean* = 1,509 ms, *SEM* = 69 ms; $F(1,60) = .356$, $p = .553$, $\eta^2 = .006$). Further, group differences in recognition speed did not become more pronounced in words from the social context relative to non-social study contexts (no significant interaction effect of group $\times$ context, $F(2,120) = 1.290$, $p = .279$, $\eta^2 = .021$).

Finally, the slower speed of recognition to words from the visuo-motor context relative to letter-detection and social judgment contexts could not be explained by more accurate processing, as accurate recognition of words from all three contexts took no more time than incorrect recognition (visuo-motor: $t(61) = 1.081$, $p = .284$; letter-detection: $t(61) = 1.004$, $p = .319$; social judgment: $t(61) = 1.487$, $p = .142$).

Discussion

The current study demonstrated that children and adolescents with ASC recognized fewer words than comparison participants if they had previously judged the words for their social valence, but no fewer words if they had judged the words for their orthographic properties (the presence of the letter 'e'). Though participants with ASC exhibited a levels of processing effect akin to comparison participants', such that their memory for words improved if they had processed a word with regards to its social properties relative to its orthographic properties, this relative improvement was much weaker than in comparison participants. These results first confirm the prediction that persons with ASC have a basic deficit in processing words for their social content, even when these words are not assigned to particular social actors. In contrast to their deficit in recognizing socially-processed words, participants with ASC were neither better nor worse than comparison participants at recognizing orthographically-processed words, suggesting that they have a spared, but not enhanced, low-level perceptual processing (in line with Henderson et al. 2009; Lombardo et al. 2007).

Why did participants with ASC remember fewer words than comparison participants, and why was their deficit particularly pronounced for words viewed in the social context? The first part of the reason may be gleaned from the study phase of the experiment: while participants with ASC were capable of judging words for their orthographic properties (presence of the letter 'e'), they had a small, yet statistically significant, impairment in judging words for their social valence. Compared to both the comparison participants' ability to process words socially, and the ASC participants' own ability to process words for their orthographic content—their ability to perform a social judgment on words was reduced. This result may lend support to the hypothesis that memory for social content in ASC is reduced due to a more basic difficulty attending to and processing social stimuli (Klin et al. 2009; Baron-Cohen et al. 1999; Piggot et al. 2004).

Importantly, however, we cannot rule out the possibility that reduced accuracy in social judgment compared with letter recognition in the ASC participants was due to imbalances in the demands of the tasks, or to idiosyncracies in the ways in which ASC participants categorized words for their social valence. Specifically, the social judgment task provided less support than the letter recognition task (i.e., while a letter is either physically present or not, a word's social valence must be inferred from knowledge that is not physically present in the word), while requiring an ability to relate one's semantic knowledge to an abstract person. In order to address this limitation, and test the hypothesis that social judgment accuracy is reduced in ASC due to its social content more stringently, it would be necessary to include additional control conditions wherein the cognitive demands from the tasks are more closely equated. For instance, a general semantic processing condition in which the valence of words is evaluated in a non-social context could be used (e.g., "would this be a good word to use about a tree?").

Returning to the question of recognition accuracy, regardless of the cause for ASC participants' reduced performance in social judgment, the ASC participants exhibited a reduced memory for socially-processed words that could not be explained solely by their less accurate processing of those words at the study phase. I.e., when examining only words that were accurately judged at the study phase, ASC participants' recognition was still reduced, particularly in the social condition. Together, these results suggest that rather than arising from a deficit in either encoding or retrieval in ASC, impairments in memory for social content arise from a combination of impairments at both the encoding and retrieval stages.

These results corroborate the Task-Support Hypothesis in autism (Bowler et al. 2004), which suggests that memory deficits in ASC are due to both difficulties at encoding and retrieval. On a neurobiological level, there is growing evidence that brain regions involved in encoding an episode are partially reactivated when that episode is later remembered (Danker and Anderson 2010). Thus, if persons with ASC have difficulty activating the necessary neural networks for processing of social stimuli at encoding (viz., a network of regions encompassing the limbic, prefrontal and medial cortical structures), they will likely have the same problem activating these networks at retrieval. One way of further testing the Task-Support Hypothesis with regards to social processing in ASC is to provide participants with a cue at retrieval that is particularly designed to remind participants of the orthographic or social properties of the word (see Morris et al. 1977). Further brain imaging studies should test the hypothesis that in ASC, underconnectivity between limbic, prefrontal posterior parietal, and medial cortices leads to deficits in both encoding and recognition of social information (Boucher and Mayes 2012).

On a clinical level, our findings can be applied to teaching memory strategies to children with ASC. Since reduced memory for social content appears to arise not only from difficulties at encoding, but from difficulties of retention and retrieval as well, it is important to train children with ASC at all of these stages. Thus, training curricula should focus both on orienting and attending to social stimuli, and further processing and retrieving social information—so that children learn to retain and retrieve social stimuli more accurately and efficiently. Further empirical studies should examine whether memory training indeed improves children's memory for social information, and whether this increased social memory improves their broader social abilities.

Finally, our results indicated that ASC participants' reduced memory for socially-encoded words could not be attributed to abnormalities in the speed of processing. Indeed, participants with ASC did not respond significantly more quickly than comparison participants, at neither the study phase nor the recognition phase; and their reduced accuracy in social conditions could not be explained by a speed/accuracy trade-off. Thus it seems that teaching children with ASC to slow their processing may not directly improve their accuracy of recognition.

As noted above, the first important limitation of the study is that our social study context ('is this a nice word to say about someone?) was significantly more complex than our non-social study context ('does the word have the letter 'e'?). Since participants with ASC have a difficulty in remembering complex information over simple, isolated stimuli (Minshew and Williams 2007), the reduced memory patterns for socially-processed words may be explained by their reduced memory for complex facts, rather than a specific social deficit. Further studies should address this limitation by equating the degree of complexity for social and non-social study contexts, or by keeping the social context constant, while varying the degree of complexity.

Second, while care was taken to select words that would be familiar to 8-year-old children and above, it is possible that ASC participants either did not understand the given trait-words, or had idiosyncratic concepts of certain trait-words, which they therefore categorized inaccurately as a 'nice word to say'. A related concern is that our participants had a wide range of Age and IQ levels, and that the ASC and comparison groups were matched for age and IQ only at the group level, rather than the individual level; thus, it is possible that differences in recognition accuracy could be attributed to group variations in VIQ, rather than autism features per se. Future studies can address these concerns by (a) matching participants at an *individual* level on age and VIQ; and (b) ensuring that all participants attribute the same meaning to all the trait-words by testing each participant's knowledge separately from the recognition task.

A third limitation of the analysis is that our operational definition of encoding as the accurate judgment of a word's social valence or orthographic properties is only an indirect index of actual encoding. Indeed, it is possible that an individual processed a word for its social or orthographic properties accurately, without deeply encoding the word in memory. Further neuroimaging studies should address this question, by examining the neural processes underlying encoding and recognition of social and non-social content in ASC.

Conclusions

Given the importance of memory for learning and development, it is imperative to understand the patterns of memory in ASC. Building upon previous studies that have identified a deficit for social memory in ASC, the current study further delineated the relative contribution of difficulties both at the encoding and the retrieval stages. While children and adolescents with ASC have a difficulty identifying the social valence of a word, and this difficulty affects their ability to later recognize the word, they have an added difficulty recognizing socially-processed words *even when* they had correctly identified it at the study phase. Future studies and clinical interventions should therefore continue to investigate and manipulate the ability of persons with ASC to encode and retrieve social information.

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