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Recognition Memory for High and Low Associative Stimuli in Autistic Individuals with Outstanding Memory Skill

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Abstract

Background: Individuals with autism exhibit typical recognition memory performance, but they show a reduced use of context and relational processing in more complex memory tasks. It is unclear whether the same is true for autistic individuals with exceptional memory skill for whom superior rote memory skill has been assumed.
Objective: In this study, we investigated recognition memory for high and low associative stimuli in autistic memory experts. In accord with the rote memory notion, we expected an equal recognition performance for high and low associative stimuli and superior memorizing of nonsense material compared to control participants.
Methods: Seven autistic memory experts and seven typically developed control subjects, matched according to age, sex, handedness, and full-scale intelligence quotient (IQ), were examined on a continuous old-new recognition paradigm, including high or low associative pseudowords and shapes. Memory expertise was characterized as a currently present outstanding memory skill above the subject's general level of ability and above the general population and was validated through direct clinical observation or some form of credible evidence.
Results: Our hypotheses were partially corroborated with autistic memory experts recognizing high and low associative shapes equally well in contrast to control participants who showed superior recognition of high associative shapes. However, memory experts did not outperform control participants in the recognition of low associative shapes. There were no differences for the recognition of pseudowords.
Conclusions: Findings do not indicate enhanced memory for nonsense material, but a failure to make use of semantic features of abstract stimuli as assumed for autism as a whole.

Key Words: Autism; memory; old/new paradigm; recognition; savant syndrome

Introduction

In the domain of memory function, autism is coined by diminished non-cued free recall, but largely intact priming, cued recall, and recognition (1;2). Furthermore, it has been argued that persons with autism do not apply semantic and syntactic meaning for remembering (3;4). Nevertheless, more recent framework provides good reason to doubt such an approach (5). For instance, persons with autism have been found to be sensitive to semantic associations (e.g., (6)), are capable of deep encoding, which is often semantically based (e.g., (7)), and show increased recognition by using semantic relationships (8). Ameli and colleagues (9) varied the meaningfulness of visual stimuli and presented pictures and nonsense shapes to high-functioning autistic individuals. They recognized more meaningful than nonsense material. On the other hand, under certain circumstances, individuals with autism spectrum disorder (ASD) showed a diminished use of context (10;11), especially on memory tests that provide little support at retrieval (8).

However, a substantial minority of the persons with autism show some sort of outstanding skill in relation to their general intellectual level (12), also labeled *savant skills*. Due to changes in diagnostic practice in autism in the last 30 years, there may be prevalence rates of savant skills including exceptional cognitive skills up to 30% (13). For this subgroup, some sort of underlying fundamentally altered memory function has been postulated. A prominent account in this regard is *rote memory* (14-16), which is information processing that avoids grasping the inner complexities and inferences of the subject that is being learned and instead focuses on memorizing the material mechanically, so that it can be recalled by the learner exactly the way it was read or heard. Although it has been demonstrated that autistic savants capture a structure and apply rules within their domain of expertise (such as music or calendar calculating; see (17)), non-meaningful memory strategies might also be present, for example, in memory savants who are able to remember all kinds of meaningless information (18).

The objective of the present study was to compare autistic individuals with outstanding memory and typically developed control persons using an old-new recognition memory paradigm of high and low associative pseudowords and shapes. In a previous study (19), we found that the same group of autistic individuals did not outperform control participants in the recognition of pseudowords or shapes. Thus, in the current study, we did not expect a better overall performance of autistic memory experts in our standard old-new paradigm. Instead, we hypothesized an interaction of condition (high/low associative) and group in a way that control participants show a memory advantage for high but not low associative stimuli. For the group of autistic memory experts we expected an equal recognition performance on low and high associative material and, in addition, a better recognition of low associative stimuli compared to control subjects.

Methods

Participants

As described in detail in Neumann et al. 2010 (19), eleven autistic individuals were recruited in cooperation with the Department of Child and Adolescent Psychiatry and Psychotherapy of the Goethe University at Frankfurt/M. They were selected from a larger sample for a magnet-encephalography study about autistic memory savants (19). Four were excluded because of an inability to follow the instructions or quit the experiment because of fatigue. All individuals exhibited idiopathic autism with fluent speech and a nonverbal IQ >85. The clinical ICD-10 diagnosis of autism (F84.0) was corroborated by assessments using the German forms of the Autism Diagnostic Interview-Revised (ADI-R, 20;21) and the Autism Diagnostic Observation Schedule (22;23).

Based on parental interviews followed by direct clinical behavior observation, all autistic individuals were classified as displaying outstanding memory skill. Thereby the scale for special, outstanding abilities of the ADI-R ("Interests and behaviors") was used to define special memory abilities and to classify memory savants if they were currently showing some outstanding memory skills above the subject's general level of ability and above the general population. Additionally, special abilities reported by parents were validated through direct clinical observation (demonstration of skill) or some form of credible evidence (e.g., school report). Exclusion criteria were anticonvulsive medication, an epileptic seizure less than 2 years prior to the study, and additional severe comorbid psychiatric or neurological conditions, as assessed by reviewing information from the subject's medical file. Autistic memory experts were all male and right-handed, with a mean age of 21.4 years (range: 8-37; SD = 10.7) and a mean full-scale IQ of 118 (range: 100-130; SD = 10.1). Their respective outstanding skills are described in Table 1. Seven typically developed individuals were recruited by summons at the University of Tübingen or were personally acquainted with the experimenters. They were matched according to sex, handedness, age (M = 20.3; range: 8-36; SD = 10.3), and full-scale IQ (M = 115; range: 100-124; SD = 9.6). General IQ was assessed with the Standard Progressive Matrices (24) in five of seven memory experts and all control participants. In two of seven autistic participants, general IQ had been assessed before with the German versions of the Wechsler Adult Intelligence Scale-Revised (25) or the Wechsler Intelligence Scale for Children-Revised (26). Here, intelligence was not tested a second time in order to save time because, in individuals with high-functioning ASD, performance on the Standard Progressive Matrices and Wechsler IQ tests are comparable (27). Scores of verbal IQ or scores of the Peabody Picture Vocabulary Test-III (PPVT-III) were only available for five of seven autistic memory experts (between 94 and 126, M = 109.8, SD = 13.6). Because of time constraints, scores of verbal IQ were not collected in the control group; however, due to the good verbal abilities of the autistic group, groups' means are not likely to differ.

TABLE 1. Characterization of autistic memory experts

Memory Savant	Age	General IQ	Verbal IQ	Diagnosis	Special Abilities
S 1	8	120[1]	94[5]	Autistic disorder	Memory for timetables and dates; visual-spatial abilities
S 2	37	124[2]	122[4]	Autistic disorder	Memory for timetables of different transportation means; musical talent, absolute pitch; calendar calculation
S 3	15	130[3]	126[3]	Asperger's disorder	Memory for timetables; drawing abilities
S 4	18	110[2]	--	Autistic disorder	Memory for underground network; calendar calculation
S 5	19	100[3]	--	Autistic disorder	Memory for timetables and dates; mental arithmetic
S 6	34	124[2]	105[4]	Autistic disorder	Memory for train schedules and highway network of Germany; memory for dates
S 7	15	119[2]	102[5]	Autistic disorder	Memory for timetables and maps, radio towers; early reading; mental arithmetic

[1] Colored Progressive Matrices; [2] Standard Progressive Matrices; [3] HAWIK/HAWIK-R; [4] HAWIE-R; [5] PPVT-III

Typically developed individuals were paid 8 € per hour for their participation. Autistic memory experts were reimbursed for travel expenses and accommodations, and they received a non-monetary gift for their participation. Children were reinforced with tokens during the experiment that they could exchange for a gift, which had been chosen in accord with their parents. According to self-report, autistic experts were highly motivated to demonstrate their exceptional skills. All participants, or their legal agents, gave informed consent to participate in the study that was approved by the Ethics Committee of the Medical Faculty of the University of Tübingen.

Experimental procedure

Participants were tested in a continuous old-new paradigm (28;29). In a block, 300 stimuli were presented continuously every 2 seconds, 100 of which were displayed only once ("new"), 100 of which were displayed for a second time ("old"), and 100 of which were displayed once, but excluded from further analysis (filler items). All participants were instructed to judge, as quickly and accurately as possible by pressing a button with their right and left hand, whether an item had been presented before. Left and right button presses for "old" and "new" responses were counterbalanced across subjects. Stimuli were taken from the "Verbal and nonverbal learning test" (30;31; Figure 1). They comprised a block of 300 pseudowords and a block of 300 shapes, half of which were high and half of which were low associative according to the test manual. Stimuli were pseudo-randomized with regard to their semantic category (high/low associative) with no more than five of each category in a row. The order of presenting either the block of pseudowords or shapes first was counterbalanced across subjects. The interval between the presentation of an item and its repetition was between 6 and 12, with a mean of 9 items. Using a self-written DOS program, stimuli were projected centrally on a translucent screen using a Pentium-S 133-MHz computer and an NEC GT2150 projector. Participants were seated at a distance of 92 cm at a vertical visual angle of 1.2 degrees and a horizontal visual angle of maximal 6.2 degrees. At the beginning of each session, the participants were instructed and started with a short practice block to ensure that they understood the task. The proper block started with a central fixation cross for 1 s. Then the stimulus (pseudo-word or shape) was presented for 500 ms, followed by the answering period that pseudorandomly varied between 1.4 and 2.2 s. The next trial started with the following stimulus.

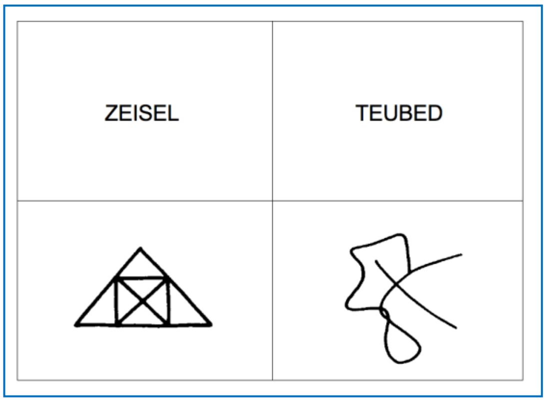

Figure 1. Stimuli used in the study from: “Verbal and nonverbal learning test” (30,31). High (left) and low (right) associative pseudowords are presented in the upper row. High (left) and low (right) associative shapes are presented in the lower row

Data analysis

Performance on a yes/no recognition test can be summarized by two measures: the hit rate (the probability that the subject classifies an old item as old), and the false alarm rate (the probability that the participant classifies a new item as old). According to Snodgrass and Corwin (32), the discrimination index *Pr* and the bias index *Br* derived from a two-high threshold model were calculated for the memory data. Higher *Pr* values [*p*(hit) − *p*(false alarm)] indicate better discrimination ability between old and new items. *Br* [*p*(false alarm) / *p*(1−*Pr*)] represents the measure of response bias. *Br* values higher than 0.5 indicate liberal response criteria (tendency to respond “old”); values lower than 0.5 suggest conservative response criteria (tendency to respond “new”). The discrimination index *Pr* and the response bias *Br* during the recognition of pseudowords and shapes were analyzed using a repeated-measures analysis of variance (ANOVA) with the within-factor “condition” (high vs. low associative) and the between-factor “group” (memory experts vs. control participants). Reaction times were analyzed with a repeated-measures ANOVA with the within-factors “condition” (high vs. low associative), “response” (hits vs. false alarms), and the between-factor “group” (autistic memory experts vs. control participants).

Results

Pseudowords

Discrimination index Pr:

For means and standard deviations of hit and false alarm rates in the recognition of high and low associative pseudowords, refer to Table 2. The repeated-measures ANOVA revealed no main effects of condition ($F_{1,12}$ = 0.11, P = .75 , η_p^2 = 0.01), or group ($F_{1,12}$ = 2.43, P = .15, η_p^2 = 0.17), or an interaction between condition and group ($F_{1,12}$ = 0.003, P = .96, η_p^2 < 0.001).

Response bias Br:

The repeated-measures ANOVA revealed a trend towards a main effect of group ($F_{1,12}$ = 4.29, P = .06, η_p^2 = 0.26) with autistic memory experts showing a conservative and control participants a liberal response bias. There was no main effect of condition ($F_{1,12}$ = 1.01, P = .33, η_p^2 = 0.08) nor an interaction between condition and group ($F_{1,12}$ = 0.19, P = .67, η_p^2 = 0.02).

TABLE 2. **Performance data (M = mean; SD = standard deviation) for autistic memory experts and control participants in the recognition of high and low associative pseudowords and shapes**

Performance			Memory Experts M (SD)	Control Participants M (SD)
Pseudowords	Hits	High associative	0.58 (0.21)	0.81 (0.15)
		Low associative	0.57 (0.17)	0.79 (0.15)
	False alarms	High associative	0.28 (0.17)	0.35 (0.16)
		Low associative	0.26 (0.15)	0.32 (0.15)
	Pr	High associative	0.30 (0.20)	0.46 (0.18)
		Low associative	0.31 (0.19)	0.47 (0.23)
	Br	High associative	0.40 (0.23)	0.65 (0.26)
		Low associative	0.38 (0.21)	0.62 (0.19)
Shapes	Hits	High associative	0.57 (0.17)	0.71 (0.25)
		Low associative	0.67 (0.28)	0.67 (0.27)
	False alarms	High associative	0.31 (0.20)	0.16 (0.12)
		Low associative	0.57 (0.26)	0.52 (0.30)
	Pr	High associative	0.26 (0.22)	0.55 (0.31)
		Low associative	0.10 (0.07)	0.14 (0.07)
	Br	High associative	0.40 (0.20)	0.44 (0.30)
		Low associative	0.64 (0.29)	0.60 (0.33)

Reaction times:

Means and standard deviations of reaction times during the recognition of high and low associative pseudowords are depicted in Table 3. The repeated-measures ANOVA revealed an interaction between the factors response and group ($F_{1,12}$ = 8.07, P < .05, η_p^2= 0.40), with control persons reacting significantly faster in hits than in false alarms ($F_{1,12}$ = 5.16, P < 0.05, η_p^2 = 0.30). There was a trend toward faster reaction times of autistic memory experts in false alarms compared with control participants ($F_{1,12}$ = 3.96, P = .07, η_p^2 = 0.25).

TABLE 3. Reaction times (in milliseconds; M = mean; SD = standard deviation) of autistic memory experts and control participants in the recognition of high and low associative pseudowords and shapes

	Reaction Times		Memory Experts M (SD)	Control Participants M (SD)
Pseudo-words	Hits	High associative	771 (211)	807 (103)
		Low associative	752 (236)	836 (142)
	False alarms	High associative	623 (153)	872 (160)
		Low associative	805 (387)	894 (183)
Shapes	Hits	High associative	786 (265)	846 (183)
		Low associative	745 (335)	882 (123)
	False alarms	High associative	791 (374)	864 (174)
		Low associative	670 (208)	848 (95)

Shapes

Discrimination index Pr:
For means and standard deviations of hit and false alarm rates in the recognition of high and low associative shapes, refer to Table 2. The repeated-measures ANOVA revealed a main effect of condition ($F_{1,12}$ = 16.0, P < .01, η_p^2 = 0.57) with high associative shapes showing a higher discrimination index than low associative shapes. There was a trend toward a main effect of group ($F_{1,12}$ = 4.35, P = .059, η_p^2 = 0.27), with control participants outperforming autistic memory experts. There was also a trend toward an interaction between condition and group ($F_{1,12}$ = 2.98, P = .055, one-tailed, η_p^2 = 0.20). Post-hoc t-tests revealed that only control participants showed a higher discrimination index in high than in low associative shapes ($F_{1,12}$ = 16.2, P < .01, η_p^2 = 0.58). There was a trend toward a higher discrimination index of control participants compared with autistic memory experts in high but not low associative shapes ($F_{1,12}$ = 3.92, P = .07, η_p^2 = 0.25).

Response bias Br:
The repeated-measures ANOVA revealed a main effect of condition ($F_{1,12}$ = 9.15, P < .05, η_p^2 = 0.43) with a more liberal response bias in low associative shapes. There were no effects of group ($F_{1,12}$ < 0.01, P = 1.0, η_p^2 < 0.001) nor an interaction between condition and group ($F_{1,12}$ = 0.28, P <= .61, η_p^2 = 0.02).

Reaction times:
Means and standard deviations of reaction times during the recognition of high and low associative shapes are depicted in Table 3. The repeated-measures ANOVA revealed a trend toward an interaction between condition and group ($F_{1,12}$ = 2.58, P = .07, one-tailed, η_p^2 = 0.18), with autistic memory experts showing a trend toward faster responses to low associative compared to high associative shapes ($F_{1,12}$ = 4.07, P = .067, η_p^2 = 0.25).

Discussion

We investigated seven autistic memory experts and seven control participants in a recognition memory paradigm with high and low associative pseudowords and shapes. We expected an interaction of condition and group with control participants but not autistic memory experts showing a recognition advantage for high associative material. This hypothesis was confirmed for the recognition of shapes, in which control participants outperformed autistic memory experts in the recognition of high but not low associative stimuli. Autistic memory experts showed similar discrimination indices for the recognition of high and low associative shapes and did not differ from the control group in the discrimination index of low associative shapes. The overall recognition performance was quite low, but hit rates exceeded false alarm rates in all conditions, so that random button press due to missing comprehension or motivation can be ruled out. For the recognition of pseudowords, neither of the groups scored better on high than on low associative pseudowords, and thus our study could not replicate the classification provided by the “Verbal and nonverbal learning test” (30;31). The absence of this effect represents an unfortunate failure to capture the variable under study. Interestingly, regardless of the associative value of pseudowords, the group of autistic memory experts showed a comparable discrimination index to control participants.

How can these findings be interpreted with regard to memory mechanisms in a group of autistic individuals with outstanding memory skill? First, outstanding memory skill in a circumscribed area seemed not to have transferred to a recognition memory paradigm with standard stimuli. Rather than being superior in the recognition of nonsense shapes, our group of autistic memory experts turned out to be inferior in the recognition of shapes with high associative value. On the other hand, in contrast to Ameli and coworkers (9), whose autistic sample performed overall worse than control participants in a visual recognition memory task and particularly bad on the recognition of nonsense shapes, our autistic sample showed at least comparable discrimination indices to control participants in pseudowords and low associative/nonsense shapes. Their memory expertise, as well as their higher level of intelligence, may thus have contributed to their normative performance. Second, autistic memory experts recognized surprisingly few high associative shapes in contrast to control participants, who showed the highest discrimination index of all conditions. The autistic group thus did not benefit from the high associative value of shapes to an extent that the control group did. Previous studies that investigated recognition of common objects (33) or semantic priming with picture stimuli (34) demonstrated the intactness or superiority of non-savant autistic individuals compared with control participants. However, one study using a false memory paradigm with geometric figures (35) found that individuals with ASD were significantly better able to discriminate true items from lure items and from that inferred restrictive associative networks in the spatial domain. In another study (9), individuals with ASD showed clearly inferior recognition performance of nonsense stimuli similar to the low associative ones of the current study, but recognition of common objects comparable to that of control participants. Taken together, these results provide evidence for an unimpaired or even superior pictorial semantic memory for objects, but a difficulty in making use of semantic features of abstract stimuli to facilitate memory in a self-organized manner. This interpretation is in accord with findings that revealed a deficiency in the use of verbal mediation strategies to maintain and monitor goal-related information in working memory of autistic children (36;37). Similarly, in verbal memory paradigms, autistic individuals were able to use semantic information to facilitate memory (6), but they showed diminished relational processing and may not do so spontaneously (5;8). Beversdorf and colleagues found a restricted use of semantic networks in individuals with ASD using false memory paradigms, which was assumed to be mediated by abnormalities in hippocampal functioning (10;11). Third, as our sample of autistic individuals was endowed with special memory skill, we expected a superior recognition of low-associative stimuli. Even in non-savant high-functioning autistic individuals, the intactness or superiority of visual-spatial abilities has often been demonstrated (38-40). According to the Theory of Enhanced Perceptual Functioning (41) there is a generally enhanced processing of low-level perceptual information leading to advantages in, for example, block design and embedded figures tasks (42-44). However, in contrast to other studies, the current investigation used a large number of complex stimuli combined with short exposure times (i.e., 500 ms). This experimental design may be disadvantageous for autistic memory experts to reveal their mnemonic skills.

There were group differences in reaction times during the recognition of shapes, when autistic memory experts tended to react faster to low than to high associative stimuli. On the other hand, they had the highest false alarm and the lowest discrimination rate of all conditions. Their fast reaction can therefore not be attributed to good performance; it may rather reflect a premature reaction to difficult stimuli. Autistic persons sometimes exhibit inhibitory deficits, especially with increasing cognitive load (45). In this context it was surprising that, during the recognition of pseudowords, autistic memory experts showed a more conservative response bias than control participants, that is, a tendency to "no" responses when unsure. In typically developing individuals, a false recognition (a tendency to "yes" responses) often occurs under speeded response conditions in the early stages of (automatic) recognition (46). On the other hand, a more conservative response bias has also been observed in other patients groups, such as individuals with schizophrenia (47) or persons under alcohol-induced memory impairment (48), and might accompany lower recognition performance.

A limiting factor of the current study is the fact that a control group of individuals with ASD but without memory skill is missing. Therefore, we are not able to disentangle effects of autism and savant syndrome. Another drawback may be the small and inhomogeneous sample that includes autistic memory experts of different ages and reduces the statistical power. However, since the savant syndrome is a rare condition, we were not able to increase the sample size. With regard to the heterogeneity of special memory areas (timetables, dates, etc.), we chose a recognition paradigm with standard stimuli. This may have been disadvantageous for probing savant memory. In future studies, memory performance may be improved by choosing tests in which stimuli reflect the savant domain.

In sum, in accord with our hypotheses, the group of individuals with ASD and special memory skill showed a comparable recognition performance for high and low associative shapes but was inferior in the recognition of high associative shapes compared with control participants. Contrary to prediction, autistic memory experts did not outperform control participants in the recognition of low associative shapes. Although there is evidence for restrictive associative networks in the spatial (as well as verbal) domain in the autistic, non-savant population (35), we attribute these findings to a failure to make use of semantic features of abstract stimuli to facilitate memory, possibly by verbal mediation strategies.

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