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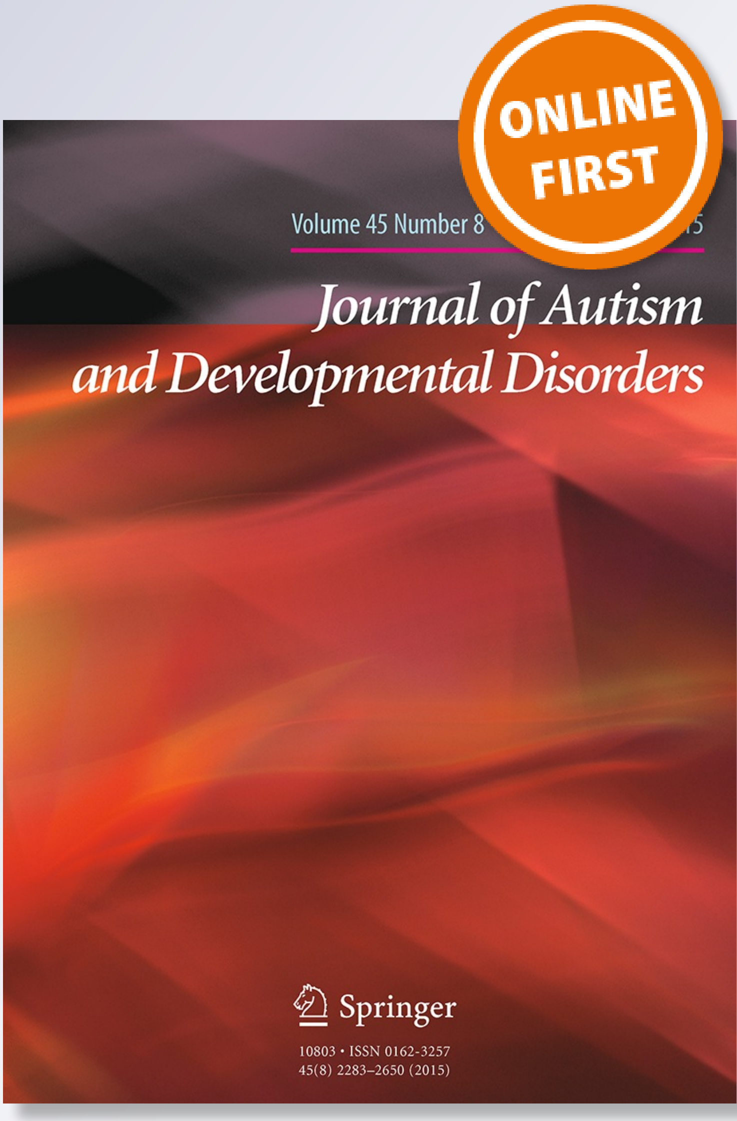

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ORIGINAL PAPER

Preserved Proactive Interference in Autism Spectrum Disorder

Joana C. Carmo[1] · Elsa Duarte[1] · Sandra Pinho[2] · Carlos N. Filipe[3] · J. Frederico Marques[1]

Abstract In this study, we aimed to evaluate further the functioning and structuring of the semantic system in autism spectrum disorders (ASD). We analyzed the performance of 19 high-functioning young adults with ASD and a group of 20 age-, verbal IQ- and education-matched individuals with the Proactive Interference (PI) Paradigm to evaluate semantic functioning in ASD (Experiment 1). In Experiment 2, we analyzed the performances of both groups in a PI paradigm with manipulation of the level of typicality. In both experiments, we observed significant effects of trial and group but no trial by group interactions, which we interpreted as robust evidence of preserved PI (build up effect) that indicated the preservation of semantic mechanisms of encoding and retrieval.

Keywords Autism spectrum disorder · Semantic memory · Categorization · Typicality · Episodic memory

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Introduction

Autism spectrum disorder (ASD) is a developmental disorder that is currently characterized by the presence of both persistent deficits in communication and social interaction in combination with a pattern of restricted, repetitive behaviors and interests in which symptoms must be present from early childhood (DSM–V, American Psychiatric Association 2013). Specifically, the social interaction symptoms might manifest as an inability to maintain competent conversation, whereas the social communication symptoms comprises both verbal and non-verbal communication deficits. It is well known that verbal communication heavily depends on categorization and conceptual knowledge or semantic memory (e.g., Lakoff 1987; Barsalou 1992; Murphy 2004). However, the hypothesis that the language and communication impairments commonly found in ASD could be explained in terms of deficits at this level was abandoned for some time (Tager-Flusberg 1996). This present study sought to contribute to the evaluation of this hypothesis by analyzing in a finer manner the functioning of categorization and semantic processing in ASD.

Research evaluating the general functioning of the long-term memory system (LTM) in ASD has generally found a pattern of preserved function in terms of overall recollection performance (Minshew and Goldstein 1993; Renner et al. 2000). However, several lines of evidence suggest that although the overall levels of free recall might be unimpaired in individuals with ASD, these individuals exhibit an atypical pattern of semantic processing in memory facilitation (i.e., a pattern that leads to superior recall) (e.g., Toichio 2008). An initial line of evidence in favor of this hypothesis came from a study by Tager-Flusberg (1991) in which the participants were required to

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recall super-span lists of semantically related and unrelated words in a one-trial learning paradigm. This study revealed that the ASD participants did not exhibit the superiority effect in the recall of semantically related word lists (compared with non-related word lists) that is observed in the individuals with typical development. In another study that compared semantically related and unrelated lists of words over three trials, Sumiyoshi et al. (2011) reported a diminished recall in the related word list condition in the ASD group compared with the control groups (i.e., siblings and typically developed participants). Moreover, based on a measure of semantic clustering (i.e., stimulus category repetitions (SCRs)) over trials, an absence of the linear increase in this memory organization score (i.e., semantic clustering) observed in controls has been observed in ASD subjects. Similarly, Bowler et al. (2008) found that in an unrelated list-learning paradigm over trials, there was actually an overall impairment in performance in an Asperger's group and that this impairment was positively correlated with Tulving's subjective organization score of the learning material (score that takes into account the order of recall on several repetitions of the same list).

Another line of evidence comes from the evaluation of the robust phenomenon of the serial position effects in the free recall of supra-span lists. Bowler et al. (2009) observed an absence of an advantage to recall for the initial portion of the word list (primacy effect) in adolescents and adults with ASD. However, this effect was found not observed in the first trial, which consisted of the repetition of the 15 words list, but was observed in subsequent repetitions of the same list. This primacy effect is thought to result from the transfer of learned information to LTM through elaborative rehearsal (Atkinson and Shiffrin 1968). In another study of the serial position effects (Toichi and Kamio 2003), the authors found that for concrete nouns, the ASD group performed worse than IQ-matched controls with respect to all three positions (i.e., the primacy, middle and recency positions). In both studies, the authors have concluded that the absence of the primacy effect supports the idea of a deficit in the semantic encoding and transfer of information to LTM (Toichi and Kamio 2003; Bowler et al. 2009). Moreover, the fact that the performance superiority of the concrete over the Abstract nouns that was observed in the controls was absent in the ASD group suggests that the concrete nouns were encoded no more semantically or associatively than the abstract nouns (Toichi and Kamio 2003).

Another robust phenomenon in semantic processing is the level-of-processing effect (Craik and Birstwistle 1971; Craik and Lockhart 1972; Craik 2002). This effect is related to the fact that semantic processing at the level of the encoding of verbal material leads to enhanced recall compared with shallower processing (either phonological or perceptual encoding). Toichi and Kamio (2002) reported that unlike the control participants, an ASD group exhibited no difference between the semantic encoding of the material and the phonological and perceptual level-of-processing. These authors suggested that the absence of this superiority effect in ASD is due to insufficient semantic memory elaboration during encoding.

Classic phenomena that are related to the encoding and retrieval processes in LTM are the *buildup* and *release* effects that are observed in the *proactive interference* (PI) paradigm (Wickens 1970, 1972, 1973). In each trial of this paradigm, the participants are exposed to a list of three words of the same class (e.g., category-membership) and are asked to recall the words after a given retention interval (typically approximately 25 s). The retention interval is filled with a backward counting task to prevent the participants from rehearsing the previously observed words. In the control condition, the characteristics of the word triads are maintained throughout each block of trials, and in the experimental condition, the characteristics of the word triads are changed on the last trial of the block (i.e., the shift trial). The first three trials correspond to the PI-buildup effect in which performance is observed to steadily decrease due to the development of proactive interference from the previous trials. In contrast, the last trial involves a change in the features of the list, which results in an increment in performance that is referred to as a release from proactive interference (PI-release). The PI-buildup effect has been explained as attributable to interference of the study materials that corresponds to reductions in the item discriminability and accessibility of the stored items. In contrast, when the category of the stimuli changes, this interference is reduced, and the corresponding improvement in performance is referred to as the PI-release effect (Craik and Birstwistle 1971; Wixted and Rohrer 1993; Marques and Morais 2000). These findings support the idea that stimuli are encoded not only as unique items but also as members of the same psychological class (Wickens 1973) even when this class membership is not explicit stated. Moreover, two studies have evaluated the role of typicality during the encoding of semantic categories with the PI release paradigm (Keller and Kellas 1978; Marques and Morais 2000). Both of these studies consistently reported that typicality indeed plays a role in conceptual organization because increments in performance were observed following shifts of the levels of typicality of the tested items (PI-release effect). Although overall performance in the typical trials was superior to that in the atypical trials, the extent of the buildup effect was comparable between the two conditions. These findings led Keller and Kellas (1978) to conclude that atypical exemplars were encoded homogeneously in terms of category membership (i.e., these exemplars are encoded as members of the correct superordinate category).

A few studies have evaluated typicality and the structures of natural categories in ASD, but inconsistent results have been reported. On the one hand, Tager-Flusberg (1985) reported no differences between children with ASD and control participants in the categorization of items that vary in typicality. Specifically, children with ASD and a control group exhibited similar patterns of under-generalization errors, i.e., failing to correctly identify the atypical and peripheral exemplars (e.g., the categorization of a penguin as a bird). Moreover, no differences emerged between the two groups in over-generalization errors, such as incorrectly identifying items that shared perceptual or functional features as members of the category (e.g., the categorization of a whale as a fish). However, in this study, the trials always had a fixed number of correct responses, which could have led to the development of strategies and promoted the underestimation of both under- and over-generalization errors.

On the other hand, Gastgeb et al. (2006) found that individuals with ASD exhibit greater reaction times than control participants in the category verification of atypical exemplars compared with typical exemplars of a given category. Thus, whether individuals with ASD exhibit abnormally structured semantics particularly at the categorical boundaries where the atypical members fall requires clarification (see also Gastgeb and Strauss 2012).

Categorization processes are a central function of the semantic system (e.g., Murphy 2004), and thus in this study, we aimed to further evaluate the functioning and structuring of the semantic system and to specifically and directly test the functioning of implicit categorical encoding and retrieval in ASD participants using the proactive interference paradigm.

In the first experiment, the performances of ASD individuals were compared to those of control participants in a proactive interference paradigm in which triads of words that varied in category membership were presented. In this experiment, we tested the participants with the PI paradigm using only typical exemplars because we were initially interested in evaluating broad semantic operations and functioning rather than analyzing the content boundaries of the semantic categories where the atypical items were located. The observation of a buildup effect as measured by a steady drop from trials 1–3 would reflect interference resulting from incidental categorical encoding, and this effect is commonly found in healthy participants.

In the second experiment, we used the release from proactive interference paradigm with a typicality manipulation. With this paradigm, we further evaluated whether the presentations of triads of items that were either typical or atypical members of a given category elicited comparable amounts of interference. For this purpose, we measured whether the PI-buildup effect was similar both groups or whether the atypical exemplars would lead to less homogeneous encoding regarding category membership in the ASD participants. The role of typicality in memory encoding in the ASD participants was finally evaluated in terms of the normal release effect that occurs when there is a shift in typicality in the last trial. Contrary to the explicit tasks of categorization and category verification used by Tager-Flusberg (1985) and Gastgeb et al. (2006), respectively, we believe that the use of an implicit evaluation of category structure can also inform us regarding the mechanisms that might exhibit usage impairments rather that true inabilities.

Experiment 1

In Experiment 1, we compared a sample of high-functioning participants with ASD (HFA) with gender-, age-, education- and verbal IQ-matched controls with a classical PI paradigm in which we manipulated the word triads' categories of belonging. In each categorical condition (i.e., vegetables, sports, fish and professions), word triads of the same category were presented for 3 consecutive trials because we aimed to evaluate the steady decrease in performance from trials 1–3 that characterizes the buildup effect. Several lines of previously presented evidence seem to indicate that ASD individuals exhibit faulty semantic processing during memory facilitation (i.e., superiority of recall) as reflected by the absences of the primacy effect (Toichi and Kamio 2003; Bowler et al. 2009), the related word list effect (Tager-Flusberg 1991; Sumiyoshi et al. 2011) and the semantic level-of-processing effect (Toichi and Kamio 2002). Therefore, in the tests of the high-functioning ASD group with the PI paradigm, we expected to observe a deficiency in the implicit encoding of items as members of the same category in the HFA individuals (i.e., a diminished PI-buildup effect).

Method

Participants

Nineteen HFA young adults (one female) and twenty young adults with typical development (one female) participated in the study. The HFA participants were selected if they scored above 70 points on both the verbal and performance subscales of the Wechsler Adult Intelligence Scale (WAIS) and were diagnosed with autism or autism spectrum disorder. The diagnoses of autism were based on the DSM-IV criteria (American Psychiatric Association 1994) and were confirmed by two observers with extensive clinical experience with autism. The Asperger's syndrome diagnostic scale (ASDS) (Myles et al. 2001) and/or the

Autism Diagnostic Observation Schedule (ADOS) (Lord et al. 1999) were used to confirm the diagnoses based on clinical evaluation.

The two groups of participants were matched for age, verbal IQ (WAIS) and education as measured by the number of years in school (see the demographic table below).

The participants with ASD were recruited through the clinical database of the *Centro de Apoio ao Desenvolvimento Infantil* (CADIN) (Cascais, Portugal). The control participants were recruited from the local community and completed an intelligence scale (WAIS, verbal subscale) administered by the experimenters. Ethical permission for the study was granted by the ethical committee of the Faculty of Psychology of the University of Lisbon (Portugal), and each participant provided written informed consent.

Materials and Procedure

The stimulus words were adapted from Marques (1997). For each of the 4 categories used (vegetables, fish, professions and sports), 9 typical exemplars were selected. Marques (1997) calculated the typicality norms for the Portuguese language by asking subjects to rate, on a 7-point Likert scale, how well the exemplars represented a given category. For each category, 3 triads of words were formed (see "Appendix 1" for a complete list of the word triads). The three triads of the same category were presented in sequence with each word corresponding to a trial for a total of 12 trials. Within each category, the order of the trials was randomized. The order of the presentation of the categories was counterbalanced across subjects. The experiment was built using E-Prime 2 (Psychological Software Tools, Inc.).

Each trial began with the presentation of a fixation cross slide for 2 s that was followed by the word triads, which were presented one-by-one for 2 s each. The participants were instructed to read the words silently. A three-digit number was then presented for 25 s during which time the participants were asked to count backwards by 3 s out loud. Subsequently, a question mark appeared to signal the end of the counting task and the beginning of the 8 s recall period in which the subjects were asked to recall the previously viewed words (see Fig. 1).

The subjects were instructed to recall as many words as possible and to try to follow the order of the words for each triad. The participants responded out loud, and the experimenter registered their answers. A blank slide presented for 2 s marked the end of the recall period and signaled the beginning of the next trial. One trial was presented as a training trial, and the experimenter began the test trials when the participants demonstrated that they correctly understood the task. All participants were tested individually and were informed that they would be tested on a memory task.

Results and Discussion

For each participant, the average correct recall score was computed for each trial. The recall score on each trial varied between 0 and 6; the participants received 2 points for each correct word in the correct order and 1 point for each correct word in the incorrect order (as in Marques and Morais 2000). The average scores according to group and trial are presented in Fig. 2.

A repeated-measures ANOVA was computed for the average correct recall scores using Trial (First, Second and Third) as a within-subjects factor and Group (HFA or Control) as a between-subjects factors (all statistical

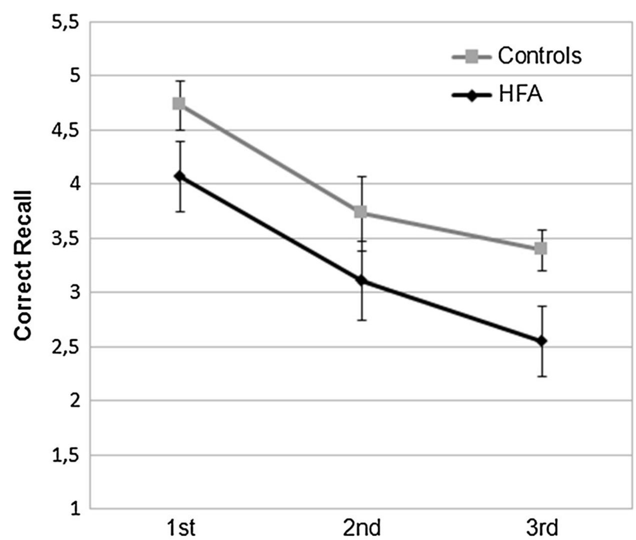
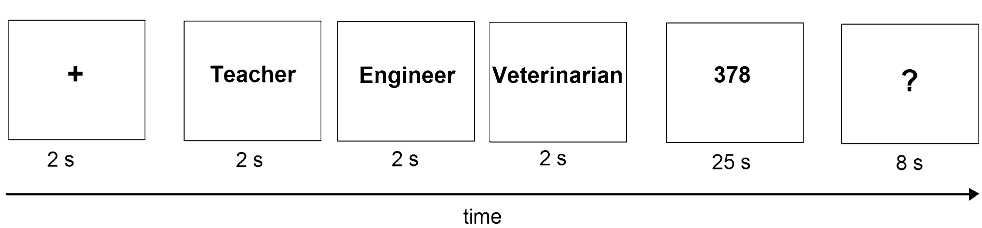


Fig. 2 Build up effect: The average correct recalls over trials for both the HFA and control groups. The *bars* represent the standard error of mean

Fig. 1 Schematic drawing of an example trial sequence for both experiments 1 and 2



analyses were performed with IBM's *Statistical Package for Social Sciences v. 21*). Significant main effects of trial ($F(2,37) = 23.75$, $p < .001$) and Group ($F(1,38) = 4.12$, $p = .05$) were observed. The Control participants exhibited higher recall scores ($M = 3.9$ $SEM = .24$) than the HFA group ($M = 3.2$, $SEM = .25$). No significant Group × Trial interaction was observed ($p > .8$). To better understand the main effect of Trial, *t* tests were performed. A clear buildup effect was observed because the recall rate was highest for the first trial ($M = 4.39$, $SEM = .19$) followed by the recall rate for the second trial ($M = 3.4$, $SEM = .25$) ($t(1,38) = 4.34$, $p < .001$). A decrease was observed in the average correct recall score for the third trial compared with that of the second ($M = 2.97$, $SEM = .18$; $t(1,38) = 2.17$, $p = .037$). In contrast to our predictions, we not only observed impaired levels of recall in the ASD group (main effect of Group) but also observed a clear effect of interference with the implicit categorical encoding of the studied items (i.e., a build-up effect; main effect of Trial type). This finding of impoverish overall recall contrasts with those of the majority of previous studies that we reviewed with the only exception of the study by Bowler et al. (2008), which also observed impaired recollection in an ASD group. The finding of the clear interference due to the categorical nature of the studied material was also unexpected. Moreover, this finding contrasts with previous evidence from ASD individuals (Tager-Flusberg 1991; Toichi and Kamio 2002, 2003; Bowler et al. 2009; Sumiyoshi et al. 2011) of an absence of memory facilitation as illustrated by the phenomena reported earlier (e.g., the levels-of-processing and primacy effects).

Temporal Component

Regarding the previous findings, one could argue that given that the participants were evaluated on their abilities to recall the triads of words in the correct order of presentation, it is possible that the temporal component of the task alone drove the poor performance of the ASD sample. Lind and Bowler (2008) reported that although very little work has directly assessed temporal cognition, there is evidence of impairment in this ability in ASD. This claim is based on the work of Boucher et al. (2007) on diachronic thinking. In this study, the authors evaluated the ability to think about events that were spread across time using several measures/components and observed a consistent impairment in a sample of children with ASD. Moreover, as early as 1996, Bennetto et al. (1996) demonstrated the compromised performance of high-functioning children with ASD in a task that evaluated the temporal order of previously presented material.

In the subsequent analyses, we assess whether it was the temporal component of the proactive interference task that

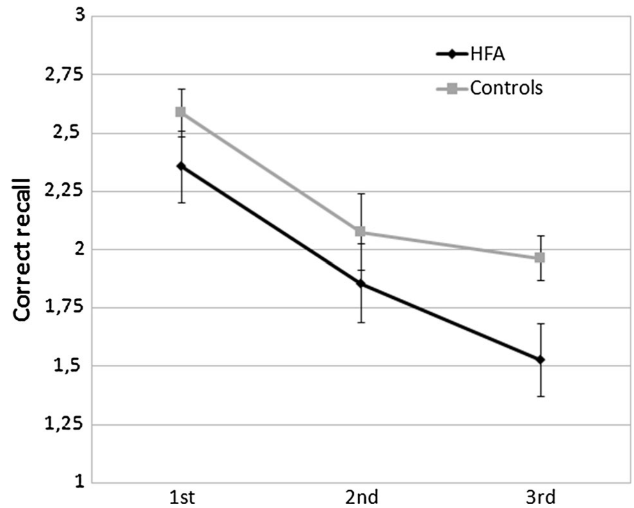


Fig. 3 Build up effect regardless of word order: Average correct recalls over trials for both the HFA and control groups. The *bars* represent the standard error of the mean

was impaired in our ASD sample. To this end, in this analysis, each participant's recall score on each trial could vary between 0 and 3 based on the number of correctly recalled words regardless of the order of presentation (see Fig. 3). A repeated-measures ANOVA was computed with Trial (first, second, and third) and group (HFA and Control) as a between-subjects factor. Subsequent *t* tests confirmed the main effect of Trial via decreases in performance from the first trial ($M = 2.47$, $SE = .09$) to second trial ($M = 1.96$, $SE = .12$) and from the second trial to the last trial ($M = 1.74$, $SE = .09$; $F(2,37) = 23{,}42$, $p > .001$). The overall recall score observed for the HFA group ($M = 1.91$, $SE = .11$) was lower than that of the Control participants ($M = 2.21$, $SE = .11$), but this effect was only marginally significant ($F(1, 38) = 3.48$, $p = .071$). Again no significant Group × Trial interaction was observed ($p > .5$).

Experiment 2

In Experiment 2, we tested the same group of participants who were examined in experiment 1 in a PI release paradigm in which we manipulated the level of typicality. Via direct testing for differences between the items that fell at category boundaries (atypical) and the typical categorical items, we sought to detect more subtle differences in categorical processing and structuring that might have been overlooked in experiment 1. Specifically, we compared the buildup effects for word triads that varied in their levels of typicality (the 1st three trials were considered and were from the same typicality condition), and the difference in the performances between the 3rd and 4th trials during which a shift in typicality occurred (release effect) was analyzed. If the atypical items were categorized differently than the typical items by the ASD participants (e.g., Gastgeb et al. 2006) then a less homogeneous set would be expected for the atypical items (i.e., not belonging to the same superordinate category) and lead to an inferior buildup effect for this condition in the HFA group. Moreover, in terms of the release effect, it was expected that the shift in typicality would lead to greater release from the interference given that the items were processed as somehow different sets of items (i.e., items not in the same and correct category).

Methods

Participants

The same participants from experiment 1 participated in this experiment. See Table 1 for the demographic characteristics of both the HFA and the control groups. The control participants consisted of typically developing individuals who were matched for gender, age, verbal IQ and education level.

Materials and Procedure

In this experiment, 4 different categories from experiment 1 were used. For each of the 4 categories (birds, furniture, fruits and vehicles), 12 typical exemplars and 12 atypical exemplars were used. The stimuli were taken from Marques and Morais (2000). Marques and Morais (2000) used the typicality norms from Marques (1997), and 12 typical exemplars and 12 atypical exemplars that differed in their familiarity ratings were selected. In the study by Marques and Morais, the number of syllables per word was controlled, and there were no differences between the groups in any category. Regarding the production frequencies, there were expected differences between the groups for all of the categories; however, the production frequency distributions of all categories were similar between the groups (i.e., the typical and atypical groups) (Marques and Morais 2000). These stimuli were also controlled for familiarity. The familiarity ratings were also drawn from Marques (1997) and were based on word ratings for the Portuguese language that were calculated on a 5-point Likert scale in which 1 represented very familiar and 5 represented not at all familiar (independently of the category of belonging). Regarding familiarity, both a concurrent and a constant manipulation were used; i.e., two groups of exemplars (birds and fruits) that differed in typicality and familiarity ratings (concurrent) were used, and two groups (furniture and vehicles) that differed in typicality but not familiarity were used. The results of this study (Marques and Morais 2000, Experiment 1) revealed that the observed typicality effects were not attributable to familiarity because the constant and concurrent manipulations produced similar results.

Twenty-four groups of 4 word triads were then created (see "Appendix 2" for the complete list). Four triads of the same category were presented in sequence, each presentation corresponded to a trial, and there were a total of 16 trials (see Fig. 1). All of the participants completed four different conditions. In the first two conditions (baseline conditions), all four trials within each category shared the same typicality level (i.e., all typical or all atypical). In the two other conditions (Shift shift conditions), the 4th trial differed in terms of typicality from the first 3 trials; i.e., there was a shift from typical to atypical items (the first 3 trials involved typical word triads, and the last trial involved an atypical triad) or vice versa (the first 3 trials involved atypical exemplars, and the 4th trial involved a typical word triad). The order of the presentation of the trials within each category was pseudo-randomized such that the likelihoods with which a given triad appeared in the various positions (1–4) were similar. The order of the categories was counterbalanced between the participants. The general procedure and trial composition were the same as those used in experiment 1. Because the individuals participated in experiments 1 and 2, the order of the administration of the experiments was also counterbalanced across the subjects.

Table 1 The demographic information of the participants

n	HFA 19 (1 female)	Controls 20 (1 female)	*p* values
Age (years)	25.32 (6.89)	25.05 (7.63)	0.91
Verbal IQ (WAIS)	104.6 (8.55)	109.9 (13.82)	0.16
Education (years)	13.21 (2.1)	12.9 (2.34)	0.67

The means and the standard deviations are provided for each group

Results and Discussion

The average correct recall scores over trials were computed as in Experiment 1. The effects of PI-buildup and PI-release were analyzed separately by accounting for the first 3 trials and the 4th trial, respectively (as in Marques and Morais 2000). The data of 2 of the HFA subjects were lost due to a technical problem.

To analyze the effects of the typicality manipulation on PI-buildup (see Fig. 4), a repeated-measures ANOVA was computed for correct recall with Group (HFA and Control) as a between-subjects factor and both Trial (first, second, and third) and Typicality (atypical triads and typical triads) as within-subjects factors. A significant main effect of Trial was found ($F(3,34) = 18.63$, $p < .001$); the highest recall rate occurred for the first trial ($M = 4.02$, $SEM = .16$) followed by the second trial ($M = 3.07$, $SEM = .23$), and the minimum recall rate was observed for the third trial ($M = 2.81$ $SEM = .22$). Subsequent *t* tests revealed that only the difference between trials 1 and 2 was significant ($p < .001$; trial 2 vs. trial 3, $p = .24$). A marginally significant effect was also found for Group; the HFA group ($M = 2.95$, $SEM = .25$) performed worse overall than the control group ($M = 3.61$, $SEM = .23$; $F(1,36) = 3.87$ $p = .057$). Although the recall was higher overall for the typical triads ($M = 3.33$, $SEM = .19$) than the atypical triads ($M = 3.22$, $SEM = .19$), this result did not reach significance, and neither did the interactions of Typicality with the other variables (all *p*s > .5).

For the analysis of the effects of the typicality manipulation on PI-release, we compared the average recall scores for the of the 4th trial (i.e., following the shift in typicality from the 3rd to the 4th trials) to the baseline condition without a shift in typicality (as in Marques and Morais 2000). Hence, the trials that involved a shift from a typical trial to an atypical trial were compared to the atypical baseline condition (i.e., both the 3rd and 4th trials were atypical). Trials involving shifts from atypical to typical triads were compared to the typical baseline condition (i.e., both the 3rd and 4th trials were typical) (see Fig. 5).

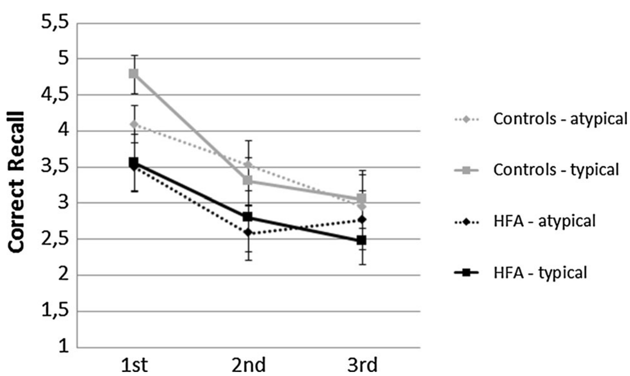
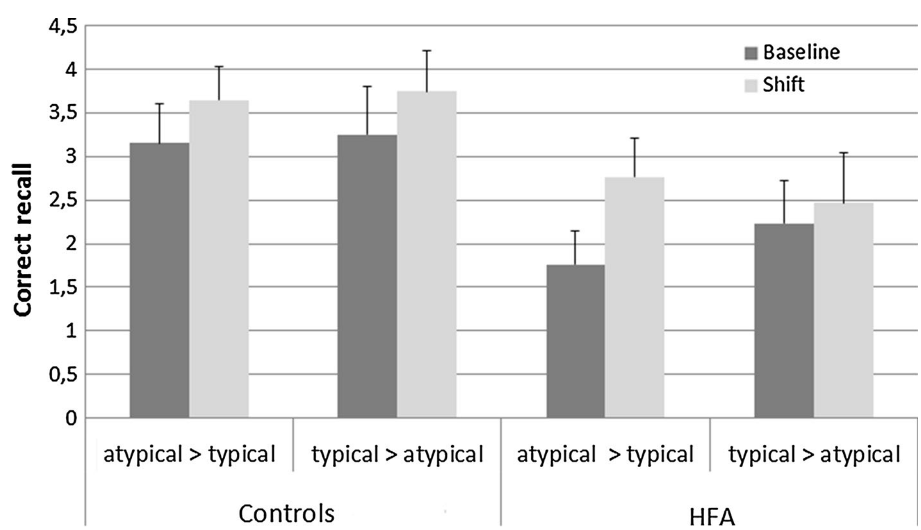


Fig. 4 Build up effects for the typical and atypical triads (*dashed lines*): Average correct recalls over trials for both the HFA and control groups. The *bars* represent the standard error of the mean

A repeated-measures ANOVA was performed for the correct recall with Condition (Shift or Baseline), Typicality (atypical or typical) and Group (HFA or Control) as independent variables. A significant main effect of Group ($F(36,1) = 6.238$, $p = .017$) was found and was due to the poor recall performance of the HFA group ($M = 2.31$, $SEM = .34$; controls: $M = 3.45$, $SEM = .31$). The difference between the trials in which a shift occurred ($M = 3.16$, $SEM = .26$) and the baseline condition ($M = 2.6$, $SEM = .26$) was also found to be significant ($F(36,1) = 4.796$, $p = .035$). Although there was no Condition × Group interaction ($p > .8$) or Condition × Group × Typicality ($p >$ 5) interactions, the amount of release following the shifts from atypical to a typical trials in the HFA group was double that observed in either shift condition in the control participants. Subsequent paired t-tests revealed that it was indeed this shift from atypical to typical trials in the HFA group ($p = .039$) that primarily drove the observed main effect (all other *p*s > .3).

This analysis in which we assessed the recall performances of participants on the 4th trial, again revealed the poorer performance of the HFA group. The main effect of Shift showed that in agreement with the literature, typicality plays a role in this memory task and leads to a release from the interference of the previous material. Quite compelling are the facts that this effect on the shift

Fig. 5 Release effect: Average correct recalls on the 4th trial for both the HFA and control groups in the baseline condition (no shift from the 3rd to 4th trials) and the shift condition. The *bars* represent the standard error of the mean



condition was nearly non-observable when HFA participants shifted from typical to atypical trials and was twice the magnitude of the effect observed in the control participants when the ASD group shifted from the atypical to the typical trials.

General Discussion

Several lines of evidence have suggested that semantic processing during encoding might be impaired in individuals with autism (e.g., Tager-Flusberg 1991; Toichi and Kamio 2003; Bowler et al. 2009). In the current study, we further explored this idea by evaluating whether individuals with ASD exhibited an interference effect during the recall materials with shared categories of belonging using the classical proactive interference paradigm.

In both experiments 1 and 2, we observed steady declines in performance from trials 1–3 in our ASD sample. These findings provide clear evidence of the PI-buildup effect and indicated that in contrast to our expectations, the categorical encoding of the studied material was preserved. Moreover, we also found that the amounts of interference were quite similar between the control and ASD groups and indicated by the lack of a trial by group interaction. The presence of a normal and consistent build up effect revealed that the participants with ASD were indeed encoding and retrieving items from memory with the aid of the semantic system in the same manner as the normal participants.

Notably however, the levels of recall exhibited by the ASD group were consistently lower in both experiments. These findings of impaired overall recall rates and preserved proactive interference are at odds with some findings in the literature that have indicated unimpaired recall with deficient semantic encoding in ASD (e.g., Tager-Flusberg 1991; Toichi and Kamio 2003; Bowler et al. 2009). Due to this unexpected result, we tentatively analyzed our results in terms of the primacy effect (see the supplementary materials) that was found absent in ASD participants (e.g., Toichi and Kamio 2003). Although this comparison is difficult and problematic, we again found that no differences emerged in the initial portions of the serial lists in our data, which indicated a normal LTM transfer component of the performance of the serial position paradigm. Note however, that in our case and in contrast with the serial position pardigm (e.g., Bowler et al. 2009) the list of words presented were semantically related. This fact could have forged the semantic and categorical encoding of the material.

In light of this pattern of results, i.e., an overall diminishment of recall, the possibility that the episodic component of this memory task (rather than the semantic component) might be compromised cannot be excluded. Interestingly, this pattern of results is remarkably similar that exhibited by early Alzheimer's disease patients in the release from proactive interference paradigm (Binetti et al. 1995). Indeed, similar to our observations in the present study, Binetti et al. (1995) reported impaired overall recall rates and the presence of a normal buildup effect in early Alzheimer's disease patients.

The idea that ASD is characterized by poor performances on tasks that demand the recruitment of the episodic system has previously been advocated (Lind and Bowler 2008, 2010; Southwick et al. 2011; Lind et al. 2014). The initial support for this idea actually came both free recall and forced-choice recognition tasks (Boucher and Warrington 1976), but this idea has also gained support from the performances of ASD individuals in tasks that evaluate memories of life past events (Boucher 1981; Lind and Bowler 2010; Lind et al. 2014) and memories of stories (Southwick et al. 2011). Additionally, Bowler et al. (2000) tested the different states of awareness that define the episodic and semantic systems in Asperger's individuals. The finding of a reduction in autonoetic consciousness (i.e., remembering responses) led these authors to advocate a moderate impairment in episodic memory in ASD.

One characteristic of the episodic memory system is the ability to remember personally experienced events in time (Tulving 1993). The temporal organization of the to-be remembered material is one possible explanation for the difference in overall performance between the two experimental groups. Indeed, the analysis of the results that did not account for the order of the presentation of the words revealed a decrease in the difference in overall performances and can thus partially account for the main effect that was observed in global performance.

Another alternative explanation is that the cost of switching between the distractor task and the recall phase of each trial also partially contributed to the diminished overall performance observed in the ASD group. Although the debate regarding cognitive flexibility and task switching costs in ASD remains open (e.g., Geurts et al. 2009; Stoet and López 2011), there are some indications of a deficiency in the task switching abilities of this population (e.g., Hill 2004; van Eylen et al. 2011).

In experiment 2, we directly tested the effects of typicality level on both the buildup and release effects within the same paradigm. We aimed to evaluate both the homogeneity of the category encoding of atypical items in our ASD sample and typicality as semantic dimension. In partial contrast to the suggestion of an abnormal category structure with respect to items that fall at the category boundaries (Gastgeb and Strauss 2012), we found that buildup was not different between the ASD and control groups. The amounts of buildup observed were similar for the typical and atypical trials (i.e., there was not interaction effect between trial and condition) and similar in the control and ASD groups (i.e., there was no interaction effect between trial and group). Given that the expected differences in the amounts of recall were not observed in the control group (Keller and Kellas 1978; Marques and Morais 2000), we are currently unable to draw any conclusions regarding typicality so far. This is a limitation of our study that we are unfortunately unable to circumvent because it might be primarily due to the different sizes of the samples used in our study and that of Keller and Kellas (1978) who used more than 60 participants and that of Marques and Morais (2000) who examined an even greater number of subjects.

To explain the release from PI observed with shifts in typicality, Keller and Kellas (1978) referred to the notion of a difference between the defining and characteristic features of concepts (Smith et al. 1974). If defining features are shared by all members of a given concept (e.g., birds have wings), then characteristic features are more shared between typical instances (e.g., birds can fly) (Smith et al. 1974; Medin et al. 2004). The lack of shared characteristic features would explain a larger PI release when shifting from typical to atypical trials. Whereas a minimal release from PI is obtained when there is a shift from atypical to typical word triads due to the similarity of the defining features between those sets (Keller and Kellas 1978). Critically, in the ASD group only in our study, we observed the opposite release effect in that this minimal gain due to the activation of shared attributes (from the atypical to typical trials) was reversed and considerably enhanced. This finding questions the structures and contents of the used categories because the presentation of atypical items did not seem to activate the defining features of all of the members of a given category and were seemingly processed as different sets than the typical exemplars as though the contents of the categories were slightly restricted and did not include the atypical exemplars. It is unclear in what manners and to what extents this abnormally high PI release effect and the putative differences in the contents of the categories could have contributed to the seemly malfunctioning semantic system in ASD. It is also unclear, whether the differences in content of categories could have result, throughout development, from a faulty episodic system or conjunctive learning that could be more punitive for atypical instances.

Admittedly, we tested only high-functioning individuals with ASD and did not examine subjects on the other end of the spectrum of this disorder; however, it is our opinion that this was the best method to evaluate the cognitive functioning of this population because it allowed us to exclude other cognitive deficits (e.g., working memory and comprehension deficits) that could have influenced the performances; hence, we can more safely make inferences and interpret our results in terms of cognitive functioning under scrutiny.

In summary, we found that individuals with ASD exhibited a clear and classical pattern of interference with the implicit categorical encoding of both typical and atypical items in a recall task. While the categorical encoding and retrieval processes of the studied materials seemed to be preserved in ASD, a poor recall rate was consistently observed in these individuals.

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Author Contributions Conceived and designed the experiments: JCC, JFM and CNF; Performed the experiments: JCC and ED; Selected and recruited participants: JCC, SP and CNF; Analyzed the data: JCC; Wrote the paper: JCC, JFM and CNF.

Appendix 1

See Table 2.

Table 2 Word triads used in first experiment and their typicality values

Triads	Typicality
1. Vegetables	
A Turnip, Cabbage, Watercress	2.38
B Broccoli, Lettuce, Spinach	2.16
C Carrot, Broccoli rabe, Tomato	1.93
Average	2.15
2. Fish	
A Hake, Sole, Salmon	2.54
B Mackerel, Trout, Tuna	2.23
C Sardine, Seabass, Codfish	2.33
Average	2.37
3. Professions	
A Judge, Manager, Doctor	2.25
B Architect, Pharmacist, Lawer	2.29
C Teacher, Engineer, Veterinarian	2.33
Average	2.29
4. Sports	
A Basketball, Tennis, Athletics	1.41
B Running, Gymnastics, Soccer	1.42
C Cycling, Handball, Swimming	1.41
Average	1.41

Appendix 2

See Table 3.

Table 3 Word triads used in second experiment and their familiarity and typicality values and average of production frequency

	Typicality	Familiarity
1. Birds		
Typical triads		
A Eagle, Duck, Canary	1.79	1.86
B Pigeon, Nightingale, Falcon	1.85	3.13
C Seagull, Turtle dove, Parakeet	1.87	2.83
D Swallow, Sparrow, Parrot	1.72	2.29
Average	1.82	2.53
Production frequency	24.75	
Atypical triads		
A Emu, Sparrow-hawk, Woodcock	3.97	3.93
B Pelican, Bantam, Goshawk	3.89	4.09
C Jackdaw, Straling, Toucan	3.84	4.42
D Jay, Ostrich, Magpie	3.77	3.56
Average	3.87	4
Production frequency	3.88	
2. Furniture		
Typical triads		
A Table, Commode, Desk	1.62	1.87
B Bed, Writing table, Wardrobe	1.63	1.79
C Cupboard, Couch, Cabinet	1.66	2.02
D Shelf, Fitment, Chair	1.58	1.95
Average	1.63	1.91
Production frequency	41.67	
Atypical triads		
A Television, Bar, Curtains	4.48	1.66
B Folding screen, Ashtray, Frame	4.65	1.78
C Watch, Carpet, Matress	4.63	1.63
D Counter, Fridge, Sideboard	4.66	2.28
Average	4.52	1.88
Production frequency	0.93	

	Familiarity	Typicality
3. Fruits		
Typical triads		
A Melon, Banana, Strawberry	1.55	1.55
B Watermelon, Pear, Orange	1.45	1.53
C Tangerine, Pineapple, Apple	1.75	1.53
D Grapes, Cherry, Peach	1.64	1.58
Average	1.6	1.55
Production frequency	50.5	
Atypical triads		
A Olive, Guava, Lime	2.97	4.27
B Chestnut, Annona, Date	3.1	4.32
C Currant, Almond, Papaya	3	4.38

Table 3 continued

	Familiarity	Typicality
D Cashew, Hazelnut, Sour berry	2.54	4.3
Average	2.9	4.32
Production frequency	2.36	
4. Vehicles		
Typical triads		
A Ambulance, Scooter, Plane	1.66	2.43
B Tram, Car, Boat	1.62	2.32
C Train, Taxi, Pickup	1.52	2.39
D Van, Jeep, Motorbike	1.96	2.3
Average	1.69	2.36
Production frequency	20.42	
Triads		
A Skis, Helicopter, Raft	1.8	5.05
B Skate, Tractor, Rocket	1.73	5.08
C Rollerblades, Canoe, Lift	1.65	5.23
D Submarine, Tricycle, Sled	1.89	5.16
Average	1.77	5.13
Production frequency	4.13	

References

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: Author.

Atkinson, R. C., & Shiffrin, R. M. (1968). Chapter: Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation* (Vol. 2, pp. 89–195). New York: Academic Press.

Barsalou, L. W. (1992). *Cognitive psychology: An overview for cognitive scientists*. Hillsdale, NJ: Lawrence Erlbaum.

Bennetto, L., Pennington, B., & Rogers, S. (1996). Intact and Impaired memory function in Autism. *Child Development, 67*, 1816–1835.

Binetti, G., Magni, E., Padovani, A., Cappa, S. F., Bianchetti, A., & Trabucchi, M. (1995). Release from proactive interference in early Alzheimer's disease. *Neuropsychologia, 33*(3), 379–384.

Boucher, J. (1981). Memory for recent events in autistic children. *Journal of Autism and Developmental Disorders, 11*(3), 293–301.

Boucher, J., Pons, F., Lind, S., & Williams, D. (2007). Temporal cognition in children with autism spectrum disorders: Tests of diachronic thinking. *Journal of Autism and Developmental Disorders, 37*, 1413–1429.

Boucher, J., & Warrington, E. K. (1976). Memory deficits in early infantile autism: Some similarities to the amnesic syndrome. *British Journal of Psychology, 67*(1), 73–87.

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

Bowler, D. M., Gardiner, J. M., & Grice, S. J. (2000). Episodic memory and remembering in adults with Asperger syndrome. *Journal of Autism and Developmental Disorders, 30*(4), 295–304.

Bowler, D. M., Limoges, E., & Mottron, L. (2009). Different verbal learning strategies in autism spectrum disorder: Evidence from the rey auditory verbal learning test. *Journal of Autism and Development Disorders, 39*, 910–915.

Craik, F. I. M. (2002). Levels of processing: Past, present…and future? *Memory, 10*, 305–318.

Craik, F. I. M., & Birstwistle, J. (1971). Proactive interference in free recall. *Journal of Experimental Psychology, 91*(1), 120–123.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11*, 671–684.

Gastgeb, H. J., & Strauss, M. S. (2012). Categorization in ASD: The role of typicality and development. *Perspectives in Language, Learning and Education, 19*, 66–74.

Gastgeb, H. J., Strauss, M. S., & Minshew, N. (2006). Do individuals with autism process categories differently? The effect of typicality and development. *Child Development, 77*, 1717–1729.

Geurts, H. M., Corbett, B., & Solomon, M. (2009). The paradox of cognitive flexibility in autism. *Trends in Cognitive Sciences, 13*(2), 74–82.

Hill, E. L. (2004). Executive dysfunction in autism. *Trends in Cognitive Sciences, 8*(1), 26–32.

Keller, D., & Kellas, G. (1978). Typicality as a dimension of encoding. *Journal of Experimental Psychology: Human Learning and Memory, 4*(1), 78–85.

Lakoff, G. (1987). *Women, fire, and dangerous things: What categories reveal about the mind*. Chicago: The University of Chicago Press.

Lind, S. E., & Bowler, D. M. (2008). Episodic memory and autonoetic consciousness in autistic spectrum disorder: The roles of self-awareness, representational abilities and temporal cognition. In J. Boucher & D. Bowler (Eds.), *Memory in Autism: Theory and evidence*. Cambridge: Cambridge University Press.

Lind, S. E., & Bowler, D. M. (2010). Episodic memory and episodic future thinking in adults with autism. *Journal of Abnormal Psychology, 119*(4), 896–905.

Lind, S. E., Williams, D. M., Bowler, D. M., & Peel, A. (2014). Episodic memory and episodic future thinking in high-functioning autism spectrum disorder: An underlying difficulty with scene construction or self-projection. *Neuropsychology, 28*(1), 55–67.

Lord, C., Rutter, M., DiLavore, P. C., & Risi, S. (1999). *Autism diagnostic observation schedule: WPS (ADOS-WPS)*. Los Angeles, CA: Western Psychological Services.

Marques, J. F. (1997). *Tipicidade, familiaridade e inclusão como determinantes de categorias semânticas (doctoral thesis)*. Faculdade de Psicologia e Ciências da Educação: Universidade de Lisboa, Portugal.

Marques, J. F., & Morais, J. (2000). Relationships between typicality, category membership, and familiarity: A study using proactive interference. *Current Psychology of Cognition, 19*(2), 189–219.

Medin, D. L., Ross, B., & Markman, A. (2004). *Cognitive psychology* (4th ed.). New York: Wiley.

Minshew, N. J., & Goldstein, G. (1993). Is Autism an amnesic disorder? Evidence from the California verbal learning test. *Neuropsychology, 7*(2), 209–216.

Murphy, G. L. (2004). *The big book of concepts*. Cambridge, MA: MIT Press.

Myles, B. S., Bock, S. J., & Simpson, R. L. (2001). *Asperger syndrome diagnostic scale (ASDS)*. Austin, TX: Pro-Ed.

Renner, P., Klinger, L. G., & Klinger, M. R. (2000). Implicit and explicit memory in autism: Is autism an amnesic disorder. *Journal of Autism and Developmental Disorders, 30*(1), 3–14.

Smith, E. E., Shobe, E. J., & Rips, L. J. (1974). Structure and process in semantic memory: A featural model for semantic decisions. *Psychological Review, 1*, 214–241.

Southwick, J. S., Bigler, E. D., Froehlich, A., DuBray, M. B., Alexander, A. L., Lange, N., & Lainhart, J. E. (2011). Memory functioning in children and adolescents with autism. *Neuropsychology, 25*(6), 702–710.

Stoet, G., & López, B. (2011). Task-switching abilities in children with autism spectrum disorder. *European Journal of Developmental Psychology, 8*(2), 244–260.

Sumiyoshi, C., Kawakubo, Y., Suga, M., Sumiyoshi, T., & Kasai, K. (2011). Impaired ability to organize information in individuals with Autism Spectrum Disorders and their siblings. *Neuroscience Research, 69*, 252–257.

Tager-Flusberg, H. (1985). The conceptual basis for referential word meaning in children with autism. *Child Development, 56*, 1167–1178.

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

Tager-Flusberg, H. (1996). Current theory and research on language and communication in autism. *Journal of Autism and Developmental Disorders, 26*(2), 169–172.

Toichi, M., & Kamio, Y. (2002). Long-term memory and levels-of-processing in autism. *Neuropsychologia, 40*, 964–969.

Toichi, M., & Kamio, Y. (2003). Long-term memory in high-functioning autism: Controversy on episodic memory in autism reconsidered. *Journal of Autism and Developmental Disorders, 33*(2), 151–160.

Toichio, M. (2008). Episodic memory, semantic memory and self-awareness in high-functioning autism. In J. Boucher & D. Bowler (Eds.), *Memory in Autism: Theory and evidence*. Cambridge: Cambridge University Press.

Tulving, E. (1993). What is episodic memory? *Current Directions in Psychological Science, 2*(3), 67–70.

Van Eylen, L., Boets, B., Steyaert, J., Evers, J., Wagemans, J., & Noens, I. (2011). Cognitive flexibility in autism spectrum disorders: Explaining the inconsistencies? *Research in Autism Spectrum Disorders, 5*(4), 1390–1401.

Wickens, D. D. (1970). Encoding category of words: An empirical approach to meaning. *Psychological Review, 77*(1), 1–15.

Wickens, D. D. (1972). Characteristics of word encoding. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory*. Washington, DC: Winston & Sons.

Wickens, D. D. (1973). Some characteristics of word encoding. *Memory & Cognition, 1*(4), 485–490.

Wixted, J. T., & Rohrer, D. (1993). Proactive interference and the dynamics of free recall. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 19*(5), 1024–1039.