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Atypical Lexical/Semantic Processing in High-Functioning Autism Spectrum Disorders without Early Language Delay

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Abstract Although autism is associated with impaired language functions, the nature of semantic processing in high-functioning pervasive developmental disorders (HFPDD) without a history of early language delay has been debated. In this study, we aimed to examine whether the automatic lexical/semantic aspect of language is impaired or intact in these population. Eleven individuals with Asperger's Disorder (AS) or HFPDD-Not Otherwise Specified (NOS) and age-, IQ-, and gender-matched typically developing individuals performed a semantic decision task in four conditions using an indirect priming paradigm. Semantic priming effects were found for near-semantically related word pairs in the controls, whereas this was not the case in the AS or HFPDDNOS participants. This finding suggests similarities in the underlying semantic processing of language across PDD subtypes.

Keywords Asperger's disorder · High-functioning pervasive developmental disorder not otherwise specified · Early language delay · Semantic priming · Phonological priming

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Introduction

Autism is diagnosed by a triad of deficits in social relatedness, communication, and restricted, repetitive, and stereotyped behaviors. Language impairment is one of the symptoms within communication deficits. However, the relationship between language and social impairments still is not clear. Previous research in autism has depicted difficulties across all aspects of language: phonology and prosody, syntax, semantics, and pragmatics (Fein *et al*., 1996; Lord & Paul, 1997; Tager-Flusberg, 1997). In contrast with frank impairments in prosody and pragmatics, the degree of semantic impairment in autism, specifically in high-functioning autism (HFA) does not seem to be unequivocal. Many studies have found that individuals with HFA, some of whom were diagnosed as Asperger's Disorder (AS) or Pervasive Developmental Disorders-Not Otherwise Specified (PDD-NOS), performed similarly to matched typically developing individuals in terms of semantic processing on word fluency tasks (Dunn, Gomes, & Sebastian, 1996), free recall tasks (Mottron, Morasse, & Belleville, 2001; Toichi & Kamio, 2003), cued recall tasks (Bennetto, Pennington, & Rogers, 1996; Mottron *et al*., 2001), and semantic priming tasks (Kamio & Toichi, 2000; Toichi & Kamio, 2001).

Recently a dimensional concept of ''autism spectrum disorders'' (ASD) has been accepted based on clinical observation and research findings (Frith, 2004; Macintosh & Dissanayake, 2004; Schopler, Mesibov, & Kunce, 1998). Autistic Disorder (AD), AS, and PDD-NOS, defined by the DSM system, are considered to be on the autism spectrum. By definition, individuals with AS and PDD-NOS may show milder deficits than AD, since diagnostic criteria for AS requires no language delay, and PDD-NOS is defined as not meeting full criteria for AD. However, comparisons between AD and AS showed no group differences in expressive language abilities in children (Mayes & Calhoun, 2001) or in language comprehension for adults (Howlin, 2003). On the neurocognitive level of language function, the differentiation is still unclear. It has been demonstrated that adults with HFASD were impaired in using semantic context on free recall (Bowler, Matthew, & Gardiner, 1997) and in false memory tasks (Beversdorf *et al*., 2000). In these studies, the presence/absence of early language delay has not been clearly addressed. More specifically, Jolliffe and Baron-Cohen (1999) have found that adults with HFA, and those with AS as well, had less preference for making contextually meaningful connections, known as coherence, unless consciously instructed to do so on the tasks using homograph and ambiguous sentences. Mottron *et al*. (2001) have also indicated that individuals with HFA and AS were impaired in using semantic cues in cued recall similarly. As for PDD-NOS, there is a paucity of research, although the diagnosis is not uncommon in clinical practice (Kurita, 1997; Towbin, 1997; Bishop, 2000); more children are diagnosed with PDD-NOS and AS than AD in the general population (Chakrabarti & Fombonne, 2001). Children with AS and PDD-NOS are also more likely to be higher functioning than children with AD, but demonstrate the same need for clinical intervention.

The present study focuses on individuals who have no history of language delay; all participants are diagnosed with AS or HFPDD-NOS rather than AD and this sample is labeled as the AS-HFPDDNOS in this study. This study adopted a priming paradigm to determine whether individuals with AS-HFPDDNOS without a history of language delay have deficits of automatic lexical/semantic processing. Mottron *et al.* (2001) demonstrated that individuals with HFA and AS benefited more from phonological cues than from semantic cues, although they performed similarly to typically developing individuals on semantic cued recall. An fMRI study provided some evidence that the relatively normal behavioral performance in HFA on a semantic decision task may be dependent on perceptual processing rather than on semantic processing (Gaffrey, Klienhans, Haist, & Müller, 2004).

If deficits of semantic priming are found in individuals with AS-HFPDDNOS, it raises the possibility that the lexical/semantic processing may be a cognitive phenotype that varies dimensionally on the autism spectrum independent of early language development. If not, an absence of language delay may make a qualitative difference in later language functioning, at least on a lexical/semantic level. If evidence of phonological priming is found in these individuals, the possibility of compensatory mechanism for reduced higher processing should be considered.

Method

Participants

Eleven children and adolescents with AS-HFPDD-NOS (eight AS, three PDD-NOS; nine males, two females) ranging in age from 9 years, 0 months to 21 years, 9 months (mean age: 14 years, 3 months) were selected from clinics and schools in Massachusetts and Connecticut. Eleven control participants with typical development (nine males, two females) ranging in age from 9 years, 7 months to 20 years, 0 months (mean age: 14 years, 5 months) were also selected from the local community. Our inclusion criteria was full scale IQ above 70, both chronological and reading age above 9 years of age, and the absence of early language delay, that is, the use of single words by age 2 and communicative phrases by age 3.

Participants with ASD were diagnosed by one experienced child psychiatrist (Y. K.) and one experienced clinical neuropsychologist (D. F.) based on available records and information obtained from semi-structured interviews with the participants and their parents or teachers. The absence/presence of early language delay was confirmed via parental interview or available records. Diagnostic agreement was obtained for all participants. Although DSM-IV-TR (American Psychiatric Association, 2000) hierarchically gives a diagnosis of AD for cases who meet both AD and AS, in this study a diagnosis of AS was given for those who manifested abnormal verbal communication but did not have the early language delay, following Kim, Szatmari, Bryson, Streiner, and Wilson (2000) and Howlin (2003). Those who did not meet DSM-IV-TR criteria of AD or AS were given a diagnosis of PDD-NOS. The 11 AS-HFPDDNOS participants had a mean Childhood Autism Rating Scale (CARS; Schopler, Reichler, & Renner, 1988) total score of 31.6 ± 3.3 and only three of them were below the CARS autism cut-off of 30 and in the high 20's. Two of these participants were adolescents with AS and one was a child with PDDNOS. Previous studies found that CARS scores tend to decrease as children with autism grow into adolescence (Mesibov, Schopler, Schaffer, & Michal, 1989) and that children with AS often obtain subthreshold CARS scores (Kamio, Ishisaka, & Takagi, 1992).

All participants had IQ estimated using a short form of WISC-III or WAIS-III (Sattler, 1988; Minshew, Turner, & Goldstein, 2005), consisting of Information, Vocabulary, Picture Completion, and Block Design; all estimated IQ scores were above 70 (mean full scale IQ = 101.9 ± 9.7, combined verbal scaled scores = 20.9 ± 3.7 for the AS-HFPDDNOS group; mean full scale IQ = 104.7 ± 10.1, combined verbal scaled scores = 22.4 ± 3.4 for the Control group). Participants had reading age measured on the Stanford Diagnostic Reading Test, third edition (SDRT, test 4; full score of 30) to confirm to comprehend written words at 9-year-old level. All of the AS-HFPDDNOS group and six control participants excluding five college students in the control group were confirmed to have reading age above 9 years of age: all scored at ceiling on this test. Thus, the AS-HFPDDNOS group and the Control group were of the same gender ratio and did not differ in chronological age (CA) (t = .052, P = .96, t-test), or IQ on a group basis (t = .843, P = .41, t-test).

Assent was obtained from the minor participant and written informed consent was obtained from a parent or a guardian, or from adult participants. The University of Connecticut's Institutional Review Board approved these procedures.

Materials

The current priming study employed a lexical decision task. Primes were words. As a control prime, the visual display ''++++'' was used because it has no meaning and was similar in length to the word primes. Half of the targets were words and the other half were non-words, produced by changing one or two letters in the corresponding word target; non-words were pronounceable but did not rhyme with the preceding prime. All words were of one or two syllables, three to seven letters long (mean length = 4.6), and had a frequency of occurrence with Standard Frequency Index (SFI) value >35 (Zeno, Ivens, Millard, & Duuvvuri, 1995). The words mainly consisted of nouns but also included a few adjectives, verbs, and prepositions. The relatedness of prime-target pairs was varied. Semantically related pairs consisted of within-category coordinate words (e.g., truck-car), because priming effects have been shown to be robust with these stimuli. To confirm the semantic relatedness of the pairs, ratings were obtained by 25 graduate students in the psychology department. Raters were presented with 50 sets of a target and two prime words together, with the instruction to judge to what extent each prime was related to the target using a 5-point rating scale (1 = not at all related to, 5 = very closely related to). For example, the relatedness between ''worm (prime)'' and ''nest (target)'' was rated on average as 1.76 and the relatedness of ''bird (prime)'' and ''nest (target)'' was 4.58. As a result, ''worm'' was defined as semantically far-related and ''bird'' as semantically near-related for ''nest.'' 35 of 50 sets with a target and two primes were retained for the study, only when the ratings for near-related pairs were above 3.5 (M = 3.92) and those for far-related pairs were in the range of 1.5–3.5 (M = 2.58). Phonologically related primes were created to rhyme with the corresponding targets without sharing the same graphemes. The 35 sets are shown in Appendix . Each test set was constructed with five far semantic, five near semantic, five phonological, five control (++++) primes and their paired target words, and 20 primes and non-word targets. Prime words were randomly assigned from the 35 sets, and assignment to word/non-word targets was counterbalanced across participants. The order of presentation was randomized for each participant.

A pilot study was conducted with 30 undergraduate students (16 males and 14 females) using these stimulus sets. The mean response time (RT) was 771.6 ± 168.3 ms for far semantic, 702.7 ± 143.6 ms for near semantic, 772.5 ± 184.4 ms for phonological, and 767.6 ± 187.6 ms for control pairs. The RTs for near semantic pairs were significantly shorter than those for far semantic, phonological, and control pairs (P < .01; P < .01; P < .01, respectively, Wilcoxon signed rank test). Except near semantic pairs, the RTs were not significantly different from the control pairs. No facilitation was observed for non-word targets. The mean error rate was 2.95 ± 2.54 (%). Thus, robust semantic priming effects were observed only for near semantic word pairs in a sample of college students.

Procedure

Stimulus presentation and data collection utilized Multi-Stim for Windows, Version 2.65. As shown in Fig. 1, a fixation point appeared in the center of a screen for 500 ms, followed by a prime for 250 ms, then a target was presented for 4,000 ms. A prime-target interval of 250 ms was chosen for the purpose of investigating automatic semantic processing based on prior studies (De Groot, 1984; Mummery, Shallice, & Price, 1999; Neely, 1977; Posner & Snyder, 1975). Participants were told that they would see pairs of letter strings serially and instructed to read both letter strings but to respond only for the target. In response

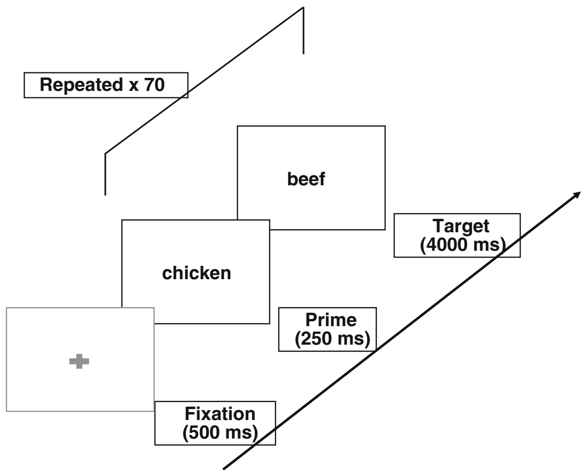

Fig. 1 Experimental set-up

to the target, participants had to decide whether it was a word or non-word and to answer by pressing a mouse as accurately and quickly as possible. This study was conducted as a part of a more comprehensive research project.

Results

Table 1 shows mean RTs, error rates and priming effects for each condition by group.

Error analyses

Total error rate data were skewed rightwardly and not normally distributed in both the AS-HFPDDNOS and the Control group (Kolomogorov–Smirnov test). Between-group comparison found no significant difference in total error rates (U = 49.5, P = .42, Mann–Whitney's test). Error rates did not differ significantly by type of relatedness condition in both the AS-HFPDDNOS and the Control group (χ^2 = 3.74, P = .38, χ^2 = 3.10, P = .38, respectively, Friedman's test). Thus, it seems that the speed-accuracy trade-off worked similarly for both groups, and consequently the priming effects observed may reflect the automatic lexical/semantic processing.

Priming Effects

The RT data of the AS-HFPDDNOS group were rightwardly skewed and not normally distributed, whereas those of the Control group were normally distributed (Kolomogorov–Smirnov test). All the RT data for both groups were included in the subsequent analyses because there were no outliers greater than two standard deviations from the mean RT in each condition for each participant. A priming effect, an index of facilitation by a related prime, was computed by subtracting the RTs to related word pairs (far semantic, near semantic, phonological) from the RTs to control pairs. Before collapsing data of all the participants with ASD, the RTs and error rates of AS participants (n = 8) were compared with those of PDD-NOS participants (n = 3). No significant differences were detected between groups (Mann–Whitney's test). Therefore, the data were collapsed as a single AS-HFPDDNOS group for the analyses.

The Control Group

The RTs to near semantic pairs were significantly shorter than RTs to control pairs (t = –2.46, P < .05, t-test), whereas the RTs to far semantic and phonological pairs were not significantly different from RTs to control pairs, indicating that the identification of semantically near-related words facilitates the subsequent lexical/semantic access. The RTs to near semantic pairs were shorter than those to far semantic and phonological pairs (t = –2.46, P < .05; t = –3.55, P < .01, t-test). Taken together with the findings of error analyses, priming effects were found only for near semantic pairs at no cost of accuracy on this task in the Control group (see Table 1).

A correlational analysis revealed that semantic priming effects for near semantic pairs were not correlated with CA, although RTs in all conditions except far semantic pairs were significantly negatively correlated with CA (Spearman's γ = –.904, P < .0001, γ = –.854, P = .001, γ = –.826, P < .005 for near semantic, phonological, and control pairs, respectively). There were no correlations between IQ and priming effects or RTs.

The AS-HFPDDNOS Group

Non-parametric statistics were used due to skewness. The RTs to far semantic, near semantic, and phonological pairs did not differ significantly from those to control pairs, indicating no priming effects in any condition (Z = –1.07, Z = –.36, Z = –1.16, respectively, Wilcoxon signed rank test). Thus, the AS-HFPDD-NOS participants performed a lexical decision task with accuracy to the similar degree as the Control participants, without being primed semantically or phonologically. A correlational analysis revealed that

Table 1 Mean Reaction Times, Error Rates, and Priming Effects by Group

	AS-HFPDDNOS (N = 11)			Control (N = 11)		
	Mean RT (SD) (ms)	Mean % error	Mean priming effect (SD) (ms)	Mean RT (SD) (ms)	Mean % error	Mean priming effect (SD) (ms)
Far semantic	1,182.8 (338.1)	12.7	41.5 (172.9)	1,005.2 (331.8)[b]	5.5	17.0 (249.3)
Near semantic	1,194.6 (438.4)	10.9	29.7 (221.3)	845.9 (193.0)[a–c]	12.7	176.2 (237.6)
Phonological	1,171.0 (362.9)	20.0	53.2 (160.5)	1,040.4 (290.0)[c]	18.2	-18.2 (267.8)
Control	1,224.2 (309.3)	7.3		1,022.2 (389.9)[a]	7.3	
Total		12.7			10.9	

[a] Near semantic < control (t = –2.46, P < .05, t-test)

[b] Near semantic < far semantic (t = –2.46, P < .05, t-test)

[c] Near semantic < phonological (t = –3.55, P < .01, t-test)

neither CA nor IQ was correlated with RTs in any condition (see Table 1).

Comparison of the RTs between the AS-HFPDDNOS and the Control Group

The RTs in each condition did not differ significantly between groups (U = 40.0, P = .18, U = 48.0, P = .41, U = 60.0, P = .97, U = 45.0, P = .31, for far semantic, near semantic, phonological, and control pairs, respectively, Mann–Whitney's test). Thus, lexical access per se was not slow in the AS-HFPDDNOS group compared to the Control group in any condition.

Discussion

The present study is preliminary due to a small sample, but to our knowledge, the first one to address automatic lexical/semantic abnormalities in individuals with HFASD without a history of early language delay. We found that highly verbal individuals with AS and HFPDDNOS were not susceptible to semantic priming effects that occurred in controls during a lexical decision-making task. That is, lexical/semantic processing was automatically facilitated when a target word was preceded by a closely semantically related word in controls, whereas this was not the case for the individuals with AS-HFPDDNOS. On the other hand, phonological priming effects were not found either in the controls or individuals with HFASD. Interestingly, despite lack of semantic priming effects, individuals with AS-HFPDDNOS were able to perform on the task similarly to the controls.

Our findings suggest that individuals with AS-HFPDDNOS have a similar deficiency in the automatic semantic processing to that which has been repeatedly reported in HFA (Dunn *et al*., 1996; Jolliffe & Baron-Cohen, 1999; Kamio & Toichi, 2000; Mottron *et al*., 2001; Toichi & Kamio, 2001), although no studies used the same paradigm as this study. Three children with HFA, who were not included in this study due to a history of language delay, performed similarly to those with AS-HFPDDNOS in part: they showed no semantic priming and one showed phonological priming. Similarities between AS and HFA have been previously reported in terms of failure to use semantic information to aid free recall (Bowler *et al*., 1997), to produce false memory (Beversdorf *et al*., 2000), to use semantic cues in cued recall (Mottron *et al*., 2001), and to connect contextual information (Jolliffe & Baron-Cohen, 1999). If the atypical automatic semantic processing found in this study is shared by individuals with HFASD independently of a history of language delay, it may account for difficulties in complex contextual understanding in verbal individuals on the autism spectrum, which may prevent them from understanding humor, irony, and metaphor in everyday communication (Happé, 1993).

Lack of phonological priming effects in AS-HFPDDNOS in this study do not support the enhanced phonological processing hypothesis (Mottron *et al*., 2001; Mottron & Burack, 2001). In Mottron *et al*.'s study (2001), individuals with HFA and AS benefited more from phonological cues and less from semantic cues on a cued recall task, compared to typically developing individuals. According to Mottron and Burack (2001), enhanced low-level perceptual functioning (such as phonological processing) may be a compensatory mechanism addressing defective higher-order processes (such as semantic processing), which accounts for echolalia and good performance on various perceptual tasks such as visual search in individuals with autism. A possible explanation why phonological priming was not observed in our study may be that the task demand was semantic and this might have inhibited phonological processing. An fMRI study during a semantic decision task demonstrated that activation was increased in visual areas and reduced in prefrontal areas in individuals with HFA (Gaffrey *et al*., 2004). This finding suggests the possibility that the task in our study might lead to enhanced visual processing rather than phonological processing. The relationship between semantic and perceptual processing needs to be explored longitudinally as well as cross-sectionally in individuals on the autism spectrum in order to explore the pathogenic role of possible compensatory mechanism.

These findings that the absence of early language delay in HFASD may not ensure intact lexical/semantic processing in later years seem to converge with clinical findings indicating that the absence of early language delay does not make difference in expressive language abilities (Mayers & Calhoun, 2001) or receptive language abilities in later years (Howlin, 2003).

There are several methodological limitations to our study. First, a prime-target interval of 250 ms may be optimal for individuals with typical development, but whether this is the case for those with HFASD has not been systematically studied so far. In this study, we tried to confirm that participants were able to read the target words, but we did not use an objective measure. Because we did not examine word priming at different intervals in the AS-HFPDDNOS sample, we cannot generalize the conclusion that individuals with AS-HFPDDNOS were not primed in contrast with the controls; it remains an open question whether priming effects would be evident under longer prime exposure. Second, we analyzed the data of AS and PDD-NOS together, although the equality of AS and PDD-NOS was not fully confirmed due to a small number of participants included in each subgroup (eight AS and three PDD-NOS). Replication with a larger sample size is needed.

Additional questions for future research are to examine the commonality of atypical automatic lexical/semantic processing across subtypes on the autism spectrum (with and without a history of language delay), and to explore semantic development and its relationship to the social development in verbally able individuals with ASD.

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Appendix

Prime				Target	
Far Semantic	Close Semantic	Phonological	Control	Word	Non-word
Worm	Bird	Guest	++++	Nest	Nust
Bike	Ship	Vote	++++	Boat	Soat
Water	Butter	Red	++++	Bread	Breat
Lip	Eye	Peer	++++	Ear	Ean
Ball	Balloon	Night	++++	Kite	Kife
Ants	Slug	Tale	++++	Snail	Snil
Boy	Woman	Curl	++++	Girl	Girp
Bed	Table	Dare	++++	Chair	Chail
Gloves	Socks	News	++++	Shoes	Shobs
Sled	Raft	Through	++++	Canoe	Canod
Train	Truck	Are	++++	Car	Sar
Tree	Flower	Awesome	++++	Blossom	Blossom
Lamp	Switch	Site	++++	Light	Dight
Dog	Sheep	Wrote	++++	Goat	Goot
Pencil	Book	Weeding	++++	Reading	Greading
Coin	Medal	Rolled	++++	Gold	Dold
House	Rug	Puppet	++++	Carpet	Marpet
Bone	Skull	Mane	++++	Brain	Prain
Lemon	Potato	Mourn	++++	Corn	Dorn
Rod	Flag	Roll	++++	Pole	Pote
Thread	String	Soap	++++	Rope	Wope
Pizza	Cookie	Ache	++++	Cake	Dake
Fruit	Candy	Beat	++++	Sweet	Sweem
Crab	Shark	Mail	++++	Whale	Whame
Egg	Chicken	Leaf	++++	Beef	Beff
Cat	Donkey	Panel	++++	Camel	Camet
Eagle	Duck	Juice	++++	Goose	Gonse
Glass	Fork	Tune	++++	Spoon	Spoot
Hat	Dress	Hurt	++++	Shirt	Skirl
Mirror	Brush	Home	++++	Comb	Camb
Cloth	Mop	Tomb	++++	Broom	Broon
Grapes	Apple	Care	++++	Pear	Peam
Saw	Hammer	Male	++++	Nail	Nait
Tape	Stapler	Wizards	++++	Scissors	Scossors

Examples of sets consisting of primes and targets

There are four kinds of primes: far semantic, close semantic, phonological, and control primes

Targets consist of words and non-words

Participants saw five far semantic prime-target word pairs, five far semantic prime-target non-words pairs, five near semantic prime-target word pairs, five near semantic prime-target non-word pairs, five phonological prime-target word pairs, five phonological prime-target non-word pairs, five control prime-target word pairs, and five control prime-target non-word pairs

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