Do Individuals with Autism Process Categories Differently?

The Role of Typicality

by

Holly Zajac Gastgeb

B.S. in Neuroscience & Psychology, Allegheny College, 1999

Submitted to the Graduate Faculty of

Arts and Sciences in partial fulfillment

of the requirements for the degree of

Master of Science in Clinical Developmental Psychology

University of Pittsburgh

2005

UNIVERSITY OF PITTSBURGH

FACULTY OF ARTS AND SCIENCES

This thesis was presented

by

Holly Zajac Gastgeb

It was defended on

October, 7, 2005

and approved by

Mark S. Strauss, Ph.D., Associate Professor

Susan B. Campbell, Ph.D., Associate Professor

Jana M. Iverson, Ph.D. Assistant Professor

Thesis Advisor: Mark S. Strauss, Ph.D., Associate Professor

Do Individuals with Autism Process Categories Differently?

The Role of Typicality

Holly Zajac Gastgeb, M. S.

University of Pittsburgh, 2005

Abstract

A critical cognitive ability that has received relatively little attention in individuals with autism is the ability to form categories. Previous studies of categorization in individuals with autism have found mixed results, some indicating that these individuals have a deficit in categorization and others suggesting that they do not. These studies are limited, however, because they have not closely investigated the role that typicality or task complexity may have on categorization. The current study addresses these issues by examining the effect of exemplar typicality on both the reaction times and accuracy of categorizing basic level exemplars. High-functioning children, teens, and adults with autism and matched controls were tested in a category verification procedure. Results indicate that the processing and accuracy of categorization improves throughout the lifespan for typical and somewhat typical category exemplars, but that processing differences are found throughout the lifespan with respect to atypical or poor category exemplars. The results are discussed in relation to potential differences in the type of processing that may be required for categorizing typical and atypical category members. Parallels are also drawn between the results of the current studies and the results of previous studies on face processing in individuals with autism.

TABLE OF CONTENTS

1.0 INTRODUCTION 1
1.1 CATEGORIZATION IN TYPICAL POPULATIONS 2
1.2 CATEGORIZATION IN ATYPICAL POPULATIONS 5
1.3 AIMS OF CURRENT STUDIES 10
2.0 EXPERIMENT 1: ROLE OF TYPICALITY IN CHILDREN'S OBJECT CATEGORIZATION 11
2.1 METHOD 11
2.1.1 Participants 11
2.1.2 Apparatus 13
2.1.3 Stimulus Materials 14
2.1.3.1 Visual Stimuli 14
2.1.3.2 Auditory Stimuli 16
2.1.4 Procedure 17
2.2 RESULTS 18
2.2.1 Preliminary Analyses 18
2.2.2 Reaction Time Results 19
2.2.3 Accuracy Results 23
2.3 DISCUSSION 24
3.0 EXPERIMENT 2: ROLE OF TYPICALITY IN TEENS' OBJECT CATEGORIZATION 25
3.1 METHOD 25
3.1.1 Participants 25
3.1.2 Apparatus, Stimulus Materials, and Procedure 26
3.2 RESULTS 26

3.2.1 Reaction Time Results **26**
3.2.2 Accuracy Results **29**
3.3 DISCUSSION **30**
4.0 EXPERIMENT 3: ROLE OF TYPICALITY IN ADULTS' OBJECT CATEGORIZATION **32**
4.1 METHOD **32**
4.1.1 Participants **32**
4.1.2 Apparatus, Stimulus Materials, and Procedures **33**
4.2 RESULTS **33**
4.2.1 Reaction Time Results **33**
4.2.2 Accuracy Results **36**
4.3 DISCUSSION **37**
5.0 GENERAL DISCUSSION **38**
REFERENCES **50**

LIST OF TABLES

Table 1. Sociodemographic Characteristics of Autism and Control Groups for Experiment 1 ... 13
Table 2. Typicality Ratings for Included Category Exemplars (Means and Standard Deviations) ... 15
Table 3. Children's Mean Accuracy Scores (% Correct) for "Combined Category" Data (Standard Deviations in Parentheses) ... 23
Table 4. Sociodemographic Characteristics of Autism and Control Groups for Experiment 2 ... 25
Table 5. Teens' Mean Accuracy Scores (% Correct) for "Combined Category" Data (Standard Deviations in Parentheses) ... 30
Table 6. Sociodemographic Characteristics of Autism and Control Groups for Experiment 3 ... 32
Table 7. Adults' Mean Accuracy Scores (% Correct) for "Combined Category" Data (Standard Deviations in Parentheses) ... 37

LIST OF FIGURES

Figure 1. Stimulus Examples 16

Figure 2. Child Reaction Times for the “Combined Category” Data by Typicality..................... 19

Figure 3. Child Percent Change in Reaction Time for the “Combined Category” Data by Typicality 21

Figure 4. Child Percent Change in Reaction Time by Category for Somewhat Typical Stimuli . 22

Figure 5. Child Percent Change in Reaction Time by Category for Atypical Stimuli 22

Figure 6. Teen Reaction Times for “Combined Category” Data by Typicality 27

Figure 7. Teen Percent Change in Reaction Time for “Combined Category” Data by Typicality28

Figure 8. Teen Percent Change in Reaction Time by Category for Atypical Stimuli 29

Figure 9. Adult Reaction Times for the “Combined Category” Data by Typicality 34

Figure 10. Adult Percent Change in Reaction Time for “Combined Category” Data by Typicality 35

Figure 11. Adult Percent Change in Reaction Time by Category for Atypical Stimuli 36

1.0 INTRODUCTION

Autism, a pervasive developmental disorder with onset before age three, has been the subject of much research over the past few years due to the alarming rise in its prevalence rates world-wide (Fombonne, 1999). According to DSM-IV, a diagnosis of autism requires qualitative impairment in social interaction and communication, restricted repetitive stereotyped patterns of behavior, interests, and activities, and language delays (American Psychiatric Association, 2000). To date, most research on autism has focused on the social deficits that are present in individuals with autism, because these deficits seem to be the most profound and noticeable. More recently, researchers have suggested that individuals with autism may also have significant cognitive deficits (Frith & Happe, 1994). At issue is the nature of these cognitive deficits and the extent to which they may underlie the better documented social deficits and the autism syndrome in general.

The three main cognitive theories in the field include executive functioning (Ozonoff, 1997; Rumsey, 1985), weak central coherence (Frith & Happe, 1994), and attentional theories (Bara, Bucciarelli, & Colle, 2001; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2001). While these theories have been able to explain some aspects of the autistic syndrome, no cognitive theory to date has been successful in explaining all of the core symptoms of autism and the entire range of abilities present in these individuals.

One critical cognitive ability, the ability to categorize, has received relatively little attention in individuals with autism despite the importance of this ability for both typically developing children and adults. Categorization skills are very important for children to develop early in life. As is often quoted from William James (1890), infants are born into a world of "great blooming, buzzing confusion" (p. 420). As a result, it is critical that they soon be able to categorize and organize the world. Ultimately, categorization allows infants to reduce memory demands and focus their attention to important aspects of objects and ignore irrelevant details. If individuals with autism differ in their abilities to categorize early in life, it is possible that such core cognitive differences could underlie some of the social, communication, and behavioral deficits that are core features of the autism syndrome. A child who is unable to organize and make sense of his or her world could become overstimulated and withdraw from others, not understand what others are trying to communicate to them, and engage in repetitive behaviors to impose a sense of control and order in a confusing world.

1.1 CATEGORIZATION IN TYPICAL POPULATIONS

Generally, categorization is the ability to recognize that discriminably different objects have common features that allow them to be grouped together. This grouping of objects allows us to organize the world and our experiences and also decreases demands on our memories. Categorization can be thought of as, "a mental process that allows individuals to integrate new information with previous experiences" and typically involves "abstraction of information during learning" (Klinger & Dawson, 1995, p. 119). Grouping items into common categories also allows individuals to generalize information from one situation to another. The ability to form categories is one of the most basic cognitive abilities; indeed, it is so basic that studies demonstrate that within the first year of life infants begin to form categories (Lewis & Strauss, 1986; Rakison & Polin-Dubois, 2001).

Considering the importance that categorization has on the way in which we learn to organize and understand our world, it is not surprising that there is much research on how we form and use categories. Classical theories of categorization implied that all categories can be defined by using a few necessary and criterial features, but this research was typically conducted using simple, artificial categories such as colored shapes (Bruner, Goodnow, & Austin, 1956). Rosch and her colleagues (Rosch 1975, Rosch 1978), in addition to other researchers, have discovered that categorization of objects that belong to more natural categories such as “dogs” cannot be explained by these classical theories, because there are no simple criterial features that define “dogness”. Classical theories have also assumed that category boundaries are definitive and clear, but research has found that these boundaries are actually “fuzzy” (Rosch, 1975; Rosch 1978). Lastly, classical theorists thought that all exemplars in a given category have equal probability of membership and equal weighting in regard to how easy they are to categorize and remember (Bruner, Goodnow, & Austin, 1956). Rosch (1975, 1978), however, found that knowledge of basic level categories such as dogs has a “typicality structure” in which some of the members are considered to be more representative or “better examples” of that category, and other members are less representative or “worse examples” and therefore less “typical”. Individuals tend to agree on which members of a category are the most and least typical, and in verification tasks, reaction times to verify or identify typical members of a category are faster than reaction times to identify less typical members of a category (Rosch, 1978). For example, for the category bird, individuals are quicker to identify or verify that a robin is a member of the category bird than a penguin. This reaction time difference reflects the nature of how items are stored in memory, that typical exemplars of a category are easier to retrieve than less typical exemplars.

In addition, adults and children have been found to learn the names of more typical members of a novel category more quickly than the names of less typical members (Heider, 1972), and children tend to learn the names of more typical members of established categories before less typical members (Barrett, 1995; Nelson, 1974). Typicality effects seem to be present from infancy in that 18 and 24 month-old infants looked significantly longer at more typical items than less typical items (Southgate & Meints, 2000). Infants were also able to categorize more typical exemplars before they categorized less typical exemplars in an object manipulation task (Bauer, Dow, & Hertsgaard, 1995). Additional evidence for the typicality effect exists in studies of prototype formation in infants. When infants were presented with a set of faces which varied in the distance between the features, they considered unseen faces that were representative of the mean values of the presented features to be more familiar than faces that they had actually seen during the study (Strauss, 1979; Younger, 1990; de Haan, Johnson, Maurer, & Perrett, 2001).

The typicality effect is also reflected in event-related potential studies which have found that at Pz and Cz, the P300 peak amplitude was greater for more typical then less typical exemplars in children, latency-to-peak was shorter to more typical than less typical exemplars in adults, and typical exemplars were categorized faster and more accurately than less typical exemplars (Ellis & Nelson, 1999; Fujihara, Nagaeishi, Koyama, & Nakajima, 1998). This type of organization of exemplars by typicality allows individuals to reduce their memory load, instill organization to their world, and simplify the complex environment within which they must interact.

1.2 CATEGORIZATION IN ATYPICAL POPULATIONS

While a plethora of research has been performed on concept formation and categorization in adults and typically developing children, there is very little research on this topic in individuals with autism. An individual lacking the ability to categorize would see each new instance or situation as unique and as a result might be overwhelmed by the complexity of the world in which he/she must interact, be unable to make decisions or inferences based on past experience, and have difficulty generalizing information across situations (Klinger & Dawson, 1995).

It has been suggested that individuals with autism may exhibit deficits in the area of concept and category formation or abstraction. A cognitive deficit in abstract reasoning has been considered to be one of the fundamental impairments documented across the entire pervasive developmental disorder spectrum. Noach (1974) was one of the first to examine conceptual abilities in individuals with autism and stated that, "Their overall intellectual functioning, their perception, and their language, in particular, seem to reflect a disturbance in the capacity for concept formation" (p. 100). Rutter (1978) discovered that as general cognitive ability decreased, abstraction abilities also decreased. The inability to form concepts based on experience, however, is also thought to be a problem in higher-functioning individuals with autism (Tsai, 1992).

The results of studies conducted to determine whether a deficit in category formation is present in individuals with autism have been mixed. Many early studies concluded that individuals with autism are able to form concepts and can categorize new objects based on these concepts. These studies, however, involved categorization based on simple definitive features such as color or size and did not examine whether individuals with autism *process* category information in the same manner as typically developing individuals, especially when the categories are more complex and have fuzzy boundaries such as natural categories (Baron-Cohen, 1991; Tager-Flusberg, 1985a; Tager-Flusberg, 1985b; Ungerer & Sigman, 1987). It is possible that, while individuals with autism can successfully categorize on the basis of simple definitive features, they may form categories in a different manner or may have difficulty categorizing when categorization is based on more complex, less perceptual, or abstract rules or features (Klinger & Dawson, 1995; Plaisted, 2000; Minshew, Goldstein, Muenz, & Payton, 1992; Shulman, Yirmiya, & Greenbaum, 1995). Another possible explanation for the mixed findings is that studies of categorization have failed to control for the typicality of the stimuli. It is possible that individuals with autism may be able to categorize typical exemplars of a category more successfully than atypical exemplars and may be using different processes to categorize typical and atypical exemplars. If this is the case, studies using more typical exemplars of a category may not indicate any differences in categorization in these individuals while studies using more atypical exemplars may show a categorization deficit.

Several studies support this notion that individuals with autism can and do form categories, but they do so in a way that is different from typically developing individuals. A few studies have provided evidence that individuals with autism do not group words into categories in order to aid in memorization (Hermelin & O'Connor, 1970; Minshew, Goldstein, Muenz, &

Payton, 1992). Hermelin and O'Connor (1970) compared children with autism to those showing typical development and delayed development and found that children with autism did not memorize words by grouping them into conceptual categories relative to children with typical or delayed development. Minshew, Goldstein, Muenz, and Payton (1992) found that individuals with autism, unlike typically developing individuals, did not use categorical information as a strategy to improve memory on the California Verbal Learning Test. In both of these studies, the individuals with autism were able to remember as many items as controls, suggesting that they did not have an impairment in rote-memory, but were not using organizing strategies of categorization to improve their memories.

Minshew, Meyer, and Goldstein (2002) conducted a study that examined the performance of high-functioning individuals with autism, compared to controls, on concept identification versus concept formation tasks. These tasks differ in that, in concept identification tasks, the concepts are not formed by the person but are inherent in the test materials. In contrast, in concept formation tasks the concepts have to be self-generated, and the person is required to generate the rules in order to group the stimuli. The researchers found that high-functioning individuals with autism had a deficit only in concept formation and that this deficit resulted in cognitive inflexibility and the inability to spontaneously form ways in which to organize information. These results support the notion that individuals with autism process and group information in a rule-based manner and are deficient when the task requires that concepts be abstracted from complex information.

One published study (Klinger & Dawson, 2001) and two unpublished studies (Plaisted, 2000) have also suggested that individuals with autism are unable to abstract a prototype or average representation of the features of a category. Klinger and Dawson (2001) compared low-functioning children with autism, children with Down's syndrome, and typically developing children's abilities to use rule-based and prototype category learning. They found that all groups were able to categorize using a rule-based strategy when the rule was explicitly stated and when the rule was implicit, but neither the autism nor Down's syndrome children were able to abstract a prototype of simple animal-like categories during category learning. Additionally, individuals with autism and Down's syndrome were able to categorize the animal-like exemplars only when there was a single distinctive feature present such as "long feet". Typically developing children, however, did not exhibit any problems in abstracting a prototype. Plaisted (2000) discussed two unpublished studies that indicate that high-functioning adults and children with autism matched with controls on general cognitive level were also unable to form prototypes. As a result, the inability to form prototypes in the Klinger and Dawson (2001) study probably cannot be explained by mental retardation or general level of cognitive functioning. This inability to abstract prototypes in individuals with autism is surprising due to the fact that studies on prototype formation in children have established that infants are able to abstract prototypes at 10 months of age (Strauss, 1979; Younger, 1986, 1990). These results indicate that individuals with autism may engage in different categorization processes than typically developing individuals and that these differences may be very basic and early developing (Klinger & Dawson, 1995; Strauss, Newell, & Best, 2003).

A study conducted by Plaisted, O'Riordan, and Baron-Cohen (1998) provides additional evidence that suggests that individuals with autism categorize and form concepts in a manner that is different from typically developing individuals. In this study, control adults were better able to discriminate familiar stimuli than novel stimuli. High-functioning adults with autism, however, were not better at discriminating familiar than novel stimuli. The authors suggested that high-functioning adults with autism process features that are common between objects poorly and, therefore, process features that are unique to an object well. If features in common between objects are processed poorly, categorization would be affected, because categorization involves the ability to determine what aspects of exemplars are common. If individuals with autism are unable to determine the commonality among items, they also may be unable to determine the commonality among situations. This could lead to an inability to use information about prior instances to inform new situations resulting in a world that is confusing and overwhelming. Poor ability to process features common to stimuli in conjunction with the ability to process features unique to a stimulus well supports the idea of the existence of different categorization processes in individuals with autism.

One possibility that has yet to be explored concerns the nature of the storage of the underlying category information that individuals with autism have about the real world. If individuals with autism focus on how objects are unique and are less able to detect the commonality that exists among exemplars of a given category, this may affect the way in which they categorize. It is also possible that typicality may play a role in processing differences in individuals with autism. For example, it is possible that individuals with autism will be able to categorize typical category members efficiently and accurately using simple definitive features, but will have difficulty categorizing less typical category members which require a different, more complex processing strategy.

1.3 AIMS OF CURRENT STUDIES

The aim of Experiment 1 was to determine the role that typicality plays in the categorization processes and abilities of non-mentally retarded children with autism using a basic level object category verification task. High-functioning children were chosen for this study, because it allows one to examine impairments that are specifically associated with autism rather then with mental retardation (Minshew, Goldstein, & Siegel, 1997). Children with autism who are not mentally retarded have all of the clinical features and developmental history of autism (Kanner, Rodriguez, & Ashenden, 1972) along with many of the other characteristic neuropathological, imaging and family history findings (Bauman & Kemper, 1994; Piven, Arndt, Bailey, & Andreasen, 1996; Piven, Palmer, Jacobi, Childress, & Arndt, 1997) without the confound of mental retardation. Basic level object categories were chosen to study, because the basic level is the level at which category members are most perceptually related to one another and perceptually unrelated to members of other basic categories (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). A category verification task was used to measure reaction times and accuracy to members of four different categories varying in typicality. If children with autism process categories differently than typically developing children, differences should emerge in the reaction time results. Children with autism may also be less accurate than typically developing children, particularly on the more atypical examples. Experiment 2 addressed similar questions with teens and Experiment 3 with adults.

2.0 EXPERIMENT 1: ROLE OF TYPICALITY IN CHILDREN'S OBJECT CATEGORIZATION

2.1 METHOD

2.1.1 Participants

Participants consisted of 34 high-functioning children with autism (age 8-12) and 26 healthy child control individuals (age 8-12). Control subjects were recruited through posters, advertisements in local newspapers, radio advertisements, and community television announcements. Individuals with autism were recruited through fliers at autism meetings, advertisements in autism newsletters, and posters in clinics serving individuals with autism.

In order to participate, all individuals were required to have full scale and verbal IQs greater than 80 as determined by the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). To be eligible to participate, individuals with autism had to meet DSM-IV criteria (American Psychiatric Association, 2000) for autism on the basis of the Autism Diagnostic Interview-Revised (ADI-R - Lord, Rutter, & Le Couteur, 1994) and the Autism Diagnostic Observation Schedule (ADOS - Lord, Rutter, Goode, Heemsbergen, Jordan, Mawhood, & Schopler, 1989) with confirmation by expert clinical opinion. The ADI-R's and ADOS-G's were administered by two individuals without consultation, allowing for independent diagnostic assessment. The staff administering the ADI-R's and ADOS-G's had extensive clinical experience with autism, and completed a training course with certification of reliability. All ADI-Rs were audiotaped and all ADOS-G's videotaped. Reliability was maintained at kappa .80 or higher. Eligible participants with autism were also free of seizure disorder and major depression at the time of the study and had a clinically significant delay in language (exclusion of those with PDD and Aspergers disorder).

For control participants to be eligible, they had to be free of past and current neurologic and/or psychiatric disorders on the basis of a semi-structured interview (SCID-I - First, Gibbon, Spitzer, & Williams, 1996). The control individuals were also required to have a negative family history in first degree relatives of affective and anxiety disorder or other major psychiatric disorder based on the Family History Screen (Weissman, Wickramaratne, Adams, et al., 2000) and a negative family history in first and second degree relatives of autism or other PDD. The exclusion of controls with a history in first degree relatives of affective or anxiety disorder and/or a history of autism in first and second degree relatives was aimed at excluding those with potential autism susceptibility genes. Control participants were also excluded if they had a history of significant difficulty during pregnancy, labor, delivery, or the immediate neonatal period or abnormal developmental milestones. Other exclusion criteria for control participants included a history of school attendance and grades inconsistent with ability level, evidence of a disparity between general level of ability and academic achievement, and a history of a loss of consciousness.

Control subjects were matched with the autism group (same mean with equal variances) on age and full scale IQ. Table 1 summarizes the participants' sociodemographic characteristics. As seen, no significant differences were found between the two groups on FSIQ.

Table 1. Sociodemographic Characteristics of Autism and Control Groups for Experiment 1

	Autism Group (N = 34)			Control Group (N = 26)		
	Mean	SD	Range	Mean	SD	Range
Age	9.91	1.38	8-12	10.85	1.19	8-12
FSIQ	105.56	10.14	85-128	108.88	10.25	89-131

Note: Age is indicated in years. SD = standard deviation; FSIQ = Full scale IQ

2.1.2 Apparatus

Participants were tested in a quiet experimental room. Each participant was seated in front of a 17-in. monitor controlled by a Dell PC computer and responded using a modified keyboard. In order to make the response keys easy to press, a keyboard with large keys (approximately one inch squares) that is commercially available for young children was used to record participants’ responses. All keys were covered by back felt except for the two response keys. These keys were labeled “true” and “false”. The position (left/right) of the “true” and “false” labels was counterbalanced across participants.

2.1.3 Stimulus Materials

2.1.3.1 Visual Stimuli

The category verification task consisted of color pictures of exemplars from four basic level object categories. The categories consisted of two natural, animate categories (cats and dogs) and two artificial, inanimate categories (couches and chairs). These categories were chosen in an attempt to include objects with which all participants would have significant experience and that could be considered to be contrasting categories. Each category was composed of 24 members and these members varied along a dimension of typicality (typical, somewhat typical, and atypical) as judged by adult ratings.

Typicality of the included object exemplars was determined through a pilot study with 100 college students. The students were shown 50 pictures from each object category on a computer monitor and asked to rate each object on a seven point typicality scale where 1 was the least typical and 7 was the most typical. The students were given the following instructions to orient them to the typicality scale, "If you think about birds, there are many different kinds of birds. Some birds like robins are really good examples of birds, because they look like what you think a bird should look like. On the other hand, a penguin is a bad example of a bird, because it does not look like other birds. Your job is to decide how good of an example other objects are on a scale from 1-7 with 1 being a really bad example like a penguin and 7 being a really good example like a robin." The students were presented with each category separately and the order was counterbalanced across participants.

Table 2. Typicality Ratings for Included Category Exemplars (Means and Standard Deviations)

	Couches	Chairs	Cats	Dogs
Atypical				
Mean	2.74	2.42	2.60	2.26
s.d.	.69	.65	1.01	.63
Somewhat Typical				
Mean	5.04	4.37	4.30	4.09
s.d.	.44	.51	.18	.44
Typical				
Mean	6.29	5.91	5.37	5.77
s.d.	.25	.53	.50	.65

Table 2 summarizes the mean ratings and standard deviations for the exemplars included in this experiment. Within each category, the eight most typical, eight average typical and eight least typical exemplars were chosen, resulting in 24 exemplars for each object category and a total of 96 exemplars in the entire experiment. Figure 1 illustrates an example of each level of typicality for each category.

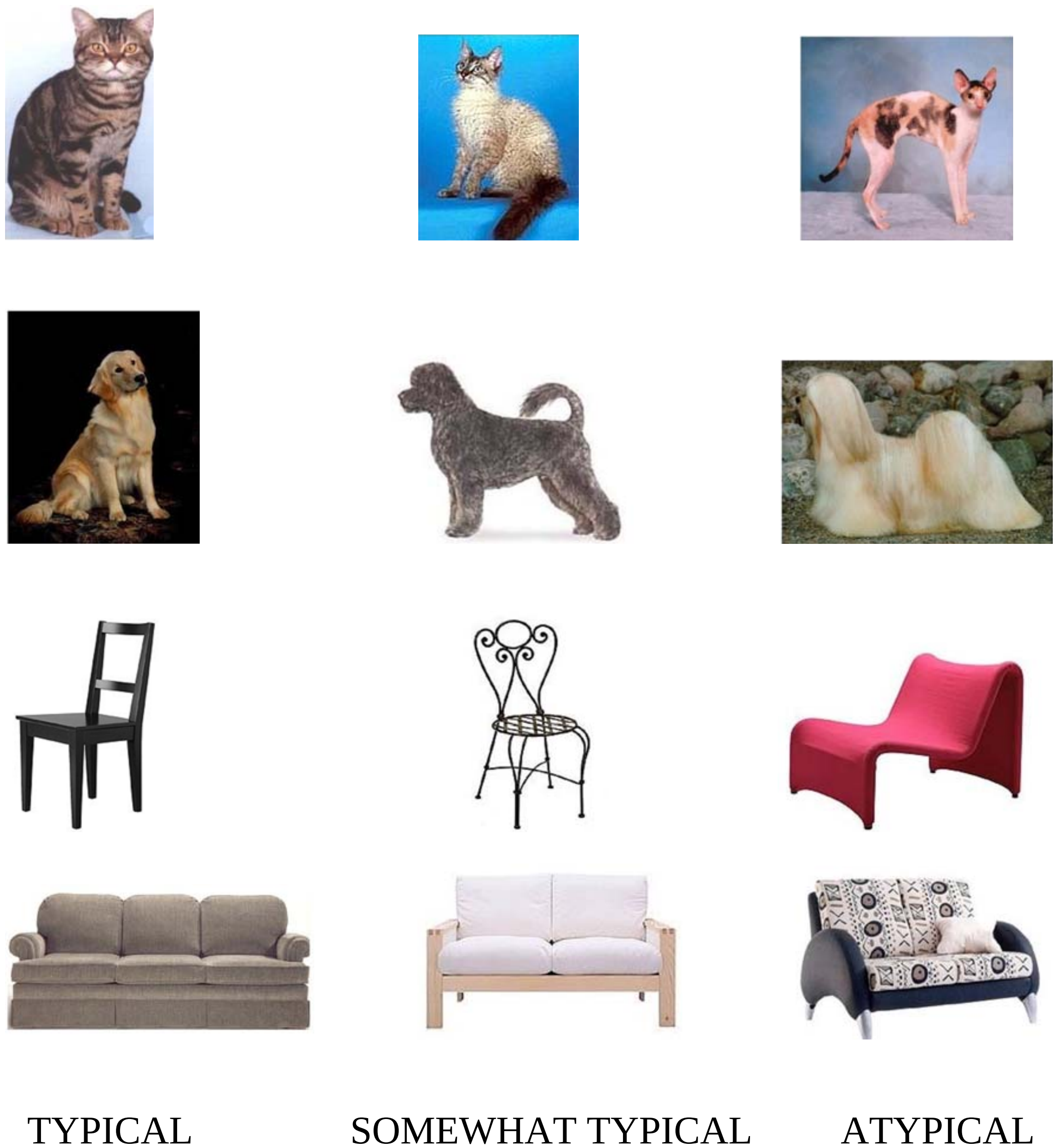

Figure 1. Stimulus Examples

2.1.3.2 Auditory Stimuli

The auditory stimuli consisted of a recorded female voice saying “dog”, “cat”, “couch”, or “chair”. All auditory stimuli were edited to ensure the same volume, duration, and intensity.

2.1.4 Procedure

A category verification procedure was used. After a press on the space bar key, an auditory stimulus was presented through the speakers, and immediately following this word, a picture of an object appeared in the center of the screen. For the natural categories, the auditory stimulus was either "cat" or "dog" and for the artificial categories "couch" or "chair". Participants were asked to judge whether the pictured object was or was not a member of the category presented auditorily. Responses were given by pressing either the button labeled "true" if the object belonged to the named category or "false" if it did not belong. The participants were instructed to respond as quickly and accurately as possible. Button presses ended the trials. Participants were given no feedback regarding the accuracy of their responses but were regularly given positive verbal reinforcement. The participants were not told what types of categories they would be seeing and were instructed to make their best guess if they were unsure of an answer. The participants were first given the instructions to the task and then were presented with four practice trials to determine whether they correctly understood the instructions before the verification task began. The practice trials consisted of a true and false verification for two object categories (birds and tables) not used in the actual study. The participants were asked if they understood the instructions, and if they did, the experiment began. If the participants had any questions or needed to review the instructions, it was done at this time. The participants were then presented with the 96 test trials.

For each object category, 25% of the correct verifications (6 verifications) were false (the word and picture did not match each other) while 75% of the correct verifications (18 verifications) were true (the word and picture did match each other). Essentially, the "false" trials were only added to the study as a necessary task parameter, and there were too few trials to allow for a complete analysis of category and typicality effects in these trials. Therefore, all results that are reported in the results section pertain to the "true" trials only. Within both the true and false test trials, participants were given an equal number of typical, somewhat typical, and atypical exemplars.

2.2 RESULTS

The primary dependent measures of interest were the reaction times and accuracy rates for each level of typicality. All analyses were performed on the "true" trials only, because these trials reflect the storage of the categories and are not biased by the confusion of the negativity that is involved in the "false" trials.

2.2.1 Preliminary Analyses

A number of preliminary analyses were done to test whether any group differences (autism vs. control) varied by stimulus category or whether the categories could be combined in further analyses. These analyses indicated that across experiments, a consistent pattern of results existed for the cat, chair, and couch categories but not for the dog category. In fact, a Group X Category interaction existed in a number of these analyses. Indeed, when the dogs were excluded from these analyses, the interactions were no longer significant. Thus, all analyses on the "combined category" data will include results from the cat, chair, and couch categories, but exclude dogs. The results for the dogs will be discussed separately from the other categories. This pattern of results will be illustrated in more detail later in the results.

2.2.2 Reaction Time Results

An initial 2-way ANOVA was conducted on the "combined category" reaction time data. The between subjects variable was Group (autism vs. control) and the within subjects variable was Typicality (typical vs. somewhat typical vs. atypical). Results indicated a significant main effect of Typicality, F (2,116) = 40.57, $p < .01$, with reactions times for both groups being slower for the less typical stimuli. Results also indicated a significant main effect of Group, F (1, 58) = 8.10, $p < .01$. In general, the responses of the children with autism were significantly slower than those of the control children. There was also a significant Typicality X Group interaction, F (2, 116) = 4.29, $p < .05$. The reaction time means for the combined category data are presented in Figure 2. As can be seen, the significant interaction indicated that typicality had more of an effect on the reaction times of the children with autism than the control children. It is this interaction that is of particular interest. Specifically, to what extent did typicality affect the reaction times of the control participants in comparison to the children with autism?

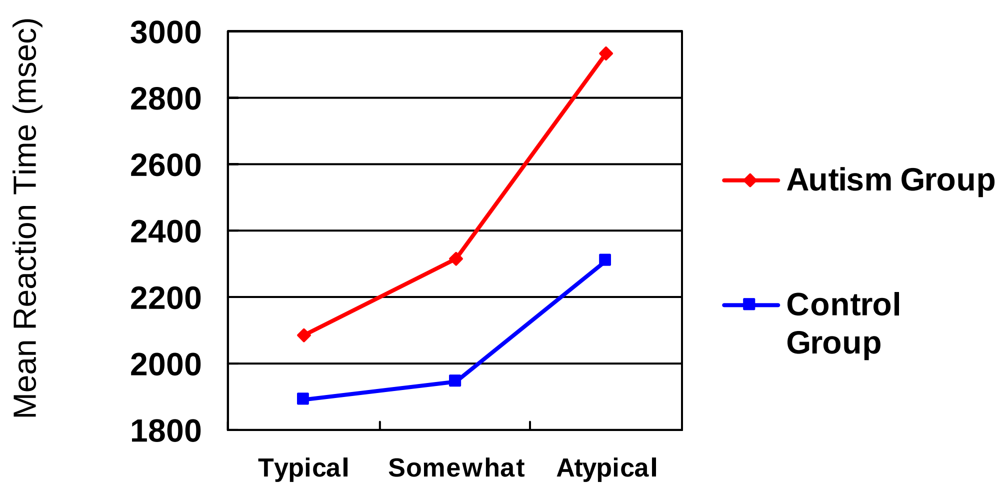

Figure 2. Child Reaction Times for the "Combined Category" Data by Typicality

Of primary interest was how much slower the reaction times were for each group when the children were shown somewhat typical or atypical stimuli, and the degree to which this slowness was the same or different between the children with autism and control children. Because the children with autism responded more slowly to all stimuli, the best way to directly compare the groups was to convert the mean reaction times for the somewhat typical and atypical stimuli to a percent change in reaction time from typical to somewhat typical (e. g. 10% change, 20% change) and a percent change in reaction time from typical to atypical. The following was the formula for calculating the percent change in reaction time:

$$\%\text{ change somewhat typical} = \frac{(\text{Mean RT typical} - \text{Mean RT somewhat typical})}{\text{Mean RT typical}} \times 100\%$$

Figure 3 shows the mean percent change in reaction time for the somewhat typical and atypical stimuli for the "combined category" data. As can be seen, the children with autism responded 10.3% slower to the somewhat typical stimuli in comparison to the control children who only responded 3.1% slower to these stimuli, $t\ (1, 58) = -1.72$, $p < .05$. This effect was even more dramatic for the atypical stimuli. For the atypical stimuli, the children with autism responded 38.2% slower to the atypical stimuli in comparison to the control children who responded only 22.1% slower to these stimuli, $t\ (1, 58) = -2.12$, $p < .05$. Thus, while the reaction times of both groups were slower for the somewhat typical and atypical stimuli, reaction times were particularly slowed for the children with autism.

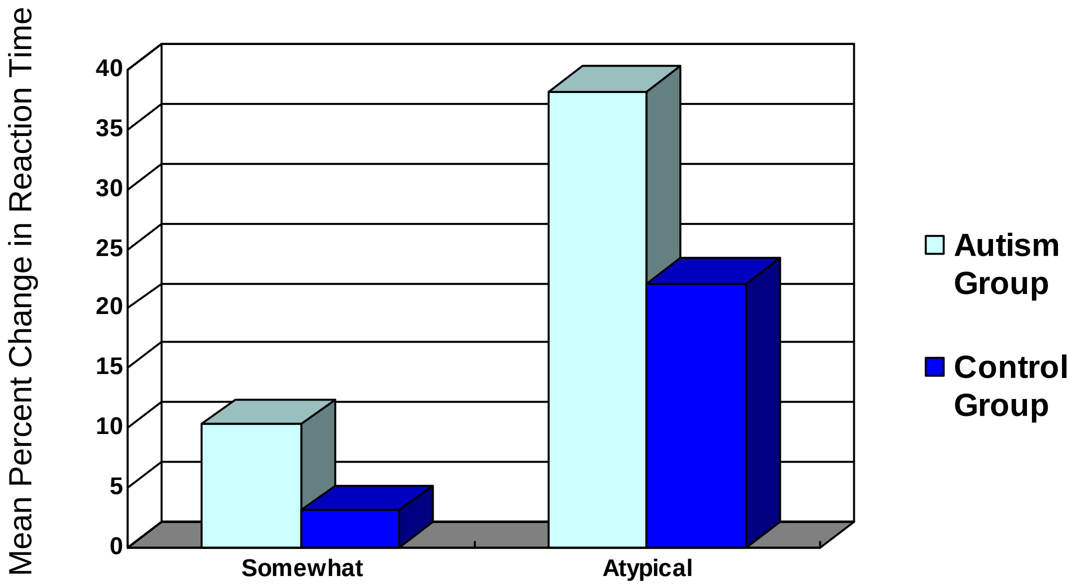

Figure 3. Child Percent Change in Reaction Time for the "Combined Category" Data by Typicality

Figures 4 and 5 show the mean percent change in reaction time for the somewhat typical and atypical stimuli for each of the individual categories in addition to the "combined category" data. It can be seen that a similar pattern of results existed for the cat, chair, couch, and "combined category" data. For all of these categories, children with autism responded more slowly than the control children to the somewhat typical and atypical stimuli. This pattern was not true for the dog category. In fact, children with autism and control children did not differ with respect to percent slower to somewhat typical or atypical dog stimuli.

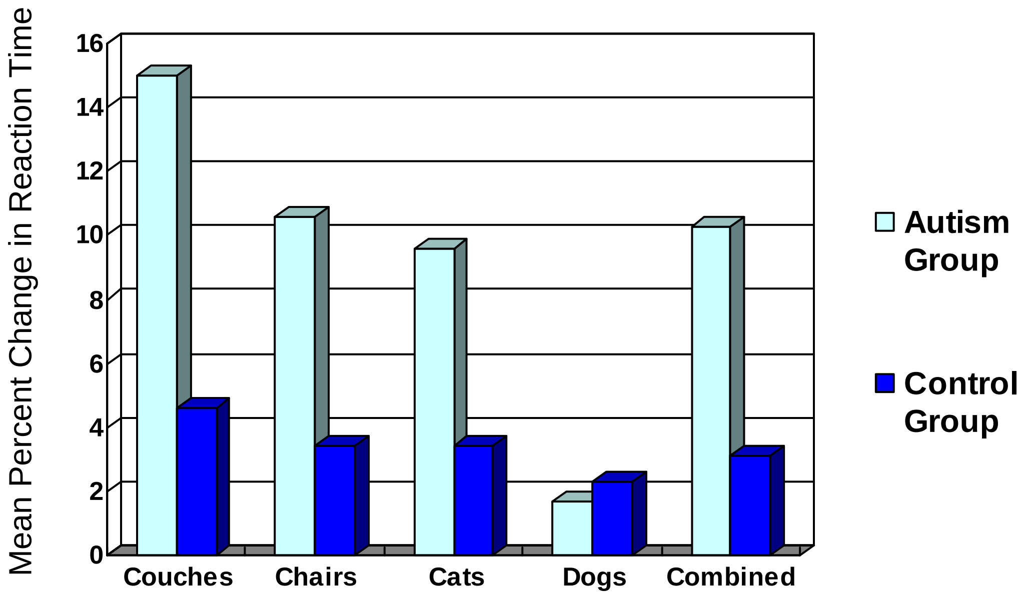

Figure 4. Child Percent Change in Reaction Time by Category for Somewhat Typical Stimuli

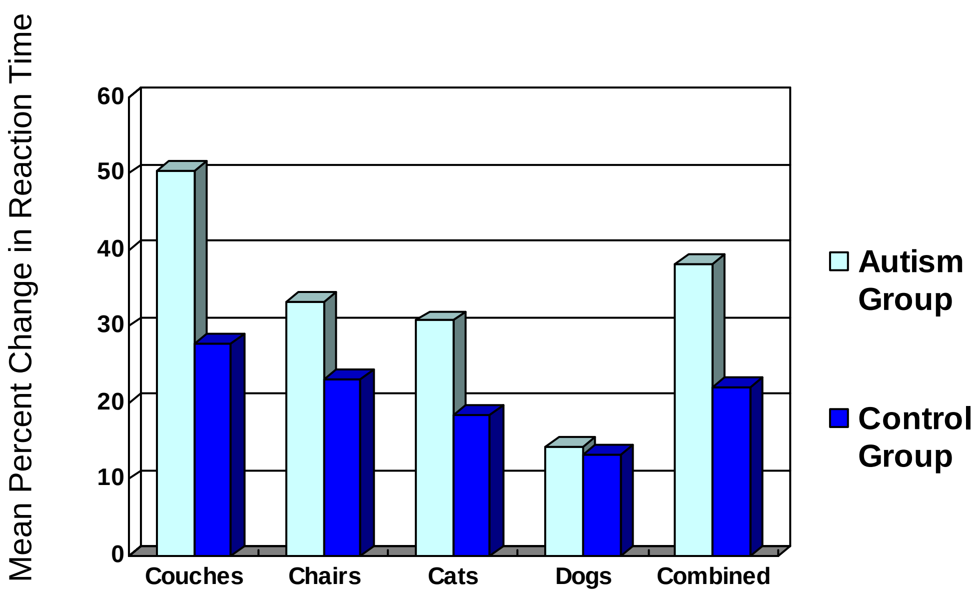

Figure 5. Child Percent Change in Reaction Time by Category for Atypical Stimuli

2.2.3 Accuracy Results

Also of interest was whether any group differences existed in children's accuracy rates as a function of typicality. An initial 2-way ANOVA was conducted on the percent correct scores for the "combined category" data. The between subjects variable was Group (autism vs. control) and the within subjects variable was Typicality (typical vs. somewhat typical vs. atypical). Results indicated a significant main effect of Typicality, F (2, 116) = 14.62, $p < .01$. There were no other significant main effects or interactions. The percent correct means and standard deviations for the "combined category" data are presented in Table 3. It can be seen that both groups were much less accurate for the atypical stimuli than the less typical or typical stimuli.

Table 3. Children's Mean Accuracy Scores (% Correct) for "Combined Category" Data (Standard Deviations in Parentheses)

	Typical	Somewhat Typical	Atypical
Autism Group	97.1% (4.6%)	96.5% (5.4%)	90.8% (10.3%)
Control Group	96.7% (4.3%)	95.8% (6.9%)	92.2% (8.8%)

2.3 DISCUSSION

Results of Experiment 1 indicate that while the reaction times of both control children and children with autism were slower to less typical stimuli, this effect was exaggerated in children with autism. That is, typicality affected the reaction times of children with autism significantly more than it affected the control children's reaction times. Interestingly, while the children with autism were as accurate as the control children, the children with autism required more processing time to categorize exemplars that were less typical. As will be considered in the general discussion, it is possible that children with autism may have responded more slowly to less typical examples of categories, because they were using a different processing strategy to categorize the stimuli. This pattern of results was similar in the cat, chair, and couch categories, but not for the dog category. In fact, the reaction times for the dog category did not show any typicality effects in either group. Some possible reasons for the lack of typicality effects for the dog category will also be considered in the general discussion.

From this experiment, it is unknown whether this pattern of results was specific to children or reflective of a specific difference in individuals with autism at all ages. For instance, with experience with object categories, would the difficulty in categorizing less typical and atypical exemplars disappear? To address this question, it was decided to perform the exact same procedure on older children between the ages of 13 and 16 with autism and control teens. If experience with object categories aids categorization of less typical and atypical exemplars, the teens with autism should not respond significantly slower to these stimuli than control teens.

3.0 EXPERIMENT 2: ROLE OF TYPICALITY IN TEENS' OBJECT CATEGORIZATION

3.1 METHOD

3.1.1 Participants

Participants consisted of 22 high-functioning teens with autism (age 13-16) and 14 healthy control teens (age 13-16), a smaller sample than was included in Experiment 1. Recruitment, inclusion/exclusion criteria, and matching criteria were identical to Experiment 1. Table 4 summarizes the participants' sociodemographic characteristics. No significant differences were found between the two groups on FSIQ.

Table 4. Sociodemographic Characteristics of Autism and Control Groups for Experiment 2

	Autism Group (*N* = 22)			Control Group (*N* = 14)		
	Mean	SD	Range	Mean	SD	Range
Age	14.23	.97	13-16	14.21	1.19	13-16
FSIQ	106.09	11.66	88-133	110.36	12.03	86-129

Note: Age is indicated in years. SD = standard deviation; FSIQ = Full scale IQ

3.1.2 Apparatus, Stimulus Materials, and Procedure

The apparatus, stimuli, and procedures were identical to Experiment 1.

3.2 RESULTS

Similar to Experiment 1, the primary dependent measures of interest were the reaction times and accuracy rates for each level of typicality. Again, all analyses were performed on the "true" trials only.

3.2.1 Reaction Time Results

An initial 2-way ANOVA was conducted on the "combined category" reaction time data. The between subjects variable was Group (autism vs. control) and the within subjects variable was Typicality (typical vs. somewhat typical vs. atypical). Results indicated a significant main effect of Typicality, F (2, 68) = 19.21, p < .01, with reaction times for both groups being slower for the less typical stimuli. Results also indicated a significant main effect of Group, F (1, 34) = 5.83, p < .05. In general, the responses of the teens with autism were significantly slower than those of the control teens. The Typicality x Group interaction was marginally significant, F (2, 68) = 2.95, p = .06. The reaction time means for the "combined category" data are presented in Figure 6. As can be seen, the marginally significant interaction indicated that typicality had more of an effect on the reaction times of the teens with autism than the control teens. Overall, the teens' reaction times in general were faster than the children's reaction times.

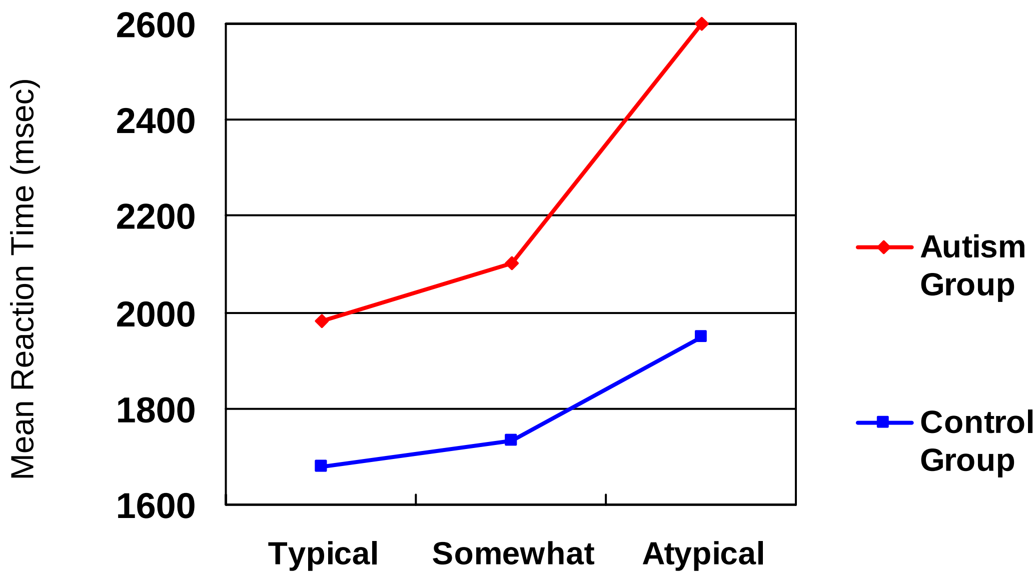

Figure 6. Teen Reaction Times for "Combined Category" Data by Typicality

As with Experiment 1, of primary interest was how much slower the reaction times were for each group when the teens were shown somewhat typical or atypical stimuli, and the degree to which this slowness was the same or different between the teens with autism and control teens. Thus, the mean reaction times were converted into percent change in reaction time from typical to somewhat typical and percent change in reaction time from typical to atypical for each category and for the "combined category" data.

Figure 7 shows the mean percent change in reaction time for the somewhat typical and atypical stimuli for the "combined category" data. In contrast to the children, teens with autism and control teens did not differ in the amount that their reaction times were slowed by the somewhat typical stimuli (M = 5.3% vs. M = 2.9%), t (1, 34) = -.42, p = .67. However, for atypical stimuli, teens with autism responded in a manner that was similar to that of children with autism. As can be seen, the teens with autism responded 31.1% slower to the atypical stimuli in comparison to the control teens who responded only 15.5% slower, t (1, 34) = -1.80, $p < .05$. Thus, the teens with autism were more efficient in processing the somewhat typical stimuli, but continued to have difficulty processing the more atypical category members.

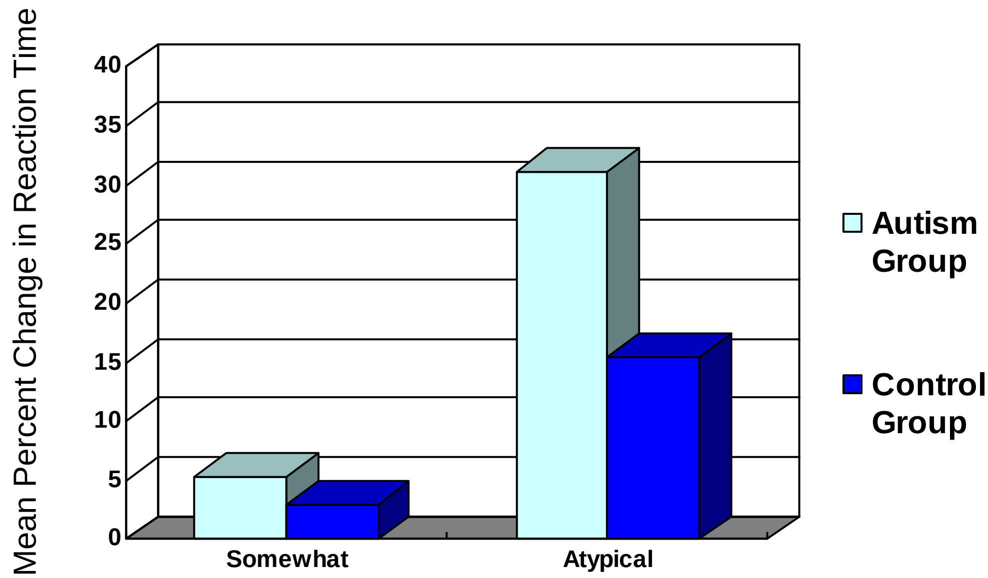

Figure 7. Teen Percent Change in Reaction Time for "Combined Category" Data by Typicality

Figure 8 shows the mean percent change in reaction time for the atypical stimuli for each of the individual categories and the "combined category" data. It can be seen that like the child data, a similar pattern of results existed for the cat, chair, couch, and "combined category" data. For all of these categories, the teens with autism responded almost two times slower than control teens to the atypical stimuli. This pattern was also true for the dogs, although typicality did not appear to have much of an effect on the reaction times for this category.

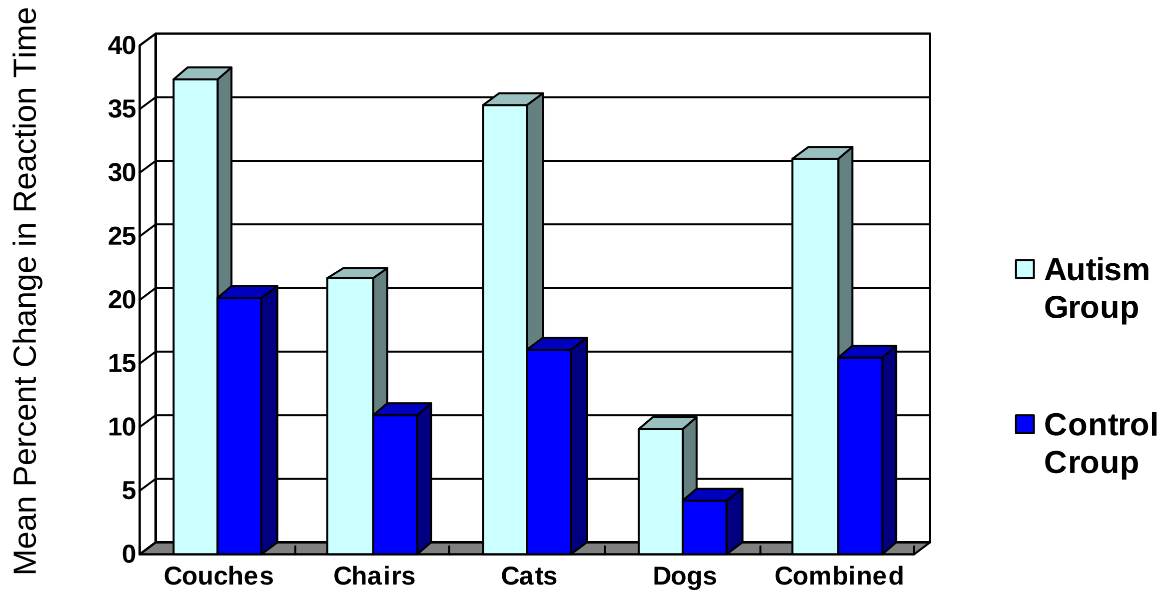

Figure 8. Teen Percent Change in Reaction Time by Category for Atypical Stimuli

3.2.2 Accuracy Results

Also of interest was whether any group differences existed in teens' accuracy rates as a function of typicality. An initial 2-way ANOVA was conducted on the percent correct scores for the combined category data. The between subjects variable was Group (autism vs. control) and the within subjects variable was Typicality (typical vs. somewhat typical vs. atypical). Results indicated a significant main effect of Typicality, F (2, 68) = 11.80, $p < .01$. There were no other significant main effects or interactions. The percent correct means and standard deviations for the "combined category" data are presented in Table 2. It can be seen that again, both groups were much less accurate for the atypical stimuli than the less typical and typical stimuli. It can also be seen that, in general, the teens were more accurate than the children for all stimuli, especially the atypical stimuli.

Table 5. Teens' Mean Accuracy Scores (% Correct) for "Combined Category" Data (Standard Deviations in Parentheses)

	Typical	Somewhat Typical	Atypical
Autism Group	98.8%	97.4%	94.1%
	(3.3%)	(4.7%)	(7.4%)
Control Group	98.6%	99.2%	94.4%
	(2.8%)	(2.0%)	(5.6%)

3.3 DISCUSSION

Results of Experiment 2 indicate that unlike the children, teens with autism and control teens responded only slightly slower to the stimuli that were somewhat typical. Thus, with experience, teens with autism were able to categorize less typical members of categories as efficiently as control teens. In contrast, teens with autism, like children with autism, responded significantly slower than control teens to atypical category members. While the teens with autism were as accurate as the control teens, the teens with autism required more processing time to categorize exemplars that were atypical. Again, it is possible that teens with autism may have responded more slowly to atypical examples of categories, because they were using a different processing strategy to categorize these stimuli. This pattern of results was similar in the cat, chair, and couch categories, but the reaction times for the dog category did not show any typicality effects in either group.

Given this developmental change from childhood to adolescence, an important question that remains is whether the two groups would respond similarly to atypical stimuli as adults. It is possible that more experience with object categories into adulthood would improve individuals with autisms' categorization efficiency and accuracy for atypical category members. To address this question, it was decided to perform the exact same procedure with adults between the age of 17 and 48 with autism and control adults. If experience with object categories aids categorization of atypical category members, the adults with autism should not respond significantly slower than control adults to these category members.

4.0 EXPERIMENT 3: ROLE OF TYPICALITY IN ADULTS' OBJECT CATEGORIZATION

4.1 METHOD

4.1.1 Participants

Participants consisted of 28 high-functioning adults with autism and 27 healthy adult control individuals. Recruitment, inclusion/exclusion criteria, and matching criteria were identical to Experiments 1 and 2. Table 6 summarizes the participants' sociodemographic characteristics. No significant differences were found between the two groups on FSIQ.

Table 6. Sociodemographic Characteristics of Autism and Control Groups for Experiment 3

	Autism Group (*N* = 28)			Control Group (*N* = 27)		
	Mean	SD	Range	Mean	SD	Range
Age	24.39	8.22	17-48	23.07	4.13	17-38
FSIQ	107.11	10.12	87-128	111.93	10.16	84-127

Note: Age is indicated in years. SD = standard deviation; FSIQ = Full scale IQ

4.1.2 Apparatus, Stimulus Materials, and Procedures

The apparatus, stimuli, and procedures were identical to Experiments 1 and 2.

4.2 RESULTS

Similar to Experiments 1 and 2, the primary dependent measures of interest were the reaction time and accuracy rates for each level of typicality. Again, all analyses were performed on the "true" trials only.

4.2.1 Reaction Time Results

An initial 2-way ANOVA was conducted on the "combined category" reaction time data. The between subjects variable was Group (autism vs. control) and the within subjects variable was Typicality (typical vs. somewhat typical vs. atypical). Results indicated a significant main effect of Typicality, F (2, 106) = 36.11, p < .01, with reactions times for both groups being slower for the less typical stimuli. Results also indicated a significant main effect of Group, F (1, 53) = 7.33, p < .01. In general, the responses of the adults with autism were significantly slower than those of the control adults. There was also a significant Typicality X Group interaction, F (2, 106) = 3.89, p < .05. The reaction times for the "combined category" data are presented in Figure 9. As can be seen, the significant interaction indicated that typicality had more of an effect on the reaction times of the adults with autism than the control adults.

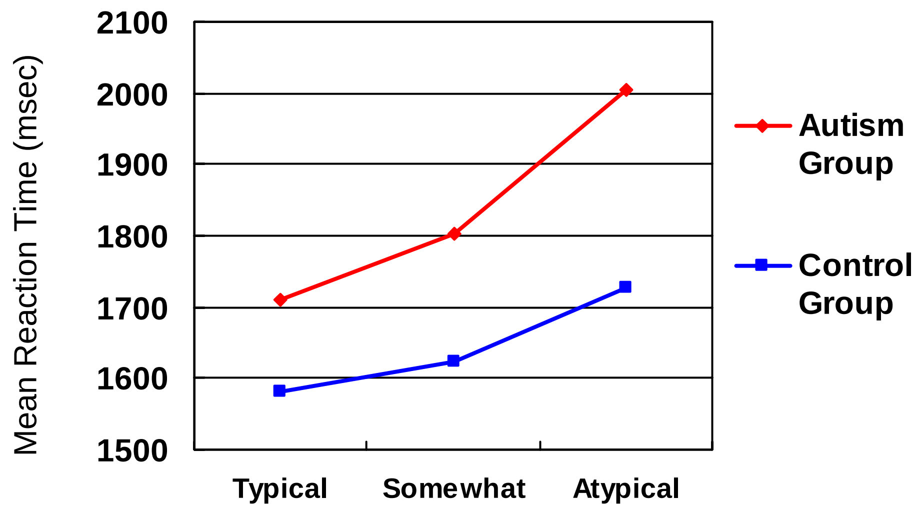

Figure 9. Adult Reaction Times for the "Combined Category" Data by Typicality

As with Experiments 1 and 2, of primary interest was how much slower the reaction times were for each group when the adults were shown somewhat typical or atypical stimuli, and the degree to which this slowness was the same or different between the adults with autism and control adults. Thus, the mean reaction times were converted into percent change in reaction time from typical to somewhat typical and from typical to atypical for each category and for the "combined category" data.

Figure 10 shows the mean percent change in reaction time for the somewhat typical and atypical stimuli for the "combined category" data. Like the teens, adults with autism and control adults did not differ in the amount that their reaction times were slowed by the somewhat typical stimuli (M = 4.8% vs. M = 2.7%), t (1, 53) = -.42, p = .34. However, for atypical stimuli, adults with autism responded in a manner that was similar to that of children and teens with autism. As can be seen, the adults with autism responded 16.1% slower to the atypical stimuli in comparison to the control adults who responded only 9.3% slower, t (1, 53) = -2.09, $p < .05$. Thus, the adults continued to have difficulty processing the more atypical category members.

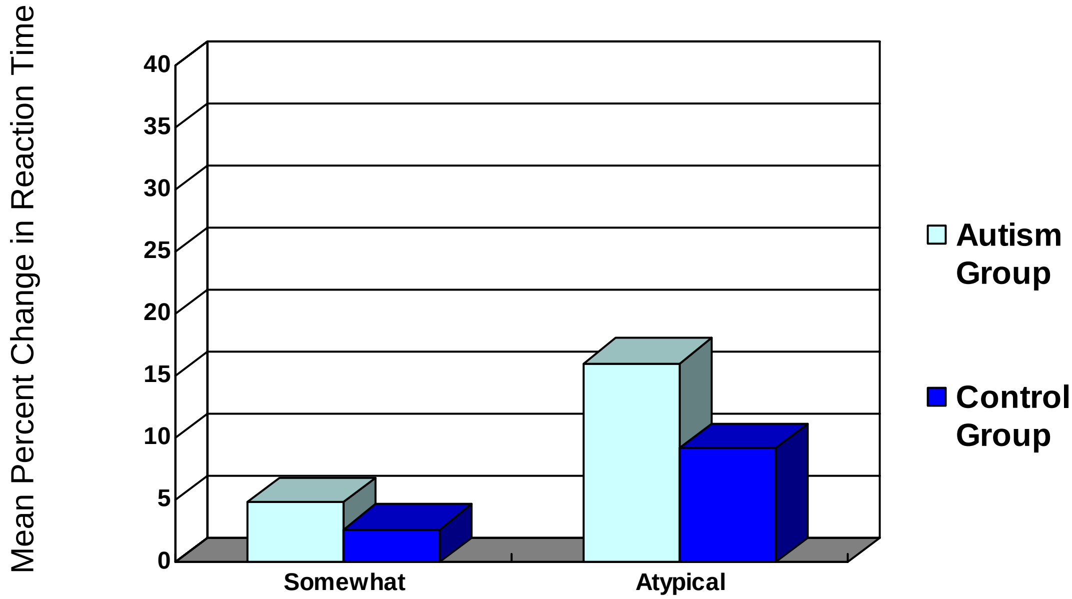

Figure 10. Adult Percent Change in Reaction Time for "Combined Category" Data by Typicality

Figure 11 shows the mean percent change in reaction time for the atypical stimuli for each of the individual categories and the "combined category" data. It can be seen that like the child and teen data, a similar pattern of results existed for the cat, chair, couch, and "combined category" data. For all of these categories, the adults with autism responded almost two times slower than the control adults to the atypical stimuli. This pattern was not true for the dog category. Again, typicality did not appear to have much of an effect on the reaction times for this category.

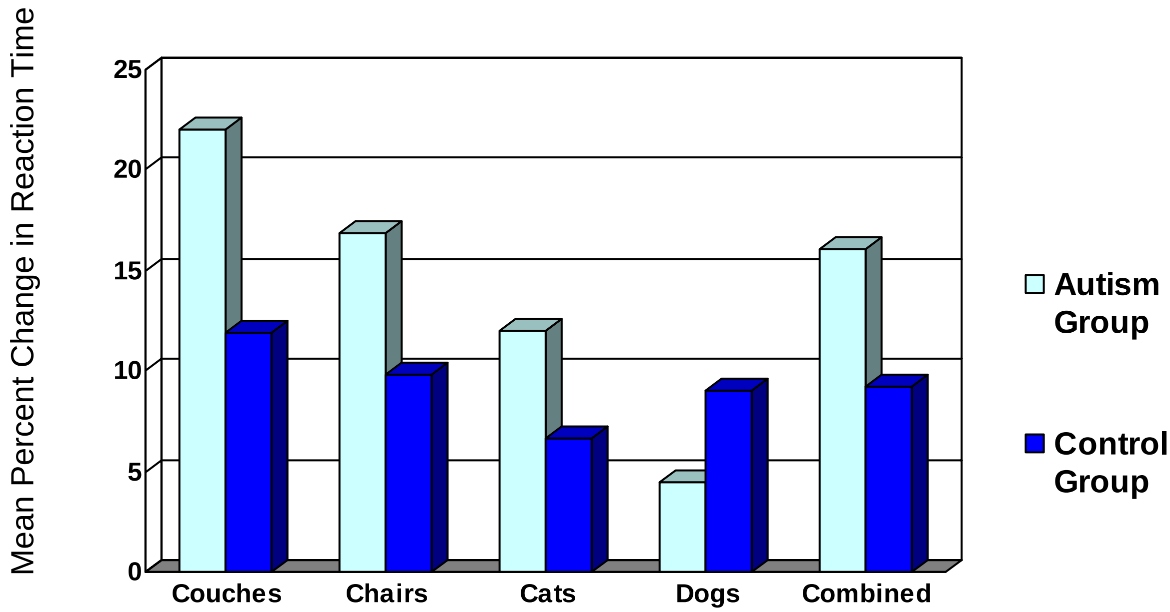

Figure 11. Adult Percent Change in Reaction Time by Category for Atypical Stimuli

4.2.2 Accuracy Results

Also of interest was whether any group differences existed in adults' accuracy rates as a function of typicality. An initial 2-way ANOVA was conducted on the percent correct scores for the "combined category" data. The between subjects variable was Group (autism vs. control) and the within subjects variable was Typicality (typical vs. somewhat typical vs. atypical). The percent correct means and standard deviations for the combined category data are presented in Table 7. Results indicated a significant main effect of Typicality, F (2, 106) = 4.40, $p < .05$, with both groups responding less accurately for the atypical stimuli than the somewhat typical or typical stimuli. Results also indicated a significant main effect of Group, F (1, 53) = 5.24, $p < .05$. While the adults with autism in general were quite accurate, they were less accurate than the control adults at all levels of typicality. The interaction was not significant.

Table 7. Adults' Mean Accuracy Scores (% Correct) for "Combined Category" Data (Standard Deviations in Parentheses)

	Typical	Somewhat Typical	Atypical
Autism Group	97.8% (4.4%)	98.3% (3.0%)	96.1% (4.4%)
Control Group	98.8% (2.5%)	99.4% (1.8%)	98.2% (3.0%)

4.3 DISCUSSION

Results of Experiment 3 indicated that adults with autism, like children and teens with autism, responded significantly slower than control adults to atypical category members. Surprisingly, adults with autism showed a processing deficit for atypical category members in that they were slower to verify these members and were less accurate than control adults. Thus, while experience with object categories was able to improve the processing of less typical category members between childhood and the teen years, this was not the case for the atypical category members. In fact, control adults' performance was at ceiling with respect to accuracy for all levels of typicality, while the adults with autism never quite reached this level of accuracy. Thus, for both reaction times and error rates, adults with autism evidence a deficit in processing atypical category members throughout the lifespan. Possible explanations for this difficulty with atypical category members will be addressed in the general discussion.

5.0 GENERAL DISCUSSION

The current study explored whether individuals with autism *process* category information in the same manner as typically developing individuals. Individuals with autism and typically developing individuals showed improvement in their categorization abilities throughout the lifespan for all levels of typicality. In fact, by the teen years, categorization ability and processing efficiency of typical and somewhat typical category members developed to the same level in both groups. In contrast, categorization processing differences were found throughout the lifespan with respect to atypical or poor category members. Indeed, adults with autism never reached the same proficiency or accuracy in categorization as the control adults for the atypical category members.

The above results derived from the cat, couch, and chair categories. In contrast, neither group demonstrated typicality effects for the dog category. This was true of all three tested age groups. This lack of effect was probably the result of having used exemplars that did not have enough variability in typicality. That is, the atypical exemplars were relatively common breeds and, hence, probably not unusual enough to cause a typicality effect.

Previous studies on the categorization abilities of individuals with autism have had mixed results, some indicating that these individuals have a deficit in categorization and others suggesting that they do not. However, none of the previous research has considered the effect that typicality and task difficulty may have on categorization ability. It is possible that individuals with autism can successfully categorize when the task involves simple and typical basic objects but have difficulty when categorization is more complex or involves less typical objects. The current study provides support for this notion. Individuals with autism in the current study were able to categorize the most typical and somewhat typical exemplars as accurately and efficiently as typically developing individuals, but the participants with autism exhibited difficulty categorizing less typical exemplars. Additionally, all previous studies of categorization in individuals with autism only measured the accuracy of categorization while ignoring potential differences in reaction time. Accuracy may not reflect difficulties in categorization in that individuals may be able to categorize successfully but may need significant amounts of processing time in order to do so. Indeed, most studies of categorization in typically developing individuals use reaction time as the primary measure of processing efficiency (e.g. Murphy, 2002).

One important question that remains is why the individuals with autism were able to process typical and somewhat typical exemplars of categories as efficiently as the control individuals by the teen years but were less efficient at categorizing atypical category members even in adulthood. It is possible that the individuals with autism engaged in different categorization processes for typical and atypical category exemplars and that these processes were differentially affected with development. For example, consider the categories of chairs and couches. Typically, chairs are short and seat one person, while couches are long and seat multiple people. Thus, typical examples may have been categorized by individuals with autism using a logical, criterial, dichotomous feature such as length (short/not short or long/not long). If this was the case, improvement from the childhood years to the teen years in categorization of somewhat typical exemplars may have resulted from increased experience with determining these criterial features and using them to aid categorization. Since previous research indicates that individuals with autism are able to categorize successfully when using simple, criterial features, it is not surprising that individuals with autism were able to categorize typical and somewhat typical category exemplars efficiently and accurately.

What is different about the processing of atypical exemplars of categories that does not allow for this type of featural processing? Again, consider the categories of chairs and couches. Imagine that you are presented with a piece of furniture that is longer than the typical chair but shorter that the typical couch. How would you decide whether this piece of furniture was a chair or not? In this example, one cannot use the simple, criterial feature of "short or not short" to decide category membership, because length does not provide enough clear information for this decision.

It is possible that the categorization of atypical category members requires processes that are more similar to those used when discriminating individual members of subordinate categories such as *desk* chairs or *rocking* chairs. Since subordinate category members look very similar, the discrimination of one category member from another involves more complex processes that become available with developing expertise (Tanaka & Taylor, 1991; Gauthier & Tarr, 1997). For example, rather than comparing only simple features, comparisons of subordinate category members often require that quantitative spatial information be considered (i.e. subtle differences in the length of a couch). Similarly when categorizing atypical or subordinate exemplars, it is often necessary to compare the exemplar to previously stored category members or to a prototype of the category and decide if the piece of furniture looks like a couch or a chair (Homa, Smith, & Macak, 2001; Smith & Medin, 2002). Finally, categorizing atypical exemplars may require the comparison of multiple features and the ability to flexibly weight these features in the decision process. For example, because the length of a piece of furniture is at the category boundary, other feature such as style, fabric, and so on may take on greater weight in the categorization decision.

To date, no studies have explored the role that configural processing may play in the object categorization of individuals with autism. However, a considerable amount of evidence exists supporting a deficit in the configural processing of faces in these individuals. With development, typically developing children slowly shift from a predominant reliance on more featural processing of faces (Schwarzer, 2000) to having adult expertise in configural processing of faces (Mondloch, Le Grand, & Maurer, 2002; Deruelle & Fagot, 2005). Configural processing in adults and children is evidenced by better recognition of parts of the face in the context of a whole face than in isolation (Joseph & Tanaka, 2003), worse memory for and less attention to inverted faces than upright faces (van der Geest, Kemner, Verbaten, & van Engeland, 2002), reliance on low spatial frequency (configuration) more than high spatial frequency (features) in the processing of faces (Deruelle, Rondan, Gepner, & Tardif, 2004), and maximal activation of the face fusiform area (FFA) during the processing of face stimuli (Haxby, Horwitz, Ungerleider, Maisog, Pietrin, & Grady, 1994; Puce, Allison, Gore, & McCarthy, 1995).

In contrast, individuals with autism never appear to develop the ability to process faces configurally as is done by adults who do not have autism. Much of the evidence for a lack of configural processing of faces is behavioral in nature. Individuals with autism have been shown to rely on part-based rather than configural encoding of faces (Hobson, Ouston & Lee, 1988; Miyashita, 1988; Boucher & Lewis, 1992; Davies, Bishop, Manstead, & Tantum, 1994). In both face recognition tasks and face observation tasks, individuals with autism tend to focus preferentially on parts of the face such as the mouth rather than the entire face (Langdell, 1978;

Klin, Jones, Schultz, Volkmar & Cohen, 2002; Joseph & Tanaka, 2003) and are better at recognizing isolated facial features and partially obscured faces than control individuals (Hobson et al, 1988; Tantum, Monaghan, Nicholson, & Stirling, 1989). Studies examining the role of spatial frequency have found that individuals with autism rely more on high spatial frequency (features) to make identity judgements (Curby & Gauthier, 2002; Curby, Schyns, Gosselin, & Gauthier , 2003; Deruelle et al, 2004). Individuals with autism have also been found to perform better on tasks involving inverted faces than control individuals indicating a lack of configural processing (Langdell 1978; Hobson et al, 1988; Tantum at al, 1989; Teunisse & de Gelder, 2003). A recent study by Lahaie et al (2005) found that individuals with autism can benefit from configural information when processing faces, although they do evidence a local bias for face processing. While this study indicates that individuals with autism have a limited ability to process faces configurally, this is not the predominant type of processing that these individuals engage in when processing faces. It is possible that individuals with autism process faces configurally under certain circumstances, but do not have the configural bias and expertise of configural processing that is a hallmark of face processing in typically developing adults.

Electrophysiological and fMRI evidence also exists that corroborate the behavioral evidence of a deficit in configural processing in individuals with autism. McPartland, Dawson, Webb, Pangiotides, and Carver (2004) found altered N170 patterns including a slower latency to faces than furniture and a lack of a face inversion effect. Grice et al (2001) discovered that typically developing individuals had a larger increase in EEG gamma activity for upright faces than inverted faces. This did not hold true for individuals with autism who experienced equivalent gamma activity to upright and inverted faces (Grice et al, 2001). The most replicated and cited finding in the fMRI literature is a hypoactivation of the face fusiform area (FFA) and activation of the more feature based object areas (inferior temporal) when viewing and discriminating faces (Schultz et al, 2000; Pierce, Müller, Ambrose, Allen, & Courchesne, 2001; Curby et al 2003, Hubl et al 2003). These studies provide further evidence of a deficit or lack of configural processing of faces in individuals with autism.

Perhaps the most directly relevant facial task to examine in relation to the results of the current set of studies is that of gender discrimination. Like objects, male and female faces can be more or less typical of their gender and these faces may require different types of processing depending on the typicality of each face for a given gender. While very little research has been conducted concerning gender discrimination in individuals with autism, one behavioral study from our lab and two fMRI studies support the notion that individuals with autism process gender more featurally and less configurally, especially when the faces are less typical.

A gender discrimination study conducted in our lab on the same participants that were involved in the current studies indicated a similar developmental phenomenon for gender discrimination as for object verification. Typically developing children were able to discriminate less representative members of each gender as well as adults by the age of 12, while individuals with autism never reached adult levels of accuracy or processing speed when categorizing less typical exemplars of male and female faces (Best, Strauss, Newell, & Minshew, 2005). Again, it is possible that individuals with autism are able to discriminate more typical males and females based on featural processes (thick or thin eyebrows) but require configural processing (quantitative judgments, weighting of features, comparisons to stored prototype) to do the more complex decision making that is involved in deciding whether an atypical stimulus is male or female.

Two fMRI studies on gender discrimination comparing control adults and adults with autism have been conducted to date (Pierce et al, 2001, Hubl et al, 2003). Both of these studies failed to find any accuracy differences between individuals with autism and control adults, although the sample sizes in both studies were very small and thus lacked enough power to find any significant differences (n = 6 and n = 7). Interestingly, the reported means for the Pierce et al study (autism = 93.3% and control = 99.7%) and Hubl et al study (autism = 95% and control = 99%) were similar to statistically significant differences found by Best et al (2005). Despite this lack of behavioral findings, in both studies, control individuals activated the FFA when engaging in gender discrimination, while individuals with autism activated inferior temporal (object) areas. Thus, individuals with autism showed the same pattern of featural processing for gender discrimination and difficulty with atypical members of a given gender as was evidenced in the current studies with objects.

This similarity between the results of studies on object categorization and gender discrimination leads one to wonder to what extent face and object processing may be analogous. Some researchers argue that faces comprise a special class of visual object which is evidenced by a special form of cognitive processing (configural processing) and selective activation of the FFA for faces and not objects (Tanaka & Farah, 1993; Kanwisher, McDermott, & Chun, 1997). Other researchers have provided evidence that refutes this claim and assert that the configural processing that is involved in faces may be an effect of expertise; an expertise that can develop for any object (Diamond & Carey, 1986; Gauther & Tarr, 1997). The discrimination of one face from another is a subordinate level task and requires expertise in the same way that discrimination of different black miniature poodles would require subordinate level processing and expertise for a dog judge. In each of these cases, the individual exemplars that must be differentiated are homogenous and thus may require configural processing and activation of the FFA (Gauthier & Tarr, 2002; Maurer, Le Grand, & Mondloch, 2002; Tarr & Cheng, 2003).

Many studies have been conducted that support the notion that “face specific” effects may not be actually exclusive to faces. Gauthier et al (2000) found that recognition of objects at a more subordinate level, as is done by experts, recruits the same areas of the brain as face recognition. Prosopagosic patients, who are impaired in their ability to recognize faces, have been also shown to have similar impairments in their ability to recognize subordinate level objects and Greebles (Gauthier et al, 1999). Tarr & Cheng (2003) purported that expertise in a certain domain can shift the level at which the objects are processed. For example, a dog show judge would not recognize dogs at the basic level (cocker spaniel, poodle) but would recognize them as individuals within a breed (Tanaka & Taylor, 1991). In fact, one study with dog show judges indicated that judges show a similar inversion effect for faces and dogs, evidence of configural processing for both types of stimuli (Diamond & Carey, 1986). Another study of bird and car experts evidenced activation in the FFA for birds or cars (Gauthier et al, 2000). Individuals who have been trained to become experts on artificial stimuli (Greebles) have also shown evidence of configural processing behaviorally and through activation of the FFA (Gauthier & Tarr, 1997; Gauthier, Williams, Tarr, & Tanaka, 1998; Gauthier et al, 1999; Gauthier & Tarr, 2002). All of the above supports the notion that that the same recognition system is involved when processing faces or objects at more specific, subordinate levels. Thus, it is argued that face recognition is an example of an area in which most individuals have expertise (Tanaka, 2001) and that dissociations between results in the face and object literature may actually be related to dissociations in the degree of expertise rather than a difference in processing strategies between objects and faces (Tarr & Cheng, 2003).

Other evidence also exists that suggests that objects and other non-social stimuli are sometimes processed in a configural manner. Baker, Behrmann, and Olson (2002) performed an object training study on macaque monkeys and found that some neurons engaged in configural processing of trained objects while others engaged in featural processing of untrained objects. Noudoost, Adabi, Moeeny, and Esteky (2005) extended these results to humans and found similarly that configural processing was important for recognition of familiar objects while featural processing was more important for recognition of unfamiliar objects. Both of these studies suggest that there is a continuum of processing of objects with featural processing on one end (unfamiliar) and configural processing at the other end (familiar) (Baker et al, 2002). Studies with faces have also suggested that both featural or configural processing are available for use when presented with a facial discrimination task and that one process may be utilized more than the other depending on the task (Cabeza & Kato, 2000; Deruelle & Fagot, 2005; Ingvalson & Wenger, 2005). Two recent studies of particular importance found deficits in configural processing of objects and/or nonsocial stimuli in individuals with autism (Deurelle, Rondan, Gepner, Wicker, & Fagot, submitted; Behrmann et al, 2005). Thus, it is possible that deficits in face and object processing in individuals with autism result from similar deficits or processes in these individuals.

The remaining question that needs to be addressed is the potential mechanism underlying the face and object processing deficits that have been found in individuals with autism. The predominant explanations for processing deficits in these individuals are centered on a lack of early social motivation and attention to faces. For example, Dawson, Webb, and McPartland (2005) have proposed that a lack of social motivation (perhaps due to differences in inherent reward systems) in individuals with autism leads to decreased expertise in configural processing (including facial discrimination and recognition) which leads to the differences in brain function that has been evidenced in these individuals (atypical brain activation and ERP differences). Schultz (2005) similarly proposed that individuals with autism do not experience the natural reinforcement to look at faces (centered in the amygdala) that typically leads to enhanced salience of faces, more experience and skill at perceiving faces, and ultimately social skills. Thus, individuals with autism lack experience with faces, leading them to experience deficits in the social realm.

The current study, in addition to recent research by Behrmann et al (2005), challenges the idea that a social deficit such as a lack of social motivation underlies the processing and social skill deficits in individuals with autism. It is possible that individuals with autism have core cognitive processing differences such as a featural/local processing bias and/or lack of configural processing expertise that either add to or underlie the social deficits that are seen in these individuals. Because faces and social situations are complex, they may require more sophisticated configural processing than is needed for objects and nonsocial stimuli. Thus, it is possible that problems with processing faces and understanding social situations are more extreme and more noticeable than those seen with objects and nonsocial information.

The current study, in conjunction with results from other studies, provides evidence that suggests that there may be significant processing differences in individuals with autism in *both* nonsocial and social domains. From early in life, infants have a number of processes that help them to decrease the amount of complexity in the world including the ability to detect statistical correlations in both language and visual stimuli (Saffran, Aslin, & Newport, 1996), to form prototypes (Strauss, 1979), and to categorize on the basis of correlated attributes (Younger, 1986). One possibility that remains is that individuals with autism may have a general problem in data reduction from birth and that the differences in perceptual processing that were evidenced in the current study are only one piece of a larger cognitive deficit. Two other studies from our lab provide preliminary evidence in support of this possibility. A study of number line estimation indicated that individuals with autism do not use logarithmic magnitude in their numerical estimates and instead engage in more linear estimations (Strauss & Turner, 2005). Logarithmic estimation is utilized by typically developing children and adults in order to simplify and reduce the amount of information that is needed in order to make an estimate. Another study on prototype formation has shown that individuals with autism do not form prototypes (Best et al, 2005). If, from birth, babies with autism are focused on details and unable to engage in various types of data reduction, the complex social world could very quickly become overstimulating and aversive to these individuals. At this point, these claims are entirely speculative and much more research needs to be performed that examines the possibility of a general problem in data reduction in individuals with autism.

In conclusion, the current study was the first attempt to examine the role that cognitive processing differences may have on categorization. Individuals with autism evidenced difficulty in categorizing atypical stimuli despite successful and efficient categorization of more typical stimuli. These results suggest a dependence on featural information in addition to a lack of configural expertise in individuals with autism across the lifespan. A significant strength of this study is that it is one of the only studies in the field of autism that has examined abilities in children, teens, and adults. This set of studies also suggests that individuals with autism may have a core cognitive difference in processing from early in life that may exist in addition to or precipitate social deficits. While the current study is an important first step, many more studies need to be conducted in order to determine the exact role that these differences play in the syndrome of autism. Even so, this set of studies highlights the need to consider of the role that cognitive processes may play in the syndrome of autism in future research.

REFERENCES

American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders, 4th ed., Text Revision (DSM-IV-TR).* Washington, DC: American Psychiatric Association.

Baker, B. I., Behrmann, M., & Olson, C. R. (2002). Impact of learning on representation of parts and wholes in monkey inferotemporal cortex. *Nature Neuroscience*, 5, 1210-1216.

Bara, B. G., Bucciarelli, M., & Colle, L. (2001). Communicative abilities in autism: Evidence for attentional deficits. *Brain & Language*, 77, 216-240.

Baron-Cohen, S. (1991). The theory of mind deficit in autism: How specific is it? *British Journal of Developmental Psychology*, 9, 301-314.

Barrett, M. (1995). Early lexical development. In P. Fletcher & B. Macwhinney (Eds.), *The Handbook of Child Language* (pp. 362-392). Oxford, England: Blackwell.

Bauer, P. J., Dow, G. A., & Hertsgaard, L. A. (1995). Effects of prototypicality on categorization in 1- to 2-year olds: Getting down to basic. *Cognitive Development*, 10, 43-68.

Bauman, M. L. & Kemper, T. L. (1994). Neuroanatomic observations of the brain in autism. In M. L. Bauman & T. L. Kemper (Eds.), *The Neurobiology of Autism* (pp. 119-145). Baltimore: Johns Hopkins Press.

Behrmann, M., Avidan, G., Leonard, G. L., Kimchi, R., Luna, B., Humphreys, K., et al. (2005). Configural processing in autism and its relationship to face processing. *Neuropsychologia*, in press.

Best, C. A., Strauss, M. S., Newell, L. C., & Minshew, N. J. (2005, May). *Face knowledge in individuals with autism: Abstracting specific information from faces.* Poster presented at the International Meeting for Autism Research, Boston, MA.

Boucher, J. & Lewis, V. (1992). Unfamiliar face recognition in relatively able autistic children. *Journal of Child Psychology and Psychiatry*, 33, 843-859.

Bruner, J. S., Goodnow, J., & Austin, G. (1956). *A Study of Thinking*. New York: Wiley.

Cabeza, R. & Kato, T. (2000). Features are also important: Contributions of featural and configural processing to face recognition. *Psychological Science*, 11, 429-433.

Courchesne, E., Carper, R., & Akshoomoff, N. (2003). Evidence of brain overgrowth in the first year of life in autism. *JAMA*, 290, 337-344.

Curby, K. M. & Gauthier, I. (2002). *Face-selectivity to highpass but not lowpass filtered images in a person with Asperger's syndrome*. In: Proceedings of the Human Brain Mapping, Sendai, Japan.

Curby, K. M., Schyns, P., Gosselin, F., & Gauthier, I. (2003). *Differential use of spatial frequency scales for face recognition in a person with Asperger's syndrome.* In: Proceedings of the 3rd Annual Meeting of the Vision Society, Sarasota, FA.

Davies, S., Bishop, D., Manstead, A. S., & Tantum, D. (1994). Face perception in children with autism and Asperger syndrome. *Journal of Child Psychology and Psychiatry*, 35, 1033-1057.

Dawson, G., Webb, S. J., & McPartland, J. (2005). Understanding the nature of face processing impairment in autism: Insights from behavioral and electrophysiological studies. *Developmental Neuropsychology*, 27, 403-424.

de Haan, M., Johnson, M. H., Maurer, D., & Perrett, D. (2001). Recognition of individual faces and average face prototypes by 1- and 3-month-old infants. *Cognitive Development*, 16, 659-678.

Deruelle, C. & Fagot, J. (2005). Categorizing facial identities, emotions, and genders: Attention to high- and low-spatial frequencies by children and adults. *Journal of Experimental Child Psychology*, 90, 172-184.

Deruelle, C., Rondan, C., Gepner, B. & Tardif, C. (2004). Spatial frequency and face processing in children with autism and Asperger syndrome. *Journal of Autism and Developmental Disorders*, 34, 199-210.

Deurelle, C., Rondan, C., Gepner, B., Wicker, B., & Fagot, J. (submitted). Global and configural shape processing in children with autism.

Diamond, R. & Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology*, 115, 107-117.

Ellis, A. E. & Nelson, C. A. (1999). Category prototypicality judgments in adults and children: Behavioral and electrophysiological correlates. *Developmental Neuropsychology*, 15(2), 193-211.

First, M. B., Gibbon, M., Spitzer, R. L., & Williams, J. B.W. (1996). *User's Guide for the Structured Clinical Interview for DSM-IV Axis I Disorders-Research Version (SCID-I).* Washington, DC: American Psychiatric Press.

Fombonne, E. (1999). The epidemiology of autism: A review. *Psychological Medicine*, 29, 769-786.

Frith, U. & Happe, F. (1994). Autism: Beyond "theory of mind". *Cognition*, 50, 115-132.

Fujihara, N., Nagaeishi, Y., Koyama, S., & Nakajima, Y. (1998). Electrophysiological evidence for the typicality effect of human cognitive categorization. *International Journal of Psychophysiology*, 29, 65-75.

Gauther, I. & Tarr, M. J. (1997). Becoming a Greeble expert: Exploring mechanisms for face recognition. *Vision Research*, 37, 1673-1682.

Gauthier, I. & Tarr, M. J. (2002). Unraveling mechanisms for expert object recognition: Bridging brain activity and behavior. *Journal of Experimental Psychology: Human Perception & Performance*, 28, 431-446.

Gauthier, I., Tarr, M. J., Anderson, A. W., Skudlarski, P., & Gore, J. C. (1999). Activation of the middle fusiform "face area" increases with expertise in recognizing novel objects. *Nature Neuroscience*, 2, 568-573.

Gauthier, I., Tarr, M. J., Moylan, J., Anderson, A. W., Skudlarski, P., & Gore, J. C. (2000). Does visual subordinate-level categorisation engage the functionally defined fusiform face area? *Cognitive Neuropsychology*, 17, 143-163.

Gauthier, I., Williams, P., Tarr, M. J., & Tanaka, J. (1998). Training 'greeble' experts: A framework for studying expert object recognition processes. *Vision Research*, 38, 2401-2428.

Grice, S., Spratling, M., Karmiloff-Smith, A., Halit, H., Csibra, G., de-Haan, M., et al. (2001). Disordered visual processing and oscillatory brain activity in autism and Williams syndrome. *Neuroreport: For Rapid Communication of Neuroscience Research*, 12, 2697-2700.

Haxby, J. V., Horwitz, B., Ungerleider, L. G., Maisog, J. M., Pietrini, P., & Grady, C. L. (1994). The functional organization of human extrastriate cortex: a PET-rCBF study of selective attention to faces and locations. *Journal of Neuroscience*, 14, 6336-6353.

Heider, E. R. (1972). Universals in color naming and memory. *Journal of Experimental Psychology*, 93, 10-20.

Herbert, M. R., Ziegler, D. A., Deutsch, C. K., O'Brien, L. M., Lange, N., Bakardjiev, A., et al. (2003). Dissociations of cerebral cortex, subcortical, and cerebral white matter. *Brain*, 126, 1182-1192.

Hermelin, B. & O'Connor, N. (1970). *Psychological Experiments with Autistic Children*. Oxford: Pergamon Press.

Hobson, R. P., Ouston, J., & Lee, A. (1988). What's in a face? The case of autism. *British Journal of Psychology*, 79, 441-453.

Homa, D., Smith, C., & Macak, C. (2001). Recognition of facial prototypes: The importance of categorical structure and degree of learning. *Journal of Memory and Language*, 44, 443-474.

Hubl, D., Bölte, S., Feineis-Matthews, C., Lanfermann, H., Federspiel, A., Strik, W., et al. (2003). Functional imbalance of visual pathways indicates alternative face processing strategies in autism. *Neurology*, 61, 1232-1237.

Ingvalson, E. M. & Wenger, M. J. (2005). A strong test of the dual-mode hypothesis. *Perception & Psychophysics*, 67, 14-35.

James, W. (1981). *The Principles of Psychology*. Cambridge: Harvard University Press.

Joseph, R. M. & Tanaka, J. (2003). Holistic and part-based face recognition in children with autism. *Journal of Child Psychology and Psychiatry*, 44, 529-542.

Kanner, L., Rodriguez, A., & Ashenden, B. (1972). How far can autistic children go in matters of social adaptation? *Journal of Autism and Childhood Schizophrenia*, 2, 9-33.

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience*, 17, 4302-4311.

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry*, 59, 809-816.

Klinger, L. G. & Dawson, G. (1995). A fresh look at categorization abilities in persons with autism. In E. Schopler & G. Mesibov (Eds.), *Learning and Cognition in Autism* (pp. 119-136). New York: Plenum Press.

Klinger, L. G. & Dawson, G. (2001). Prototype formation in autism. *Development and Psychology*, 13, 111-124.

Lahaie, A., Mottron, L., Arguin, M., Berthiaume, C., Jemel, B., & Saumier, D. (2005). Face perception in high-functioning autistic adults: Evidence for superior processing of face parts, not for a configural face processing deficit. Unpublished manuscript.

Langdell, T. (1978). Recognition of faces: An approach to the study of autism. *Journal of Child Psychology and Psychiatry*, 19, 255-268.

Lewis, P. & Strauss, M. S. (1986). Infant concept development. In G. Whitehurst (Ed.), *Annals of Child Development*. Connecticut: J. A. I. Press.

Lord, C., Rutter, M., Goode, S., Heemsbergen, J., Jordan, H., Mawhood, L., et al. (1989). Autism diagnostic observation schedule: A standardized observation of communicative and social behavior. *Journal of Autism and Developmental Disorders*, 19, 185-212.

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism Diagnostic Interview-Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, 24, 659-695.

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences*, 6, 255-260.

McPartland, J., Dawson, G., Webb, S., Pangiotides, H. & Carver, L. (2004). Event-related brain potentials reveal anomalies in temporal processing of faces in autism spectrum disorder. *Journal of Child Psychology and Psychiatry*, 45, 1235-1245.

Minshew, N. J., Goldstein, G., Muenz, L. R., & Payton, J. B. (1992). Neuropsychological functioning in non-mentally retarded autistic individuals. *Journal of Clinical and Experimental Neuropsychology*, 14, 749-761.

Minshew, N. J., Goldstein, G., & Siegel, D. J. (1997). Neuropsychologic functioning in autism: Profile of a complex information processing disorder. *Journal of the International Neuropsychological Society*, 3, 303-316.

Minshew, N. J., Meyer, J., & Goldstein, G. (2002). Abstract reasoning in autism: A dissociation between concept formation and concept identification. *Neuropsychology*, 16(3), 327-224.

Miyashita, T. (1988). Discrimination of facial components in autistic children. *Shinrigaku Kenkyu*, 59, 206-212.

Mondloch, C. J., Le Grand, R., & Maurer, D. (2002). Configural face processing develops more slowly that featural face processing. *Perception*, 2002, 553-566.

Murphy, G. L. (2002). *The big book of concepts.* Cambridge: MIT Press.

Nelson, K. (1974). Concept, word and sentence: Interrelations in acquisition and development. *Psychological Review*, 81, 267-285.

Noach, M. (1974). Concept formation in the speaking autistic child. *International Journal of Mental Health*, 3, 100-109.

Noudoost, B., Adabi, M., Moeeny, A., & Esteky, H. (2005). Configural and analytical processing of familiar and unfamiliar faces. *Cognitive Brain Research*, 24, 436-441.

Ozonoff, S. (1997). Components of executive function deficits in autism and other disorders. In J. Russell (Ed.), *Autism as an Executive Disorder* (pp. 179-211). United Kingdom, Oxford University Press.

Pierce, K., Müller, R.-A, Ambrose, J., Allen, G. & Courchesne, E. (2001). Face processing occurs outside the fusiform 'face area' in autism: Evidence from functional MRI. *Brain*, 124, 2059-2073.

Piven. J., Arndt, S., Bailey, J., & Andreasen, N. (1996). Regional brain enlargement in autism: A magnetic resonance imaging study. *Journal of the American Academy of Child and Adolescent Psychiatry*, 35, 1-7.

Piven, J., Palmer, P., Jacobi, D., Childress, D., & Arndt, S. (1997). The broader autism phenotype: Evidence from a family history study of multiple-incidence autism families. *American Journal of Psychiatry*, 154, 185-190.

Plaisted, K. C., O'Riordan, M. A., & Baron-Cohen, S. (1998). Enhanced discrimination of novel, highly similar stimuli by adults with autism during a perceptual learning task. *Journal of Child Psychology and Psychiatry*, 39, 765-775.

Plaisted, K. C. (2000). Aspects of autism that theory of mind cannot explain. In Baron-Cohen, S., Tager-Flusberg, H. & Cohen, D. J. (Eds.), *Understanding Other Minds: Perspectives from Developmental Cognitive Neuroscience*. New York: Oxford University Press.

Puce, A., Allison, T., Gore, J. C., & McCarthy, G. (1995). Face-sensitive regions in human extrastriate cortex studied by functional MRI. *Journal of Neurophysiology*, 74, 1192-1199.

Rakison, D. H. & Polin-Dubois. (2001). Developmental origin of the animate-inanimate distinction. *Psychological Bulletin*, 127, 209-228.

Rinehart, N. J., Bradshaw, J. L., Moss, S. A., Brereton, A. V., & Tonge, B. J. (2001). A deficit in shifting attention present in high-functioning autism but not Asperger's disorder. *Autism*, 5, 67-80.

Rosch, E. (1975). The nature of mental codes for color categories. *Journal of Experimental Psychology: Human Perception and Performance*, 1, 303-322.

Rosch, E. (1978). Principles of categorization. In E. Rosch & B. B. Lloyd (Eds.), *Cognition and Categorization* (pp. 27-48). Hillsdale, NJ: Erlbaum.

Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology*, 8, 382-439.

Rumsey, J. M. (1985). Conceptual problem solving in highly verbal, nonretarded autistic men. *Journal of Autism and Developmental Disorders*, 15, 23-26.

Rutter, M. (1978). Diagnosis and definitions of childhood autism. *Journal of Autism & Childhood Schizophrenia*, 8, 139-161.

Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science*, 274, 1926-1928.

Schultz, R. T. (2005). Developmental deficits in social perception in autism: The role of amygdala and fusiform face area. *International Journal of Developmental Neuroscience*, 23, 125-141.

Schultz, R. T., Gauthier, I., Klin, A., Fulbright, R. K., Anderson, A. W., Volkmar, F., et al. (2000). Abnormal ventral temporal cortical activity during face discrimination among individuals with autism and Asperger syndrome. *Archives of General Psychiatry*, 57, 331-340.

Shulman, C., Yirmiya, C., & Greenbaum, C. W. (1995). From categorization to classification: A comparison among individuals with autism, mental retardation and normal development. *Journal of Abnormal Psychology*, 104 (4), 601-609.

Schwarzer, G. (2000). Development of face processing: The effect of face inversion. *Child Development*, 71, 391-401.

Siegel, D. J., Minshew, N. J., & Goldstein, G. (1996). Wechsler IQ profiles in diagnosis of high-functioning autism. *Journal of Autism and Developmental Disorders*, 26, 389-406.

Southgate, V. & Meints, K. (2000). Typicality, naming, and category membership in young children. *Cognitive Linguistics*, 11, 5-16.

Smith, E. E. & Medin, D. L. (2002). The exemplar view. In D. J. Levitin (Ed.), *Foundations of cognitive psychology: Core readings* (pp. 277-292). Cambridge: MIT Press.

Strauss, M. S. (1979). The abstraction of prototypical information by adults and 10-month old infants. *Journal of Experimental Psychology: Human Learning and Memory*, 50, 618-632.

Strauss, M., Newell, L., & Best, C. (2003, April). *The development of face expertise: The perception and recognition of faces by infants, preschoolers and individuals with autism.*

Paper presented at the Society for Research in Child Development Biennial Meeting, Tampa, FL.

Strauss, M. S., Turner, K., Booth, J., & Minshew, N. J. (2005, May). *Numerical estimation: Do individuals with autism demonstrate superior abilities?* Poster presented at the International Meeting for Autism Research, Boston, MA.

Tager-Flusberg, H. (1985a). Basic level and superordinate level categorization in autistic, mentally retarded, and normal children. *Journal of Experimental Child Psychology*, 40, 450-469.

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

Tanaka, J. W. (2001). The entry point of face recognition: Evidence for face expertise. *Journal of Experimental Psychology: General*, 130, 534-543.

Tanaka, J. & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology*, 46, 225-245

Tanaka, J. W. & Taylor, M. (1991). Object categories and expertise: Is the basic level in the eye of the beholder? *Cognitive Psychology*, 23, 457-482.

Tantum, D., Monaghan, L., Nicholson, H. & Stirling, J. (1989). Autistic children's ability to interpret faces: A research note. *Journal of Child Psychology and Psychiatry*, 30, 623-630.

Tarr, M. J. & Cheng, Y. D. (2003). Learning to see faces and objects. *Trends in Cognitive Sciences*, 7, 23-30.

Teunisse, J. P. & de Gelder, B. (2003). Face processing in adolescents with autistic disorder: The inversion and composite effects. *Brain & Cognition*, 52, 285-294.

Tsai, L. Y. (1992). Diagnostic issues in high-functioning autism. In E. Schopler & G. Mesibov (Eds.), *High-functioning Individuals with Autism* (pp. 11-40). New York: Plenum Press.

Ungerer, J. A. & Sigman, M. (1987). Categorization skills and receptive language development in autistic children. *Journal of Autism and Developmental Disorders*, 17, 3-16.

van der Geest, J. N., Kemner, C., Verbaten, M. N., & van Engeland, H. (2002). Gaze behavior of children with pervasive developmental disorder toward human faces: A fixation time study. *Journal of Child Psychology and Psychiatry*, 43, 669-778.

Wechsler, D. (1999). *Wechsler Abbreviated Intelligence Scale*. San Antonio: The Psychological Corporation.

Weissman, M. M., Wickramaratne, P., Adams, P., et al. (2000). Brief screening for family psychiatric history. *Arch Gen Psych*, 57**:**675-682.

Younger, B. (1986). The segregation of items into categories by ten-month-old infants. *Child Development*, 56, 1574-1583.

Younger, B. (1990). Infant categorization: Memory for category-level and specific item information. *Journal of Experimental Child Psychology*, 50, 131-155.