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Do Individuals With Autism Process Categories Differently? The Effect of Typicality and Development

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This study examined the effect of exemplar typicality on reaction time and accuracy of categorization. High-functioning children (age 9–12), adolescents (age 13–16), and adults with autism (age 17–48) and matched controls were tested in a category verification procedure. All groups showed improved processing throughout the lifespan for typical and somewhat typical category exemplars. However, individuals with autism responded more slowly than matched controls to atypical exemplars at all ages. The results are discussed in terms of potential differences in the type of processing that may be required for categorizing typical and atypical category exemplars. Parallels are also drawn to the results of previous studies on face processing in individuals with autism.

Autism is a pervasive developmental disorder characterized by qualitative impairments in social interaction and communication and repetitive stereotyped patterns of behavior, interests, and activities (American Psychiatric Association, 2000). To date, most research on autism has focused on social deficits, because they are both necessary and unique to the diagnosis. More recently, researchers have suggested that individuals with autism may also have significant cognitive deficits (e.g., Frith & Happe, 1994; Mottron & Belleville, 1993; Ozonoff, 1997; Plaisted, O'Riordan, & Baron-Cohen, 1998). Several theories have been proposed to explain these cognitive, deficits including executive functioning (e.g., Ozonoff, 1997), weak central coherence (e.g., Frith & Happe, 1994), and attentional theories (e.g., Burack, 1994). While these theories explain some behaviors associated with autism, they have had limited success in explaining all of the core symptoms.

One critical aspect of cognitive processing that has received little attention in individuals with autism is categorization. Categorization is critically important, and it is evident that within the first year of life infants begin to form categories (e.g., Lewis & Strauss, 1986; Quinn & Oates, 2004). Categorization reduces demands on memory and allows individuals to focus on 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 these differences could make a significant contribution to the social, communication, and behavioral deficits that are core features of autism. A child who is unable to organize and make sense of the world could become overstimulated and withdraw from others and not understand what others are communicating. This is not to say that individuals with autism do not have underlying problems in theory of mind, language, and problem-solving abilities but that their minimal abilities might become rapidly over-taxed by their failure to automatically categorize information.

Categorization in Typical Populations

Considering the importance of categorization, it is not surprising that there is much research on how categories are formed and used. Classical theories of categorization conceptualized categories as groups of equally weighted exemplars that are clearly bounded and defined using simple criterial features. In studying natural categories, Rosch (1978) discovered that natural categories such as "dogs" do not have simple criterial features but have "fuzzy boundaries". Categories also have "typicality structures" in

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which some of the members are more representative or "better examples" of the 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 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. Such reaction time differences reflect memorial storage; typical exemplars of a category are easier to retrieve than less typical exemplars.

Additionally, children learn the names of typical members of novel categories more quickly than less typical members (e.g., Barrett, 1995). Typicality effects seem to be present from infancy in that 18- and 24-month-old infants look significantly longer at more typical items than less typical items (Southgate & Meints, 2000). Studies of prototype formation in infants also provide evidence for the typicality effect early in life (e.g., Strauss, 1979).

Categorization in Individuals With Autism

While a plethora of research has been performed on categorization in adults and typically developing children, there is very little research on this topic in individuals with autism. Results of studies conducted to determine if there are categorization deficits in individuals with autism have been mixed. Early studies concluded that individuals with autism are able to form categories successfully. These studies, however, used categories that had 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 (Tager-Flusberg, 1985; Ungerer & Sigman, 1987). It is possible that while individuals with autism can successfully categorize on the basis of simple definitive features, they may have difficulty categorizing when categorization is based on more complex or less perceptually apparent features (Klinger & Dawson, 1995; Plaisted, 2000). Another possible explanation for the mixed findings is that studies of categorization have failed to control for typicality of the stimuli. It is possible that while individuals with autism may be able to categorize typical exemplars, less typical exemplars may pose more difficulty. As category exemplars become less typical, criterial features also become less apparent and decision processes become more difficult. Thus, studies using only typical exemplars of a category may not indicate deficits in these individuals. Studies using atypical exemplars, however, may show categorization deficits as the task becomes more difficult.

Several studies support the notion that individuals with autism can successfully categorize when the task is simple or rule based, but have difficulty when categorization is more abstract or complex. Minshew, Meyer, and Goldstein (2002) found that high-functioning individuals with autism can group information in a rule-based manner but have difficulty when the task requires that concepts be abstracted from complex information. Several studies suggest that individuals with autism are unable to abstract prototypes or average representations of the features of a category. Klinger and Dawson (2001) compared the abilities of children with autism and typically developing children to use rule-based and prototype category learning. They found that both groups could categorize using a rule-based strategy when there was a simple distinctive feature, but children with autism were unable to abstract a prototype of animal-like categories.

Similarly, Plaisted (2000) conducted two studies that indicated that high-functioning adults and children with autism were also unable to form prototypes. The inability to abstract prototypes in individuals with autism is surprising as studies on prototype formation in children have established that infants are able to abstract prototypes by 3 months of age (Bomba & Siqueland, 1983; Quinn, 1987; Younger & Gotlieb, 1988). Taken together, these results suggest that individuals with autism may engage in different categorization processes than typically developing individuals. With respect to natural categories, it is possible that individuals with autism are able to categorize typical category members efficiently and accurately using simple definitive features but have difficulty categorizing less typical category members which require a different, more complex processing strategy.

Another aspect of categorization that has yet to be explored is the developmental course of categorization in individuals with autism. While studies have examined whether children *or* adults with autism can categorize, no study has examined processing differences across the lifespan. Are categorization differences apparent in both children and adults with autism? If so, are there any improvements with development? How does the development of categorization compare in typically and atypically developing individuals? To answer these questions, it is necessary to study children, adolescents, and adults using the same categorization task.

Thus, the current study is unique in that it examines categorization processes across development from childhood to adulthood. It is also the first study to consider the role of typicality or task difficulty in categorization. Finally in contrast to previous studies on the categorization abilities of individuals with autism, this study used stimuli from natural categories as opposed to artificial categories.

Experiment 1 was designed to look at the ability of high-functioning children and adolescents with autism to categorize natural category exemplars. A verification task was designed to allow measurement of both accuracy and reaction time to category exemplars varying in typicality from typical to atypical.

Experiment 1

Method

Participants

Child participants were 28 high-functioning children with autism and 24 healthy child control individuals between the ages of 9 and 12. Adolescent participants were 20 high-functioning adolescents with autism (age 13–16) and 19 healthy control adolescents (age 13–16). Control participants in each age group (child or adolescent) were matched with the autism group (same mean with equal variances) on age, Full Scale Intelligence Quotient, Verbal Intelligence Quotient, and Performance Intelligence Quotient. Table 1 summarizes the participants' demographic characteristics. No significant differences existed between the autism and control groups on any of the demographic variables.

Table 1

Demographic Characteristics of Autism and Control Groups for Experiment 1

	Autism group ($N = 28$)		Control group ($N = 24$)	
	M	*SD*	*M*	*SD*
Children				
Age	10.32	1.16	10.92	1.06
VIQ	104.11	11.61	106.38	10.57
PIQ	107.79	13.49	107.63	10.99
FSIQ	106.68	10.58	108.04	10.22
Gender (M:F)	27:1		19:5	
Ethnicity	28 Caucasian		23 Caucasian 1 unknown/other	

	Autism group ($N = 20$)		Control group ($N = 19$)	
	M	*SD*	*M*	*SD*
Adolescents				
Age	14.25	0.97	14.11	1.15
VIQ	102.60	12.79	107.95	12.80
PIQ	110.70	11.20	108.11	9.67
FSIQ	107.15	11.52	109.16	11.66
Gender (M:F)	15:5		16:3	
Ethnicity	17 Caucasian 3 unknown/other		16 Caucasian 2 African American 1 unknown/other	

Note. FSIQ = Full-Scale IQ; PIQ = Performance IQ; VIQ = Verbal IQ.
Age is indicated in years.
Ethnicity was obtained by parent report.

Participants were recruited through posters and newspaper, radio, and television advertisements. Participants with autism were administered a diagnostic evaluation consisting of the Autism Diagnostic Observation Schedule–General (ADOS–G; Lord et al., 1989) and the Autism Diagnostic Interview-Revised (ADI–R; Lord, Rutter, & Le Couteur, 1994) with confirmation by expert clinical opinion. Both instruments were scored using the *Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition* (American Psychiatric Association, 2000) scoring algorithm for autism. Children and adolescents with Asperger's disorder or PDD-NOS were excluded. Participants with autism were also required to be in good medical health, free of seizures, have a negative history of traumatic brain injury, and have an IQ >80 as determined by the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999).

Control participants were volunteers recruited from the community. Parents of potential control participants completed questionnaires on demographic and family information to determine eligibility. Control participants were required to be in good physical health, free of past or current neurologic or psychiatric disorders, have a negative family history of first-degree relatives with major psychiatric disorders, and have a negative family history in first- and second-degree relatives of autism spectrum disorder. Control participants were also excluded if they had a history of poor school attendance or evidence of a disparity between general level of ability and academic achievement suggesting a learning disability. The Wide Range Achievement Test–IV was administered to exclude the presence of a learning disability.

Apparatus

Testing occurred in a quiet room. Each participant sat in front of a 43-cm monitor controlled by a computer and responded using a modified keyboard with large keys (approximately 2.54 cm squares) that is commercially available for young children. Black felt covered all keys except the two response keys labeled "true" and "false." The position (left/right) of the "true" and "false" labels was counterbalanced.

Stimulus Materials

Visual stimuli. The category verification task consisted of color pictures of exemplars from four basic level object categories that were equal in size. The categories consisted of two natural, animate categories (cats and dogs) and two artificial, inanimate categories (couches and chairs). Thus, the categories included objects with which all participants had significant experience. Each category consisted of 24 members, all of which varied along a dimension of typicality (typical, somewhat typical, and atypical) as judged by previously obtained adult ratings.

A pilot study with 100 college students determined the typicality of the included object exemplars. Students viewed 50 pictures from each object category on a computer monitor and rated each object on a 7-point typicality scale. Before rating the pictures, students heard the following instructions, "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 to 7 with 1 being a *really bad example* like a penguin and 7 being a *really good example* like a robin." The students viewed each category separately with the order counterbalanced across participants. Participants indicated their ratings for each stimulus by circling the number corresponding to their rating on an answer sheet. Selected stimuli for inclusion in the study consisted of the 8 stimuli from each category that the college students rated as most typical of the category (most typical), the 8 stimuli rated as least typical (least typical), and the eight stimuli that bordered both sides of the mean of the category (somewhat typical). Thus, the experiment included 24 exemplars for each object category and a total of 96 exemplars. Table 2 shows the means and standard deviations of the typicality ratings for the typical, somewhat typical, and least typical groups of stimuli.

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

	Couches	Chairs	Cats	Dogs
Atypical				
M	2.74	2.42	2.60	2.26
SD	0.69	0.65	1.01	0.63
Somewhat typical				
M	5.04	4.37	4.30	4.09
SD	0.44	0.51	0.18	0.44
Typical				
M	6.29	5.91	5.37	5.77
SD	0.25	0.53	0.50	0.65

Auditory stimuli. The auditory stimuli consisted of the same recorded voice saying "dog," "cat," "couch," or "chair." All auditory stimuli were of the same volume, duration, and intensity.

Procedure

The experiment consisted of a category verification procedure. First the participant heard an auditory stimulus 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 judged whether the pictured object was or was not a member of the category presented auditorily. Participants responded by pressing the "true" button if the object belonged to the named category or "false" if it did not belong. Participants were encouraged to respond as quickly and accurately as possible and did not receive any feedback on the accuracy of their responses.

Following the instructions, participants performed 4 practice trials to insure they understood the instructions. The practice trials consisted of true and false verifications of two categories (birds and tables) not used in the study. Following the practice trials, participants were given the 96 test trials.

For each object category, 25% of the verifications were false (the word and picture did not match each other) while 75% of the verifications were true (the word and picture did match each other). Essentially, the "false" trials were a necessary task parameter, with the expectation that the results of this limited number of trials would not be analyzed. 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 viewed an equal number of typical, somewhat typical, and atypical exemplars.

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 "false" trials.

Preliminary Analyses

A number of preliminary analyses determined 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 × Category interaction existed in a number of these analyses. However, 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. Because the number of child versus adolescent participants was fairly different and the child data were more variable than the adolescent data, it was decided not to carry out overall analyses with age as a factor. Instead, the results for the children will be presented followed by the results for the adolescents.

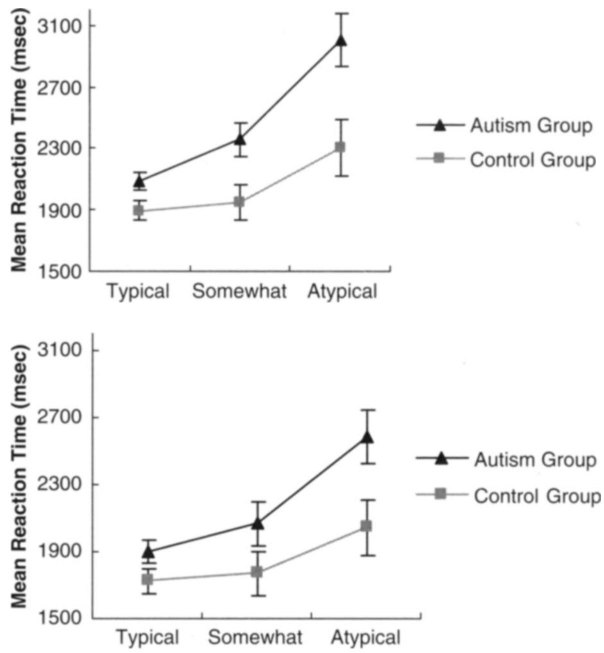

Figure 1. (a) Reaction times for the combined category data by typicality for children. (b) Reaction times for the combined category data by typicality for adolescents.

Child Results

Reaction time results. A two-way analysis of variance (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, $F(2, 100) = 36.35$, $p < .01$, with reaction times for both groups being slower for the less typical stimuli. Results also indicated a significant main effect of group, $F(1, 50) = 8.10$, $p < .01$. In general, the responses of children with autism were significantly slower than those of control children. There was also a significant Typicality × Group interaction, $F(2, 100) = 4.94$, $p < .05$. The reaction time means for the combined category data are presented in Figure 1a. As can be seen, the significant interaction indicated that typicality had more of an effect on the reaction times of children with autism than control children. It is this interaction that is of particular interest. Specifically, to what extent did typicality affect the reaction times of control children in comparison with children with autism?

Of primary interest was how much slower the reaction times were when the children categorized either somewhat typical or atypical stimuli in comparison with typical stimuli. Because the children with autism responded more slowly than the control children to all stimuli, the reaction times for both groups were converted into percentage scores indicating how much more slowly (in percentage) each group responded to the somewhat typical and atypical stimuli in comparison with the typical stimuli.

Results indicated that children with autism responded 12% more slowly to the somewhat typical stimuli in comparison with control children who only responded 3% more slowly to these stimuli, $t(50) = -2.03$, $p < .05$. This effect was even more dramatic for the atypical stimuli, as children with autism responded 42% more slowly to the atypical stimuli in comparison with control children who responded only 22% more slowly to these stimuli, $t(50) = -2.43$, $p < .01$. Thus, while the reaction times of both groups were slower for the somewhat typical and atypical stimuli, reaction times were particularly slowed for children with autism.

Figure 2a shows the mean percentage change in reaction time for the 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 control children to the somewhat typical and atypical stimuli. This pattern was not true for the dog category.

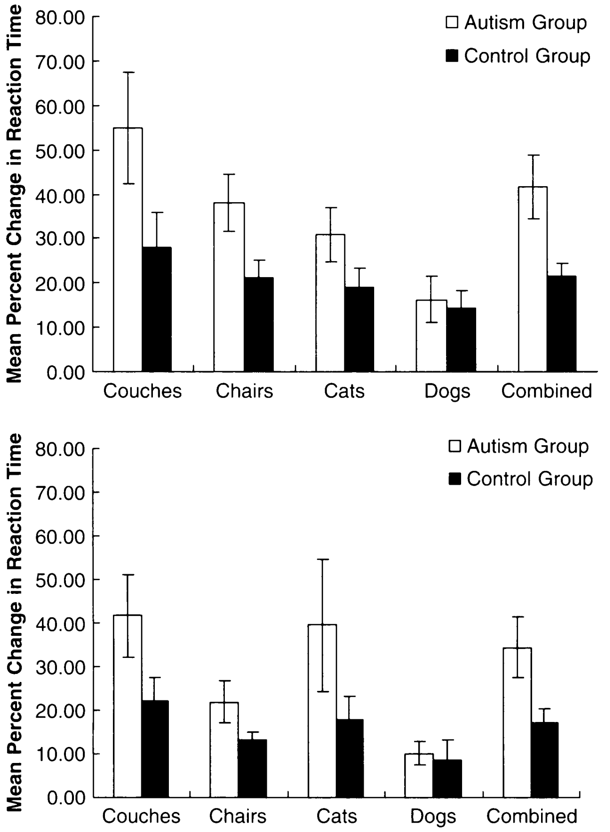

Figure 2. (a) Percentage change in reaction time by category for atypical stimuli for children. (b) Percentage change in reaction time by category for atypical stimuli for adolescents.

In fact, children with autism and control children did not differ in the amount that their reaction times were slowed by the somewhat typical or atypical dog stimuli.

Accuracy results. A two-way ANOVA was conducted on the percentage 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 showed a significant main effect of typicality, $F(2, 100) = 11.85$, $p < .01$, indicating that all participants were less accurate on the atypical stimuli ($M = 92\%$) than the somewhat typical ($M = 96\%$) or typical ($M = 97\%$) stimuli. There were no other significant main effects or interactions.

Adolescent Results

Reaction time results. A two-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, $F(2, 74) = 28.02$, $p < .01$, with reaction times for both groups being slower for the less typical stimuli. Results also indicated a significant main effect of group, $F(1, 37) = 4.39$, $p < .05$. The responses of adolescents with autism were significantly slower than those of control adolescents. The Typicality × Group interaction was also significant, $F(2, 74) = 3.47$, $p < .05$. As can be seen in Figure 1b, the significant interaction indicated that typicality had more of an effect on the reaction times of adolescents with autism than the control adolescents.

As with the child data, of primary interest was how much slower the reaction times were when the adolescents were given either somewhat typical or atypical stimuli in comparison with typical stimuli. Thus, again, the reaction times for each group were converted into percentage scores indicating how much more slowly (in percentage) each group responded to the somewhat typical and atypical stimuli in comparison with the typical stimuli.

Results indicate that in contrast to the children, adolescents with autism and control adolescents did not differ in the amount that their reaction times were slowed by the somewhat typical stimuli, $t(37) = -0.91$, $p = .37$. However, for atypical stimuli, the results for the adolescents were similar to the child results. That is, adolescents with autism responded much more slowly than control adolescents to the atypical stimuli, $t(37) = -2.23$, $p < .05$. Thus, adolescents with autism were more efficient in processing the somewhat typical stimuli, but continued to have difficulty processing the more atypical category members.

Figure 2b shows the mean percentage 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. Again, this pattern was not true for the dog category.

Accuracy results. A two-way ANOVA was conducted on the percentage correct scores for the combined category data with group (autism vs. control) as the between-subjects variable and typicality (typical vs. somewhat typical vs. atypical) as the within-subjects variable. Results showed a significant main effect of typicality, $F(2, 74) = 12.00$, $p < .01$, indicating that all adolescents were less accurate for the atypical stimuli ($M = 94\%$) than the somewhat typical ($M = 98\%$) or typical stimuli ($M = 98\%$). There were no other significant main effects or interactions.

Discussion

Results of Experiment 1 indicate that while the reaction times of both control children and children with autism were slower for the somewhat typical and atypical 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 for somewhat and atypical stimuli. However unlike children with autism, the reaction times of adolescents with autism were not significantly slower than control adolescents for the somewhat typical stimuli. Thus, with experience, adolescents with autism were able to categorize somewhat typical members of categories as efficiently as control adolescents. In contrast, adolescents with autism, like children with autism, responded significantly more slowly than control adolescents to atypical category members. As will be considered in the general discussion, it is possible that children and adolescents with autism 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 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.

Given the developmental change from childhood to adolescence for somewhat typical stimuli, an important question is whether the two groups would respond similarly to atypical stimuli as adults. It is possible that more experience with object categories into adulthood improves categorization efficiency and accuracy for atypical category members in individuals with autism. To address this, the exact same procedure was performed with adults with autism and control adults. If experience with object categories aids categorization of atypical category members, adults with autism should not respond significantly more slowly than control adults to these category members.

Experiment 2

Method

Participants

Participants were 28 high-functioning adults with autism and 27 healthy adult control individuals. Recruitment, inclusion/exclusion criteria, and matching criteria were identical to Experiment 1. Table 3 summarizes the participants' sociodemographic characteristics. No significant differences existed between the two groups on any of the demographic variables.

Table 3

Demographic Characteristics of Autism and Control Groups for Experiment 3

	Autism group (N = 28)		Control group (N = 27)	
	M	*SD*	*M*	*SD*
Age	24.39	8.22	23.07	4.13
VIQ	103.43	13.88	109.96	9.75
PIQ	109.04	7.50	111.52	10.40
FSIQ	107.11	10.12	111.93	10.16
Gender (M:F)	25:3		25:2	
Ethnicity	25 Caucasian 1 African American 2 unknown/other		25 Caucasian 2 unknown/other	

Note. FSIQ = Full-scale IQ; PIQ = Performance IQ; VIQ = Verbal IQ.
Age is indicated in years.
Ethnicity was obtained by self-report.

Apparatus, Stimulus Materials, and Procedures

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

Results

Similar to Experiment 1, 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.

Reaction Time Results

A two-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 reaction times for both groups being slower for the less typical stimuli. Results also indicated a significant main effect of group, $F(1, 53) = 7.33$, $p < .01$. The responses of adults with autism were significantly slower than those of control adults. There was also a significant Typicality × Group interaction, $F(2, 106) = 3.89$, $p < .05$. The

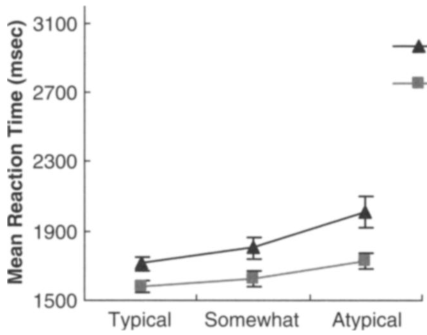

Figure 3. Adult reaction times for combined category data by typicality.

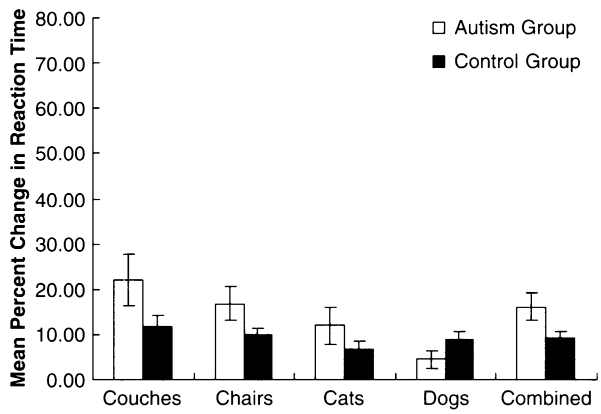

Figure 4. Adult percentage change in reaction time by category for atypical stimuli.

reaction times for the combined category data are presented in Figure 3. As can be seen, the significant interaction indicated that typicality had more of an effect on the reaction times of adults with autism than control adults.

As with Experiment 1, of primary interest was how much slower the reaction times were for each group when the adults viewed somewhat typical or atypical stimuli in comparison with typical stimuli. Thus, the mean reaction times for each group were converted into percentage scores indicating how much more slowly (in percentage) each group responded to the somewhat typical and atypical stimuli in comparison with the typical stimuli.

Results indicated that like the adolescents, adults with autism and control adults did not differ in the amount that their reaction times were slowed by the somewhat typical stimuli, $t(53) = -.42$, $p = .34$. However, for atypical stimuli, adults with autism responded in a manner that was similar to that of children and adolescents with autism. As can be seen, adults with autism responded more slowly to the atypical stimuli in comparison with control adults, $t(53) = -2.09$, $p < .05$. Thus, adults with autism continued to have difficulty processing atypical category members.

Figure 4 shows the mean percentage 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 adolescent data, a similar pattern of results existed for the cat, chair, couch, and combined category data in the adults. Again, this pattern was not true for the dog category.

Accuracy Results

A two-way ANOVA was conducted on the percentage correct scores for the combined category data with group (autism vs. control) as the between-subjects variable and typicality (typical vs. somewhat typical vs. atypical) as the within-subjects variable. Results showed a significant main effect of typicality, $F(2, 106) = 4.40$, $p < .05$, indicating that all participants were slightly less accurate for the atypical stimuli (M = 97%) than the typical (M = 98%) or somewhat typical stimuli (M = 99%). There was also a significant main effect of group, $F(1, 53) = 5.24$, $p < .05$, indicating that adults with autism were slightly less accurate than control adults.

Discussion

Results of Experiment 2 indicated that adults with autism, like children and adolescents with autism, responded significantly more slowly 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 slightly less accurate than control adults. Thus, while experience with object categories improved the processing of somewhat typical category members between childhood and the adolescent 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 adults with autism never quite reached this level of accuracy. Thus, for both reaction times and error rates, adults with autism evidenced a deficit in processing atypical category members throughout the lifespan.

General Discussion

This study was the first to examine categorization abilities in individuals with autism across the lifespan and one of few studies to utilize reaction time to measure potential processing differences. The study explored how individuals with autism and matched controls process categories that varied in typicality and how these abilities change with development.

The results clearly indicated that both 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 adolescent years, categorization ability and processing efficiency of typical and somewhat typical category members developed to a comparable 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 in categorization as control adults for the atypical category members.

Previous studies on the categorization abilities of individuals with autism resulted in mixed findings, some indicating a deficit in categorization and others not. However, none of the previous research considered the effect that typicality or task difficulty may have on categorization ability. The results of this study suggest that individuals with autism can readily categorize when the task involves simple and typical basic objects but have difficulty when categorization is more complex or involves less typical objects. 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 categorize successfully but may need significant amounts of processing time in order to do so. Indeed, studies of both facial processing (De Sonneville et al., 2002) and visual attention (Margolis, Kirk, Kemp, & Korkman, 2001) suggest that while children reach adult levels of accuracy at relatively young ages, there is continual improvement in processing efficiency as reflected in their decreasing reaction times.

The above results must be qualified by the fact that these results were found for the categories of couches, chairs, and cats, but not dogs. Importantly, reaction time typicality effects were not found for the dogs for either control participants or participants with autism. At issue is why there were no typicality effects for the dogs in either group. One possibility is that the lack of effect was due to the particular exemplars specifically used in this study and that other exemplars would have resulted in an effect. While the mean ratings in terms of typicality for the dogs were comparable to the other categories, looking more carefully at the particular stimuli used in the study, it appears that all of the categories contained atypical stimuli that were different enough from the perceptual structure of the basic level category that they truly appeared "different" or atypical. In contrast, for the dogs, the atypical exemplars used (e.g., poodle, llhasa apso, bedlington terrier) still clearly looked like dogs. Thus, as is explained in more detail later in the discussion, these atypical exemplars may not have required any additional processing as is usually needed to categorize atypical exemplars.

An alternative possibility is that the dog exemplars were so well known to both groups of participants that the task was no longer a categorization but more of an identification or a recognition task. That is, participants may have directly recognized the actual breeds of the dogs. Indeed, participants in both groups often knew the names of all of the breeds of dogs as they demonstrated after testing. While both these explanations are speculative, it is important to note again that the lack of typicality effect was found for both groups and thus comparisons of their categorization abilities could not be made for this particular category.

A more significant question that remains is why individuals with autism processed typical and somewhat typical exemplars of categories as efficiently as control individuals by the adolescent years but categorized atypical category members less efficiently even in adulthood. At issue is why individuals, with or without autism, are slower at processing atypical exemplars and why this effect is exaggerated in individuals with autism. One possible explanation is that the efficiency of categorizing exemplars is related to an individual's familiarity with the category. That is, as one gains familiarity and experience with the members of a category, they process them more efficiently. Hence, typicality effects may come from the rarity of atypical members relative to more typical members; and the differences seen between control and autistic participants may be the result of their differential life experiences with the categories during development. While this possibility cannot be ruled out, there are two arguments against this explanation. First, prior research on categorization suggests that typicality effects are relatively independent of familiarity (e.g., Rosch, 1978). Rare, but typical looking exemplars tend to be categorized as quickly as typical exemplars. More importantly, there is no evidence in the high-functioning autism literature that suggests that individuals with autism have any less experience with common objects such as cats, chairs, or couches. Indeed, research suggests that individuals with autism spend less time attending to social stimuli and more time attending to nonsocial stimuli like common objects (Klin, Jones, Schultz, Volkmar, & Cohen, 2002). Thus, this explanation is unlikely but cannot be ruled out on the basis of the current data.

An alternative explanation is that atypical exemplars are actually *processed* differently than typical exemplars. Research on adult categorization suggests that atypical exemplars are processed more like members of a subordinate category than as members of a basic level category (Jolicoeur, Gluck, & Kosslyn, 1984; Murphy & Brownell, 1985; Piatt & Tanaka, 2005). That is, because atypical members are different from the perceptual structure of the basic level category, they require additional processing time. This research suggests two potential explanations for the extra processing time needed to categorize atypical stimuli, and it is possible that either, or both, of these processes are deficient in individuals with autism. Piatt and Tanaka (2005) suggest that atypical stimuli require additional semantic analyses in order to be categorized at the basic level. Thus, it is possible that individuals with autism never become efficient at these secondary semantic processes that are needed for categorizing atypical stimuli. While the participants were matched on Verbal and Performance IQ, perhaps the individuals with autism were slower at accessing the additional semantic information necessary for categorizing atypical stimuli.

Jolicoeur et al. (1984) suggest that rather than additional semantic processing, atypical stimuli require additional *perceptual* processing in order to be categorized. Thus, it is possible that individuals with autism have difficulty with the type of additional perceptual processes that are needed to categorize atypical stimuli. For the remainder of this paper, these additional perceptual processes will be referred to as "subordinate perceptual processes," because they are equivalent to the types of processes needed for subordinate level categorization (e.g., Gauthier et al., 2000).

We suggest that at least three types of processes may be included under the term subordinate perceptual processes. To illustrate these processes, imagine an atypical piece of furniture that is longer than the typical chair but shorter than the typical couch (i.e., a loveseat). How does one decide whether this piece of furniture is a chair or not? 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. Rather than comparing only simple features, comparisons of subordinate or atypical category members require that quantitative spatial information be considered (i.e., subtle differences in the length of a couch). Additionally when categorizing atypical or subordinate exemplars, it is necessary to carry out a careful comparison of the exemplar to stored category members or to a prototype of the category and decide if the piece of furniture looks more like the prototype or stored exemplars of couches or chairs (Homa, Smith, & Macak, 2001). Finally, categorizing atypical and subordinate 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 features 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 subordinate perceptual processes may play in the object categorization of individuals with autism. However, direct evidence that individuals with autism have difficulty with subordinate perceptual processes comes from the face and prototype literature. It is important to note that the corresponding term for subordinate perceptual processes in the face literature is configural or holistic processes. Many studies have found that individuals with autism process faces more featurally or part-based rather than using more subtle quantitative comparisons (e.g., Boucher & Lewis, 1992; Joseph & Tanaka, 2003; Klin et al., 2002). Several studies also suggest that individuals with autism are unable to abstract prototypes or average representations of the features of a category (Best, Strauss, Newell, & Minshew, 2005; Klinger & Dawson, 2001; Plaisted, 2000). Finally, a recent study (Strauss et al., 2005) on gender categorization found that, while individuals with autism were able to accurately categorize the gender of faces that were typical of men or women, they had difficulty (in terms of both accuracy and reaction time) at categorizing atypical exemplars of gender. Thus, the face and prototype literature provides evidence of deficits in two of the subordinate level perceptual processes that are probably important for the categorization of atypical stimuli.

Another question that remains is what improves that allows typically developing individuals to become more efficient at processing atypical stimuli with development. Turning again to the face literature, 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/holistic processing of faces (e.g., Mondloch, Le Grand, & Maurer, 2002). Importantly, these authors argue that in children and adults both featural and holistic (or subordinate) processes are available and that the type of processing that is engaged depends on the task and the developmental abilities of the person. For example, distinguishing two very different looking individuals (one has a beard and the other does not) may merely require comparisons of some simple features. In contrast, distinguishing two very similar looking individuals may require more configural/holistic processes. Thus, throughout the lifespan, people can engage in either type of processing, but with development they become more efficient at the type of processing that is needed for configural processing of faces. In the present study with objects, it may be that, similar to faces, with development children become more efficient at using subordinate perceptual processes which allow them to categorize atypical stimuli more quickly. However, individuals with autism never reach a level of efficiency similar to control participants.

The possibility that individuals with autism have a common problem processing subordinate information across both objects and faces is important for assessing current theories on face processing and autism. Many researchers assume that it is an early lack of interest/attention to faces that leads to an inability of individuals with autism to develop efficient subordinate or holistic perceptual face processes. For example, both Dawson (Dawson, Webb, & McPartland, 2005) and Schultz (Schultz, 2005) have argued that a lack of early social motivation and attention to faces leads to decreased expertise in configural/holistic processing. The current study, in addition to recent research by Behrmann et al. (2006), 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 a deficit in the skills that are applied to both faces and objects but that the deficit is only seen when individuals with autism must process stimuli that require more subordinate perceptual processes like faces, atypical objects, or subordinate categories. Future research should be aimed at distinguishing the role of deficits in subordinate perceptual processes by studying more subordinate level categorization and examining the ability of individuals with autism to acquire expertise in a nonsocial subordinate category such as leaves or Greebles (e.g., Gauthier et al., 2000).

Finally, it should be noted that there are similarities between our discussion and theories that suggest that individuals with autism are more focused on local details at the expense of processing more global information such as weak central coherence (Frith, 1989) and enhanced perceptual functioning (Mottron, Dawson, Soulières, Hubert, & Burack, 2006). While these theories provide a useful framework for thinking about autism, they have been applied to a variety of tasks from language to perception to face processing. Thus, at issue is how this local bias may affect specific abilities such as categorization. The current study suggests a potential set of underlying processes with respect to categorization that may be different in individuals with autism. It is believed that these differences are involved when individuals process subordinate categorical information and include the ability to make subtle quantitative comparisons of spatial information, the careful comparison of exemplars to stored representations or prototypes, and the ability to consider multiple features in the decision process. The extent to which these deficits are related specifically to just a bias toward local processing or to other more central problems such as the comparison of exemplars to stored prior information or the ability to make subtle quantitative comparisons will be an important avenue to explore in future research.

In conclusion, 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. While the current study tested only high-functioning individuals who were older than 8 years, these categorization differences may be more profound in either younger children or lower functioning individuals. 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 (Bomba & Siqueland, 1983; Quinn, 1987; Strauss, 1979; Younger & Gotlieb, 1988), and to categorize on the basis of correlated attributes (Younger, 1986). While speculative, one possibility is that individuals with autism may have general problems in data reduction from infancy and that the differences in perceptual processing that were evidenced in the current study are only one piece of a larger cognitive deficit. Previously cited studies showing that individuals with autism have difficulty forming prototypes and categories support this view. Again, while speculative, this possibility presents an interesting avenue for future research.

The current study also highlights the importance of developmental studies in understanding the cognitive deficits that are present in individuals with autism. This study was the first to examine the role that cognitive processing differences may have on categorization from childhood to adulthood. As a result, this study provides a developmental picture of improvement in categorization and development of subordinate perceptual processes with limitations for individuals with autism.

References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders, 4th ed., text revision (DSM–IV–TR)*. Washington, DC: American Psychiatric Association.

Barrett, M. (1995). Early lexical development. In P. Fletcher & B. Macwhinney (Eds.), *The handbook of child language* (pp. 362–392). Oxford, UK: Blackwell.

Behrmann, M., Avidan, G., Leonard, G. L., Kimchi, R., Luna, B., Humphreys, K., et al. (2006). Configural processing in autism and its relationship to face processing. *Neuropsychologia, 44*, 100–129.

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.

Bomba, P. C., & Siqueland, E. R. (1983). The nature and structure of infant form categories. *Journal of Experimental Child Psychology, 35*, 294–328.

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

Burack, J. A. (1994). Selective attention deficits in persons with autism: Preliminary evidence of an inefficient attentional lens. *Journal of Abnormal Psychology, 103*, 535–543.

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 Sonneville, L. M. J., Verschoor, C. A., Njiokiktjien, C., Op het Veld, V., Toorenaar, N., & Vranken, M. (2002). Facial identity and facial emotions: Speed, accuracy, and processing strategies in children with autism. *Journal of Clinical and Experimental Neuropsychology, 24*, 200–213.

Frith, U. (1989). *Autism: Explaining the enigma*. Oxford, UK: Blackwell.

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

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.

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.

Jolicoeur, P., Gluck, M. A., & Kosslyn, S. M. (1984). Pictures and names: Making the connection. *Cognitive Psychology, 16*, 243–275.

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.

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.

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.

Margolis, M., Kirk, U., Kemp, S., & Korkman, M. (2001). The role of executive functions on visual attention. *Journal of the International Neuropsychological Society, 7*, 154.

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

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

Mottron, L., & Belleville, S. (1993). Study of perceptual analyses in high level autism subject with exceptional graphical abilities. *Brain and Cognition, 23*, 229–309.

Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders, 36*, 27–43.

Murphy, G. L., & Brownell, H. H. (1985). Category differentiation in object recognition: Typicality constraints on the basic category advantage. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11*, 70–84.

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). Oxford, UK: Oxford University Press.

Piatt, C. G., & Tanaka, J. (2005). *The electrophysiology of categorizing typical and atypical objects*. Paper presented at the PEN X workshop, Pittsburgh, PA.

Plaisted, K., O'Riordan, M., & 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 S. Baron-Cohen, H. Tager-Flusberg, & D. J. Cohen (Eds.), *Understanding other minds: Perspectives from developmental cognitive neuroscience*. New York: Oxford University Press.

Quinn, P. C. (1987). The categorical representation of visual pattern information by young infants. *Cognition, 27*, 145–179.

Quinn, P. C., & Oates, J. M. (2004). Early category representations and concepts. In J. M. Oates & A. Grayson (Ed.), *Cognitive and language development in children* (2nd ed., pp. 21–60). Oxford, UK: Blackwell Publishers.

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

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.

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

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

Strauss, M., Newell, L., Best, C. A., Rump, K. M., Gastgeb, H., & Minshew, N. (2005). *Discrimination of facial gender by typically developing children and individuals with autism*. Poster presented at the Society for Research in Child Development Biennial Meeting, Atlanta, GA.

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.

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

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

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

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

Younger, B., & Gotlieb, S. (1988). Development of categorization skills: Changes in the nature or structure of infant form categories. *Developmental Psychology, 24*, 611–619.