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Prototype Formation in Autism: Can Individuals with Autism Abstract Facial Prototypes?

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Abstract

Prototype formation is a critical skill for category learning. Research suggests that individuals with autism may have a deficit in prototype formation of some objects; however, results are mixed. The current study used a natural category, faces, to further examine prototype formation in high-functioning individuals with autism. High-functioning children (age 8–13 years) and adults with autism (age 17–53 years) and matched controls were tested in a facial prototype formation task that has been used to test prototype formation abilities in typically developing infants and adults (Strauss, 1979). Participants were familiarized to a series of faces depicting subtle variations in the spatial distance of facial features, and were then given a forced choice familiarity test between the mean prototype and the mode prototype. Overall, individuals in the autism group were significantly less likely to select the mean prototype face. Even though the children with autism showed this difference in prototype formation, this pattern was driven primarily by the adults, because the adults with autism were approximately 4 times less likely to select the mean prototype than were the control adults. These results provide further evidence that individuals with autism have difficulty abstracting subtle spatial information that is necessary not only for the formation of a mean prototype, but also for categorizing faces and objects.

Keywords

prototype; autism; categorization; face perception

Prototype formation is a critical skill for making sense of a world with infinite categories to learn. A prototype is a representation of past information that depicts the average of variations within a category. Forming a prototype decreases memory load allowing individuals to store a single representation of experienced items. Within the first year, infants can form prototypes of faces (Rubenstein, Kalakanis, & Langlois, 1999; Strauss, 1979), objects (Younger, 1990) and dot patterns (Younger & Gotlieb, 1998).

Evidence of prototype formation comes from studies of the prototype effect—the tendency to falsely remember a prototype as previously seen despite never actually seeing it. In a classic study by Posner and Keele (1968), adults trained on dot patterns varying in distortion levels from a prototype tended to falsely remember the unseen prototype and considered it to be as familiar as previously seen dot patterns. This effect has been replicated with abstract

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forms (Homa, Goldhart, Burrue-Homa, & Smith, 1993) and faces (Reed, 1972) in various populations including individuals with cognitive and mental health impairments (Hayes & Conway, 2000; Hayes & Taplin, 1993; Kéri, Kelemen, Benedek, & Janka, 2001).

The limited research on prototype formation in individuals with autism suggests that they may be unable to abstract a prototype and do not exhibit the prototype effect. Klinger and Dawson (2001) found that low-functioning children with autism were unable to abstract a prototype of simple animal-like categories, a finding that has recently been replicated with high-functioning children and adults (Klinger, Klinger, & Pohl, 2006). Plaisted (2000) also demonstrated that high-functioning adults and children with autism were unable to form prototypes.

In contrast, Molesworth, Bowler, & Hampton (2005, 2008) did not find evidence of a lack of prototype formation in a group of high-functioning children with autism spectrum disorder, however, their results may not reflect intact prototype formation abilities. For some stimuli, the varied features were perceptually obvious allowing individuals with autism to learn values of one particular feature without forming a prototype of the entire object category. For other stimuli, the varied features were qualitative (e.g., shape), making it possible to falsely remember the prototype, because it shared feature values with many training stimuli. Thus, participants may have remembered frequently seen feature values rather than abstracting a prototype.

One issue yet to be considered in prototype formation studies in individuals with autism is their ability to perceive subtle spatial variations in a given category. For example, in the natural category of dogs, many features vary. Features such as color are discrete, qualitative, and non-spatial in nature. For discrete features, the most representative value is the feature that is seen most often (e.g., brown). However, other features such as muzzle length are continuous, quantitative, and spatial in nature. For continuous features, the most representative value is that which is most typical or average (e.g., mean length). Strauss (1979) found that when spatial variations are more obvious or extreme, the mode prototype is considered more familiar. In essence they are perceived as discrete features. In contrast, when spatial variations are more subtle, they are viewed as continuous, and the mean prototype is considered more familiar.

The importance of being able to differentiate subtle spatial variations is particularly important for subordinate level categorization (e.g., individual poodles or people), and research shows that individuals with autism have difficulty categorizing this type of information (Gastgeb, Strauss, & Minshew, 2006). Individuals with autism may have difficulty processing subtle spatial information necessary to form a mean prototype. However, they may be more skilled at processing obvious or discrete features or spatial information required to form a mode prototype. Thus, it is possible that the mixed results in previous prototype formation studies are due to differing degrees of subtlety in the features or spatial distances varied.

Our aim was to further investigate whether individuals with high-functioning autism can form prototypes. To date, prototype formation studies focusing on individuals with autism have used animal-like stimuli, often with obvious qualitative features. Faces, a natural category that has subtle spatial variations, could provide a better test of the type of abstraction ability needed to categorize subordinate objects and identify individual faces. To better understand whether high-functioning individuals with autism can abstract mean prototypes, we investigated their ability to form a mean prototype of subtly varying facial information.

Method

Participants

One hundred volunteers were recruited through advertisements. Of these, 49 were typically developing individuals, and 51 were individuals with autism. Demographic information for the full sample as well as the sample split into adults and children are shown in Tables 1 and 2. Written informed consent was obtained using procedures approved by the University of Pittsburgh Medical Center Institutional Review Board.

Autism diagnoses were assessed with the Autism Diagnostic Observation Schedule-General (Lord, Rutter, DiLavore, & Risi, 2003) and the Autism Diagnostic Interview-Revised (Rutter, LeCouteur, & Lord, 2003) and were confirmed with expert clinical opinion. Participants with autism were healthy, free of seizures, and had a negative history of traumatic brain injury. Control participants had a negative family history of autism spectrum disorders in first and second degree relatives. They were healthy, free of past or current neurological or psychiatric disorders, and showed no evidence of learning disabilities. The control and autism groups were matched on chronological age, verbal (VIQ), performance (PIQ), and full scale (FSIQ) IQ scores as assessed by the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999). All participants had FSIQ scores above 80.

Stimuli

Stimuli were line drawn faces originally designed by Strauss (1979) for a study of prototype formation in infants and adults. Strauss varied four continuous facial attributes: face length, nose length, nose width, and amount of eye separation along five continuous values and included two conditions, a wide condition utilizing feature values 1, 3, and 5 and a narrow condition utilizing feature values 2, 3, and 4. In the current study we tested participants in the narrow condition, because it is a test of whether individuals can abstract a mean prototype. Each facial attribute varied along three continuous values (i.e., 2, 3, 4) with 3 being the average value. Further information on stimuli creation can be found in Strauss (1979).

Procedure

Participants were familiarized to 14 faces in a Microsoft PowerPoint presentation. Faces were viewed individually on a 40-cm monitor for 2 seconds each. Similar to Strauss (1979), within the 14 face exemplars, non-average values (i.e., 2 and 4) of each facial attribute were seen twelve times; whereas, average values of each facial attribute (i.e., 3) were seen only twice (See Table 3 for a summary of all value combinations). Thus, participants were more frequently familiarized to non-average values, rarely seeing average values. They also never saw either the mean prototype (i.e., face 3333) or the mode prototypes (i.e., face 2222 or 4444). See Figure 1 for examples of familiarization faces.

Immediately following familiarization, participants responded to a forced choice test with two novel faces side by side (See Figure 2). One face was the mathematical average of the varied facial attributes or the mean prototype (i.e., face 3333), and the other face was the mathematical mode of the varied facial attributes or the mode prototype (i.e., either face 2222 or face 4444). Both presentation side and which mode prototype was presented was counterbalanced across participants. For the forced choice test, participants were prompted: "Point to the face that looks more familiar to you; that is, which one looks like you saw it before?" Thus, this design assessed whether participants considered the mean prototype or the mode prototype to be more familiar.

Results

Full sample

Of primary interest was whether individuals selected the mean prototype and whether there was a difference in the number of individuals who selected the mean prototype with respect to a diagnosis of autism. A chi-square analysis revealed a significant association between diagnosis and mean prototype selection, $\chi^2(1) = 5.71, p < .05$ (see Table 4a). Based on the odds ratio, individuals in the control group were 2.83 times more likely to select the mean prototype than were individuals in the autism group. Binomial tests indicated that the control group was significantly more likely to select the mean prototype (38 of 49, $p < .001$) than the mode prototype, whereas the individuals with autism selected the mean prototype at chance (28 of 51; $p = .55$). In order to ensure that this preference for the mean prototype was due to the familiarization stimuli and not a preexisting bias, a separate group of 90 college students were shown the mean and mode prototypes and asked to choose which face was more familiar. Binomial tests indicated that the students were not more likely to choose the mean prototype as more familiar (51 of 90; $p = .25$). Therefore, it is unlikely that the control individuals had a preexisting bias for the mean prototype.

Although the control and autism groups were matched on age and FSIQ, to further elucidate whether these demographic variables had an impact on the participants' selection of the mean prototype, several point-biserial correlations were conducted. For both the control and autism groups, neither age (autism: $r = -.013, n = 51, p = .93$; control: $r = .13, n = 49, p = .36$) nor FSIQ (autism: $r = -.05, n = 51, p = .73$; control: $r = -.19, n = 49, p = .18$) were significantly correlated with selecting the mean prototype. In addition, for the autism group, none of the ADOS subscales (Communication, Reciprocal Social Interaction, and Total) were significantly correlated with selection of the mean prototype (all p -values $> .77$).

Split Sample

Given the wide age range of the participant sample, of interest was whether similar odds ratios would be evident in both children and adults with autism, or if the previous finding was driven by one age group. To this end, we split the sample into child and adult groups. See Table 2 for the demographic breakdown of children and adults.

Child group—A chi-square analysis revealed no association in the child group between diagnosis and mean prototype selection, $\chi^2(1) = 2.43, p = .12$ (see Table 4b). Binomial tests indicated that while the child control group demonstrated a marginally reliable likelihood of selecting the mean prototype (18 of 26, $p = .08$) versus the mode prototype, the children with autism selected the mean prototype at chance (13 of 27; $p = 1.0$).

Adult group—A chi-square analysis revealed a marginally significant association in the adult group between diagnosis and mean prototype selection $\chi^2(1) = 3.70, p = .055$ (see Table 4c). Based on the odds ratio, adults in the control group were 3.99 times more likely to select the mean prototype than were adults in the autism group. Binomial tests indicated that the adult control group was significantly more likely to select the mean prototype (20 of 23, $p < .001$) than the mode prototype, whereas the adults with autism selected the mean prototype at chance (15 of 24; $p = .31$).

Discussion

The current study is the first to examine whether high-functioning individuals with autism can form a mean prototype of facial information. Overall, the control group chose the mean prototype more often than the autism group, suggesting a difference in prototype formation

abilities for the autism group. When the sample was split into children and adults, the pattern suggested that the effects might be driven more by the older study participants, but confirmation of this moderating variable awaits further study. The marginally significant results in the child group reflect a continuing development of the processing abilities that are needed to discriminate subtle spatial variation in typically developing children.

These results add to those of Klinger and colleagues, suggesting that individuals with autism have difficulty forming mean prototypes. Whereas some previous studies used stimuli where it was not necessary to form the mean prototype in order to succeed (e.g., Molesworth, et al.), the current study provided a more stringent test of mean prototype formation for several reasons. First, the current study used faces, a natural category exhibiting subtle featural variations that are quantitative in nature. Second, stimuli were designed using subtle variations of continuous facial attributes that were combined to ensure participants saw mean prototype values less frequently than mode prototype values. Thus, pure memorization of features would result in individuals choosing the mode prototype more often, whereas abstracting average features would result in choosing the mean prototype more often.

The current study suggests that individuals with autism don't automatically abstract prototypical information during an exposure paradigm with passive face viewing. Still at issue is whether individuals with autism can form mode prototypes. Molesworth and colleagues have found that individuals with autism can form a mode prototype, but our study did not replicate this finding (i.e., the autism group did not choose the mode prototype more than the mean prototype). One possible explanation for the difference in results is the amount of subtlety in the features that were varied. It is possible that when the varied features are more obvious or qualitative in nature, individuals with autism can abstract this information. Klinger & Dawson's (2001) finding that individuals with autism could form a prototype when there was an obvious rule for category membership supports this notion.

Still, an important question is why individuals with autism have difficulty forming mean prototypes, something even infants do successfully. To form a mean prototype, one must attend to different objects in the world, encode how features vary, learn the boundaries of featural variation, and store a mental average of these variations for each object category. For faces in particular, one needs to be able to encode the variations of spatial or configural features. Prior research on face recognition abilities of individuals with autism has shown that they have difficulty processing configural/spatial information and instead attend to non-configural/non-spatial information such as features and details (e.g., Sasson, 2006). Individuals with autism may not attend to the variation of spatial features of faces/objects unless the variation is obvious. For example, typically developing individuals learn that noses range from very wide to very narrow, with all sizes in between, but individuals with autism may only notice that noses are either wide or narrow. If this is the case, individuals with autism would have difficulty abstracting an accurate average. Attention to non-configural information could also negatively affect mean prototype formation. That is, because of an enhanced attention to non-configural details, they may process categories more dichotomously (as big/small or wide/narrow). Hence their attention to details may hinder the detection of variations that occur within continuously varying features (such as nose width), and they may only learn that noses are wide or narrow (dichotomous).

In summary, the current results provide further evidence that individuals with autism have difficulty forming prototypes, and more specifically mean prototypes of facial information. It is possible that the results may reflect chance behavior; however, the control group showed clear evidence of selecting the mean prototype at levels greater than chance. It may also be argued that the results of the autism group were not due to a difference in mean prototype formation but rather a general face perception deficit from reduced attention to

faces resulting in less experience with faces. Since infants have minimal experience with faces and can abstract mean prototypes, this possibility is less likely but cannot be ruled out. To determine how early mean prototype formation deficits are present in individuals with autism; future research should replicate these results and extend studies to younger populations. Future research should also be aimed at the nature of the prototype that is abstracted by individuals with autism (e.g. mean vs. mode) and the extent to which varied dimensions (e.g. subtle continuous vs. obvious discrete) affect the type of prototype formed.

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Figure 1.
Example familiarization stimuli.

Figure 2.
Example test stimuli.

Table 1

Participants' Diagnostic and Demographic Characteristics

Autism Group (N = 51)		Control Group (N = 49)	
M (SD)	(Range)	M (SD)	(Range)
CA	18.4 (10.6)	19.1 (11.9)	(8 – 53)
VIQ	104.8 (10.6)	104.4 (8.8)	(84 – 121)
PIQ	105.7 (12.8)	107.0 (8.6)	(88 – 132)
FSIQ	105.8 (9.2)	106.6 (8.8)	(86 – 129)
M: F	49:2	39:10	
Ethnicity	49 Caucasian	43 Caucasian	
	1 Hispanic	5 African American	
	1 Other	1 Other	

Note. CA = Chronological Age in years; VIQ = Verbal IQ; PIQ = Performance IQ; FSIQ = Full Scale IQ; Ethnicity obtained by self-report

Table 2
Participants' Diagnostic and Demographic Characteristics Split into Child and Adult Groups

	Adult Groups		Child Groups			
	Autism <i>N</i> = 24	Control <i>N</i> = 23	Autism <i>N</i> = 27	Control <i>N</i> = 26	<i>p</i> -value	
	<i>M</i> (<i>SD</i>) (Range)	<i>M</i> (<i>SD</i>) (Range)	<i>M</i> (<i>SD</i>) (Range)	<i>M</i> (<i>SD</i>) (Range)		
CA	26.9 (10.0) (17 – 53)	28.5 (11.6) (17 – 53)	10.8 (1.6) (8 – 13)	10.9 (1.8) (8 – 13)	.95	
VIQ	104.0 (11.6) (87 – 130)	105.1 (8.1) (91 – 117)	105.5 (9.8) (86 – 122)	103.7 (9.5) (84 – 121)	.50	
PIQ	102.3 (13.0) (80 – 128)	106.0 (8.1) (91 – 119)	108.8 (12.0) (87 – 135)	107.8 (9.1) (88 – 132)	.72	
FSIQ	103.7 (9.7) (86 – 126)	106.6 (8.0) (93 – 120)	107.7 (8.5) (95 – 126)	106.6 (9.7) (86 – 129)	.64	
M:F	22:2	19:4	27:0	20:6		
Ethnicity	23 Caucasian 1 Other	19 Caucasian 3 African American 1 Other	26 Caucasian 1 Hispanic	24 Caucasian 2 African American		

Note. CA = Chronological Age in years; VIQ = Verbal IQ; PIQ = Performance IQ; FSIQ = Full Scale IQ; Ethnicity obtained by self-report

Table 3

Summary of Facial Attribute Values

	Face Length	Nose Length	Nose Width	Eye Separation
Familiarization Faces				
Face 1	2	2	4	4
Face 2	4	3	2	4
Face 3	2	2	4	3
Face 4	2	3	2	4
Face 5	4	4	3	2
Face 6	4	2	2	4
Face 7	2	4	2	4
Face 8	3	4	2	2
Face 9	4	4	2	2
Face 10	3	2	4	4
Face 11	2	4	4	2
Face 12	2	4	3	2
Face 13	4	2	4	2
Face 14	4	2	4	3
Test Faces				
Prototype	3	3	3	3
Mode	2	2	2	2
Mode	4	4	4	4

Table 4**Table 4a****Contingency Table for Selection of Prototype for Full Sample**

	Autism Group (N=51)	Control Group (N=49)
Prototype	28 (54.9%)	38 (77.6%)
Not Prototype	23 (45.1%)	11 (22.4%)

Table 4b**Contingency Table for Selection of Prototype for Child Group**

	Autism Group (N=27)	Control Group (N=26)
Prototype	13 (48.1%)	18 (69.2%)
Not Prototype	14 (51.9%)	8 (30.8%)

Table 4c**Contingency Table for Selection of Prototype for Adult Group**

	Autism Group (N=24)	Control Group (N=23)
Prototype	15 (62.5%)	20 (87.0%)
Not Prototype	9 (37.5%)	3 (13.0%)