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# Prototype formation in autism

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**Abstract**
Individuals with autism have difficulty integrating information and generalizing previously learned concepts to new situations. It was hypothesized that these problems result from an underlying impairment in category formation. Persons with autism may not abstract a summary representation (a prototype) during category learning and, instead, may form categories by memorizing a list of rules. Children with autism, Down syndrome, and normal development participated in one set of category learning tasks that could be solved using a rule-based approach and a second set of tasks in which there was no rule that defined category membership (prototype tasks). In the rule-based tasks, all groups were successful at using a rule to learn a new category. In the prototype tasks, only the typically developing children were able to learn a new category. Neither the persons with autism nor the persons with Down syndrome appeared to develop a prototype during category learning. These data suggest that persons with autism and Down syndrome have difficulty categorizing new information by forming prototypes and, instead, tend to rely on a rule-based approach to learning.

The information-processing skills of persons with autism have intrigued researchers for nearly 30 years. During this time, there has been a consensus in the field that individuals with autism have trouble generalizing information across a number of different experiences, but the exact nature of the cognitive impairment that leads to this difficulty remains a mystery. One cognitive process that allows individuals to generalize information across situations is categorization. Categorization is a cognitive process that allows persons to organize information into conceptual groupings and then make inferences about new information based on previously formed concepts. For example, once a child learns a concept called "dog," he or she can categorize a new animal as either belonging or not belonging to the "dog" category. If that animal does belong to the dog category, the child can make inferences about the animal based on previous experiences with members of that category (e.g., the animal can probably bark). Without this ability to categorize new information based on previous experience, a child would view each new situation as something completely unique and may become overwhelmed by the complexity of the environment. We hypothesized that the difficulty generalizing information across settings in persons with autism is linked to an impaired categorization process. This theory is detailed in Klinger and Dawson (1995) but will be reviewed briefly here along with empirical support.

There is some limited empirical support for the idea that categorization skills may be impaired in person with autism. Several re-

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searchers (Bowler, Matthews, & Gardiner, 1996; Hermelin & O'Connor, 1970; Minshew, Goldstein, Muenz, & Payton, 1992) have suggested that, in contrast to typically developing individuals, persons with autism may not group items into conceptual categories during recall (e.g., they do not list all the fruits, then all the vehicles, etc.). For example, Bowler and colleagues found that typical adults were able to recall more words from a list of related words than from a list of unrelated words. Individuals with Asperger's syndrome remembered as many words from the unrelated list as typical adults. In contrast, they did not show improved recall for the list of related words. These studies suggest that persons with autism may not rely on categorization as a mechanism to enhance their memory. However, the issue of whether persons with autism are capable of categorization is not addressed.

There have been four studies that have directly addressed the question of whether persons with autism are capable of categorization. Tager–Flusberg (1985a, 1985b) evaluated categorization abilities using a matching-to-sample task in which children were shown a target picture and then asked to choose a picture from the same category, and a sorting task in which children were asked to sort pictures by category. For both tasks, she found no differences in performance between children with autism, mental retardation, and normal development who were matched on receptive language mental age. Similarly, Ungerer and Sigman (1987) found no differences between preschool-age children with autism and children with normal development who were matched on chronological age in their ability to sort objects into categories on the basis of perceptual (e.g., color and shape) and functional (e.g., furniture, fruit, and vehicles) domains. These studies demonstrated that persons with autism are capable of categorizing information. However, these studies do not address the question of whether persons with autism use the same *processes* of categorization as persons without autism when learning new information. This issue was addressed by Shulman, Yirmiya, and Greenbaum (1995), who reported that individuals with autism showed intact categorization of perceptual information (e.g., sorting by geometric shape) but were specifically impaired on categorization tasks requiring the internal manipulation of information (e.g., sorting representational objects). The purpose of the present study was to further examine the issue of whether persons with autism use the same processes of concept formation as persons without autism. In particular, we were interested in categorization of information that required integration of information across experiences. Prior to detailing specific hypotheses, we next present a brief description of theories of concept formation in typical development.

## Concept Formation in Normal Development

In the 1st year of life, there must be some way in which infants are able to organize the new information they encounter in order to simplify their environment and reduce the amount of information that needs to be stored and retrieved from memory. Researchers have suggested an abstraction process whereby a single best example (a prototype) is abstracted from experience with different category members and stored in memory. Posner and Keele (1968, 1970) have argued that a prototype is the central tendency of a particular category. This central tendency is created by computing the average of all previously experienced category members. By storing summary images (prototypes) in memory, individuals do not need to memorize all instances of a category and can recognize previously unseen members of a category (Rosch, 1978). This concept formation strategy effectively simplifies the environment and reduces memory load.

The ability to abstract a prototype from experience with different members of a category is thought to be an automatic process that develops within the 1st year of life (Husaim & Cohen, 1981; Strauss, 1979; Walton & Bower, 1993; Younger, 1990). For example, using an infant habituation paradigm, Younger (1990) showed 10-month-old infants pictures of animals from the same category that varied on size of features (e.g., length of legs). Following the familiarization phase, infants responded as if the prototype animal was more familiar than an animal composed of familiar features and did not appear to remember specific animals that they had seen during the familiarization trials. Similar results have been found in infants ranging from a few hours of age to 1 year of age in studies using facial features (Strauss, 1979; Walton & Bower, 1993) and dot patterns (Bomba & Siqueland, 1983). These results suggest that during the 1st year, and perhaps within a few hours of birth, infants do not learn categories by memorizing specific examples; rather, they learn by forming prototype representations of category examples.

The tendency to form prototypes during concept formation continues into adulthood (Posner & Keele, 1968, 1970). However, as children age, they are also able to use other methods of categorizing new information. For example, Younger (1990) found that by the 2nd year of life infants were able to form a prototype and could also remember individual category members. Kossan (1981) found that second graders were able to use rules to learn new categories. In Kossan's study, however, when the rules were complex or when there were no rules that defined category membership, children who tried to learn rules were unable to distinguish between two categories of novel animals. Children who did not try to learn a set of rules and used a more holistic or prototype style of concept formation, however, were successful at learning the categories. Thus, when a person's information processing abilities are strained, or when there is no rule that defines category membership, it may actually be to the child's disadvantage to attempt to discover a set of rules that defines a category (Markman, 1989).

## Prototype Versus Rule-Based Approach to Categorization in Autism

It is possible that persons with autism do not use a prototype style of concept formation and instead try to formulate rules that define each category. While this particular approach may be successful in some situations, as Kossan's work demonstrates, this approach is not effective when learning complex categories. Most natural categories are complex and cannot be defined by a list of rules. An attempt to create such a list may lead to categorization errors. For example, while most dogs have four legs, a tail, and bark, this list of rules is not true of every instance of the dog category. Social information is particularly unpredictable and complex and, thus, difficult to define (Klinger & Dawson, 1992, 1995). For example, there is no list of rules that defines concepts such as "happiness" or "stranger." An insistence on using a rule-based approach to categorization may explain why persons with autism have such a difficult time understanding social information.

There is some anecdotal evidence from parents, clinicians, and individuals with autism themselves to support the notion that persons with autism may not form prototypes when learning new categories of objects. For example, in Temple Grandin's autobiographic writings about her life with autism, she describes an inability to form a generic, generalized image of a category and instead she forms a "video library" in which she memorizes every instance of a category that she experiences (Grandin, 1995). Clearly, her writings suggest that she has developed categories, but she does not appear to form a prototype during category learning.

Frith and colleagues (Frith, 1989; Frith & Happé, 1994) have proposed that the problems experienced by people with autism in integrating information across experiences is due to a lack of "central coherence." Frith and Happé define central coherence as a characteristic of normal information processing that allows people to "draw together diverse information to construct higher-level meaning in context" (Frith & Happé, 1994). They hypothesized that a lack of central coherence in autism could explain their inability to gain the "gist" of a situation and a tendency to rely on memorizing each individual aspect of a situation. Frith's description of central coherence seems parallel to the process of prototype formation in concept learning, and her hypothesis of a weak central coherence in autism seems similar to our hypothesis that individuals with autism are unable to form prototype representations.

Several studies have provided evidence for the hypothesis that persons with autism do, in fact, use rule-based strategies. Hermelin and O'Connor (1986) found that autistic individuals with savant abilities were able to infer and apply rules necessary to calculate past and present calendar dates. Berger and colleagues (Berger, van Spaendonck, Horstink, Buytenhuijs, Lammers, & Cools, 1993) found that individuals with autism were able to infer the correct category rule in order to successfully sort cards depicting geometric designs. However, when the rule was changed unexpectedly, participants with autism had difficulty learning to use a new rule. Thus, although they had difficulty shifting set, their initial rule acquisition was not impaired.

Taken together, there is some tentative support for the idea that persons with autism may use an unusual process of concept formation. While they are able to categorize information during concept learning, they may use a rule-based style of processing rather than an abstract or prototype form of processing. Because prototype formation is present within the 1st year of life while rule-based categorization develops later in childhood, reliance on a rule-based style of concept formation does not seem attributable to a developmental delay. Thus, we are proposing that persons with autism have an unusual style of concept formation that is not due to a developmental delay.

In order to test this hypothesis, we examined categorization performance in three different sets of conditions. In one condition, there was no rule or set of rules that determined category membership. Thus, the participants were required to form a prototype representation in order to correctly learn the new concept. In the second condition, participants were explicitly told that there was a rule that defined category membership. In the third condition, there was a rule that defined category membership, but participants were expected to infer this rule for themselves. We predicted that persons with autism would be unable to learn a new concept when prototype formation was required, but would be able to learn a new concept when either explicit or inferential rule-based processing was required.

## Method

### *Participants*

The participants were 12 individuals with autism, 12 individuals with Down syndrome, and 12 individuals with normal development. Participants with autism were recruited through an existing research subject pool at the University of Washington Department of Psychology. They ranged in age from 5 years 10 months to 21 years 3 months. A diagnosis of autism was made according to the criteria specified by the *Diagnostic and Statistical Manual of Mental Disorders,* third edition, revised (DSM-III-R; American Psychiatric Association, 1987). Diagnostic ratings were completed following a structured play session designed to systematically elicit DSM-III-R symptoms and a parent interview conducted by one of the authors. Participants with Down syndrome and with normal development were recruited to serve as mental age matched comparisons for the persons with autism. Participants with Down syndrome were recruited through an existing subject pool at the University of Washington Center on Human Development and Disability and ranged in age from 7 years 8 months to 19 years 2 months. Normally developing children were recruited from an existing subject pool of volunteer parents compiled at the University of Arkansas Department of Psychology.

Using infant habituation paradigms, prototype formation has been reported in infants as young as 8 hr old (Walton & Bower, 1993). However, when relying on children's ability to choose a picture rather than measuring infant gaze pattern, prototype formation has not been found consistently in children under 5 years of age (Inn, Walden, & Solso, 1993). In piloting, we were able to demonstrate a prototype effect in children with a receptive language of at least 4 years. Thus, in the present study children were excluded if they had a receptive language mental age of less than 4 years. Four children with autism and 4 children with Down syndrome were excluded because they did not meet this screening criteria. One child with autism was not cooperative during testing and a valid receptive language age was not obtained; this child was also excluded. The final sample size included 12 children in each diagnostic group.

Across all three diagnostic groups, participants were individually matched on language comprehension mental age assessed by the Peabody Picture Vocabulary Test—Revised (PPVT-R; Dunn & Dunn, 1981). The decision to use the PPVT-R as a matching measure was based on Tager–Flusberg's research demonstrating that verbal mental age (measured by the PPVT-R) rather than nonverbal mental age was the best predictor of categorization ability in children with autism, mental retardation (including Down syndrome), and typical development (Tager–Flusberg, 1985a). Each child with autism whose receptive language age was below 8 years was matched to a child with Down syndrome and a child with normal development whose receptive language ages were within 6 months of the autistic child's receptive language age. Persons with autism receiving a receptive language age of 8 or more years were matched within 1 year to persons with Down syndrome and normal development. Across all three groups, PPVT-R scores ranged from 4 years 1 month to 12 years 1 month. In order to ensure that the normally developing children were representative of the population, children whose PPVT-R standard scores were outside the normal range (i.e., below 85 or above 115) were excluded from the study. Demographic data for participants in each of the three diagnostic groups are summarized in Table 1.

### *Experimental stimuli*

The stimuli consisted of black-and-white drawings of imaginary animals. Each drawing was mounted on an 8 × 8 in. poster-board card. There were five different animal categories. Each of the animal categories was similar in complexity (e.g., equivalent number of features) and was given a novel one-syllable name (e.g., mip, dak, sop, pev, or tuz). See Figure 1 for an example of each category.

Animals were created following the methodology described by Younger (1985, 1990). Within each category of animal, four features varied along quantitative dimensions. For example, members of the "pev" category (see Figure 1) varied in length of beak, height of eye, length of leg, and width of head. Each feature varied along five discrete values. For example, in the pev category, the smallest beak length was 2.5 cm and subsequent lengths increased by .50 cm. The smallest length was assigned a value of 1 and the largest length was assigned a value of 5.

*Prototype stimuli.* Familiarization stimuli were developed such that children were shown animals composed of feature values 1, 2, 4, and 5. The features associated with value 3 were not seen during familiarization trials. However, the figure composed of all value 3 features was the mathematical average (i.e., the prototype) of the previously seen animals. As an example, the values of the familiarization stimuli for the "mip" animal category (see Figure 1) are listed in Table 2. A test set of pictures consisted of either the prototype (3333) or one of the previously seen familiarization animals (1515, 5151, 1155, or 5511) versus a novel animal composed of previously seen features in a new combination (1551 or 5115).[1]

*Rule stimuli.* Rule stimuli were identical to the familiarization stimuli used in the prototype condition except that one feature was consistently large (i.e., had a value of 5) or small

1. Novel animals were composed of familiar features that were not similar to the prototype (e.g., feature values 1 and 5). When features that were similar to the prototype were used (e.g., feature values 2 and 4), normally developing children did not differentiate between the prototype animal (3333) and a similar animal (e.g., 2442). Thus, data are only presented for novel animals composed of feature values 1 and 5. To insure that novel animals and familiar animals were composed of the same features, only familiar animals composed of feature values 1 and 5 were used (i.e., 1515, 5151, 1155, or 5511).

**Table 1.** *Participant characteristics*

| Characteristics | Diagnostic Group: Autism | Down Syndrome | Normally Developing |
|---|---|---|---|
| Chronological age (years-months) | | | |
| Mean | 14-5 | 14-2 | 6-8 |
| Range | 5-10 to 21-3 | 7-8 to 19-2 | 4-4 to 11-8 |
| PPVT standard score | | | |
| Mean | 56.8 | 51.3 | 99.9 |
| Range | 39[a]–87 | 39–68 | 81–114 |
| PPVT mental age (years-months) | | | |
| Mean | 6-9 | 6-7 | 6-8 |
| Range | 4-1 to 12-1 | 4-5 to 11-0 | 4-1 to 11-4 |
| Gender | | | |
| Males | 10 | 8 | 10 |
| Females | 2 | 4 | 2 |

[a]The minimum possible PPVT Standard Score is 40. Any participant whose score was below 40 is listed as having a score of 39.

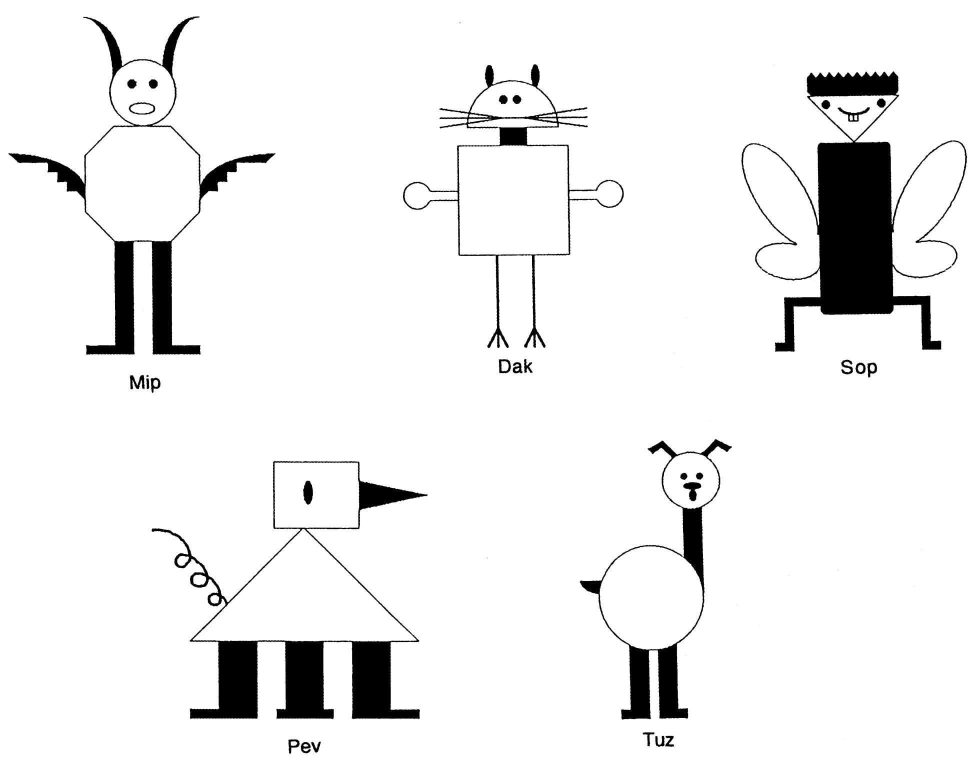


**Figure 1.** Examples of each animal category.

**Table 2.** *Feature values for the prototype condition for the mip animal category*

| Stimulus Number | Familiarization Stimuli Horn Width | Wing Width | Mouth Width | Foot Length |
|---|---|---|---|---|
| 1 | 1 | 5 | 1 | 5 |
| 2 | 1 | 1 | 5 | 5 |
| 3 | 2 | 4 | 2 | 4 |
| 4 | 2 | 2 | 4 | 4 |
| 5 | 4 | 2 | 4 | 2 |
| 6 | 4 | 4 | 2 | 2 |
| 7 | 5 | 1 | 5 | 1 |
| 8 | 5 | 5 | 1 | 1 |

*Note:* Feature values were developed by Younger (1985, 1990).

(i.e., had a value of 1). This one feature determined category membership (e.g., the presence of long feet in the mip animal category determined category membership). Test stimuli consisted of two novel animals that were identical except that one followed the rule (e.g., it had long feet) and the other did not (e.g., it had short feet).

### *Procedure*

There were four different sets of trials: two sets of the prototype conditions and two sets of the rule-based conditions (one explicit rule and one implicit rule task). The order of conditions was counterbalanced across participants. A different category of animal was used for each condition, and the type of animal for each condition was counterbalanced across participants. To avoid experimenter bias, a research assistant placed cards in the correct order before handing them to the experimenter and then recorded the children's answers. Labels were on the back of each card, and neither the experimenter nor the participants looked at the labels.

During familiarization trials, participants were shown eight examples of a category member compared to eight noncategory examples. The same eight noncategory comparison animals were used for all of the conditions. Order of presentation and side of presentation was determined randomly for each participant. On the first familiarization trial, participants were told the name of the target animal and then asked to touch the target animal on each subsequent trial. They were given 5 s to choose the category member and encouraged to look at the pictures for the full 5 s.[2] They were told to "look closely" because it was going to get "tricky" later on. Participants were praised for a correct response, and all incorrect responses were corrected. During the familiarization trials, 75% accuracy (i.e., choosing the correct animal six out of eight times) was required to continue the study. The familiarization trials for the mip prototype condition are shown in Figure 2.

Test trials were administered immediately following the familiarization stimuli. No feedback or corrections were provided during the test trials. If a participant responded that both animals were category members, the participant was encouraged to choose the "best" animal. All participants willingly made a choice when given this additional prompt.

*Prototype conditions.* Two sets of trials examined category learning in which no rule or set of rules defined category membership. Participants were shown the target animal (e.g., "This is a mip.") and then told to point to the target animal on all subsequent familiarization and testing trials (e.g., "Touch the mip."). Following the familiarization phase, two paired-comparison test trials were presented: (a) the prototype (3333) paired with a novel animal composed of familiar features (1551 or 5115) and (b) a randomly chosen previously seen familiarization stimulus (1515, 5151, 1155, or 5511) paired with stimulus 1551 or 5115 (the stimulus that was not paired with the prototype was chosen). Test pair order was counterbalanced across participants. The test stimuli are shown in Figure 3.

2. Five seconds was the maximum amount of time that normally developing children could be coaxed to look at the stimuli cards before making a decision and was the same presentation time used by Strauss (1979) in his infant studies.

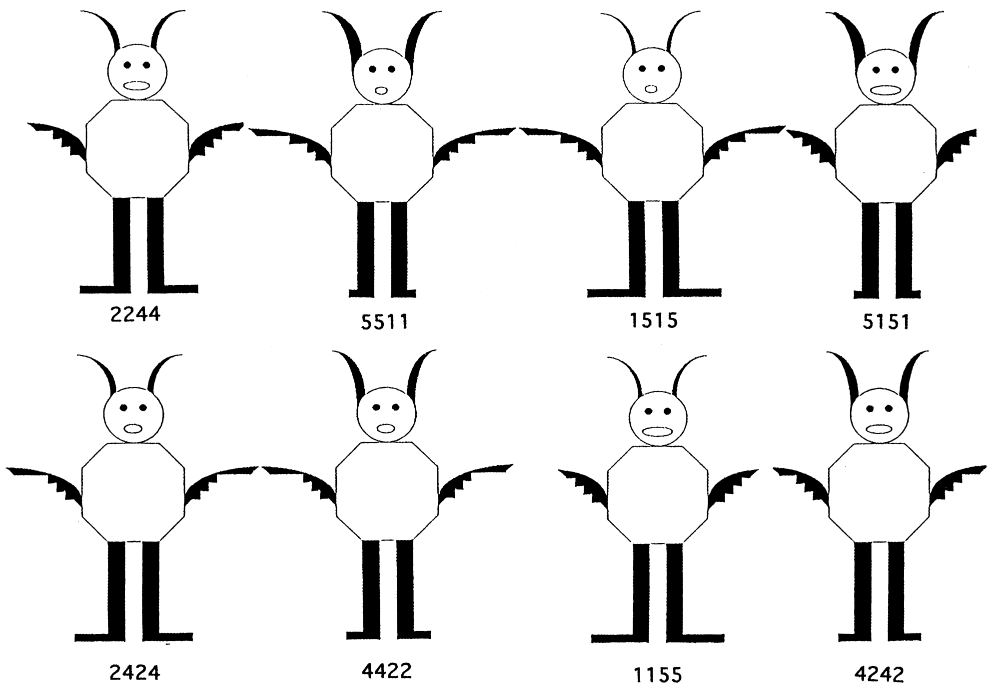


**Figure 2.** Familiarization stimuli for the "mip" animal category in the prototype condition.

*Explicit rule condition.* This condition assessed the ability to categorize novel information in which an explicit rule defined category membership and was used to ensure that participants were able to form some basic categories. This condition was identical to the prototype condition, except that during the familiarization trials participants were told that there was a rule that defined category membership and were told the relevant rule (e.g., "This is a mip. All mips have long feet."). Three features varied in size, but one feature (e.g., foot size) remained constant throughout the familiarization trials. The rule was reiterated on every familiarization trial. During familiarization trials, participants who chose the correct animal were praised for remembering the rule, and those who were incorrect were reminded of the rule. Test trials consisted of three paired comparisons composed of two animals that varied only on the feature that determined category membership (e.g., same wing length, horn width, and mouth width, but with one animal having long feet and one animal having short feet). Participants were asked to choose the target animal (i.e., "Touch the mip.").

*Implicit rule condition.* This task was identical to the explicit rule condition except that participants were not told that there was a rule that could be used to learn the new category. As in the explicit rule condition, three features varied in size and the one feature that determined category membership remained constant across the familiarization trials. Although there was a rule that determined membership (i.e., the size of the constant feature), participants were expected to infer the rule. That is, they needed to figure out that the one constant feature determined category membership. While there was no rule that determined category membership in the prototype condition, there was a rule that determined category membership in the implicit condition.

## Results

### *Prototype condition*

*Prototype versus novel animal comparisons.* Across conditions, children received two paired comparisons contrasting the prototype

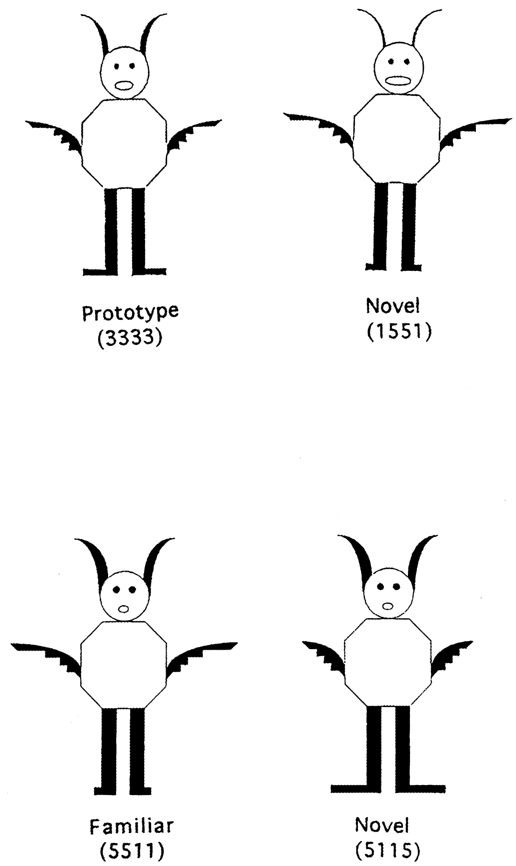


**Figure 3.** Test stimuli for the "mip" animal category in the prototype condition.

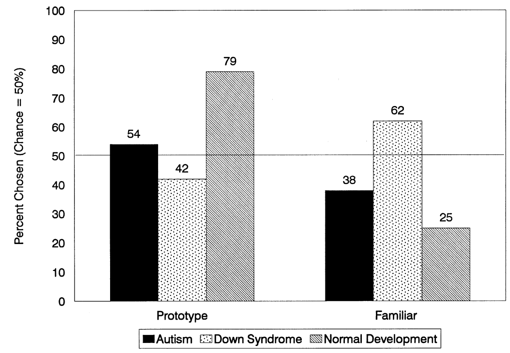


**Figure 4.** Percentage of trials that (a) the prototype and (b) the familiar stimuli were chosen during the prototype category learning tasks.

with a novel animal. Data from the two prototype trials were combined for these analyses. Thus, participants could choose the prototype in both of the conditions (100%), in one of the conditions (50%), or in neither of the conditions (0%). The mean percentage of trials in which the prototype was chosen for each diagnostic group is depicted in the left side of Figure 4. Performance across diagnoses was compared using a matched-subject ANOVA,[3] and there was a significant effect of diagnosis, $F$ (2, 22) = 3.67, $p < .05$.

For each diagnostic group, performance was then compared to chance using single sample $t$ tests in order to test whether each diagnostic group showed evidence of acquiring prototype representations. Normally developing children chose the prototype 79% of the time over the novel animal. This was significantly more often than chance (i.e., 50%), $t$ (11) = 3.02, $p < .02$. In contrast, the participants with autism chose the prototype over the novel animal 54% of the time, and the participants with Down syndrome chose the prototype 42% of the time. Neither of these groups performed at levels that were different from chance, both $t$ (11) < 1, *ns*. These data suggest that both individuals with autism and individuals with Down syndrome did not form prototype representations during category learning.[4]

Across all three groups, there was no relationship between receptive language mental age and participants' ability to chose the prototype, suggesting that prototype formation was not related to receptive language mental age ($r$ = .15, *ns*). Additionally, prototype formation was not significantly affected by order of condition presentation. That is, prototype

3. Because participants were individually matched on their receptive language mental age, data analyses were conducted using a matched-subjects ANOVA. Thus, diagnosis was treated as a within-subject factor.

4. An examination of individual scores for each participant also failed to show prototype formation in children with autism or Down syndrome. The number of children with autism ($N$ = 3) and the number of children with Down syndrome ($N$ = 5) who chose the prototype on both test trials did not differ from the frequencies expected by chance ($N$ = 3). In contrast, significantly more typical children chose the prototype on both trials ($N$ = 8) than would be expected by chance.

formation was not changed if a rule-based task occurred prior to the prototype task.

*Familiar versus novel animal comparisons.* Across conditions, participants received two paired comparisons contrasting an animal seen during the familiarization trials with a novel animal. Thus, participants could choose the familiar animal over the novel animal 0%, 50%, or 100% of the time. The mean percentage of trials in which the familiar animal was chosen is depicted in the right side of Figure 4. Performance across diagnoses was compared using a matched-subject ANOVA, and there was a significant effect of diagnosis, $F(2, 22) = 5.37$, $p < .013$.

For each diagnostic group, performance was then compared to chance using single sample $t$ tests in order to test whether each diagnostic group showed evidence of remembering the familiar animal that they had seen during the familiarization trials. None of the groups of participants chose the familiar animal over the novel animal more often than chance. Specifically, normally developing children chose the familiar animal 25% of the time over the novel animal. They actually chose the familiar animal significantly less often than expected by chance, $t(11) = -3.316$, $p < .05$. The participants with autism chose the familiar animal over the novel animal 38% of the time, and the participants with Down syndrome chose the familiar animals 62% of the time. Neither of these groups performed at levels that were different from chance, both $t(11) < 1$, *ns*. These data suggest that none of the diagnostic groups relied on memorization of individual exemplars when learning new categories.

Across all three groups, there was no relationship between receptive language age and participants' ability to chose the familiar stimuli, suggesting that memory for the familiar animal was not related to receptive language mental age ($r = .08$, *ns*).

*Rule-based condition*

Each person received three test comparisons in the explicit and implicit rule sets of trials. The percent correct (0%, 33%, 67%, or 100%) was calculated for each person in each type of trial (explicit or implicit rule). The mean percentage of trials in which the animal that followed the rule was chosen is depicted in Figure 5. Performance across diagnoses was compared using a matched-subject ANOVA. Participants with autism, Down syndrome, and normal development did not, overall, differ in their rate of correct categorization on rule-based test trials, $F(2, 22) < 1$, *ns*. However, there was a significant effect of rule type (explicit vs. implicit), suggesting that diagnostic groups performed more accurately in the explicit than the implicit rule condition, $F(1, 11) = 5.21$, $p < .05$.

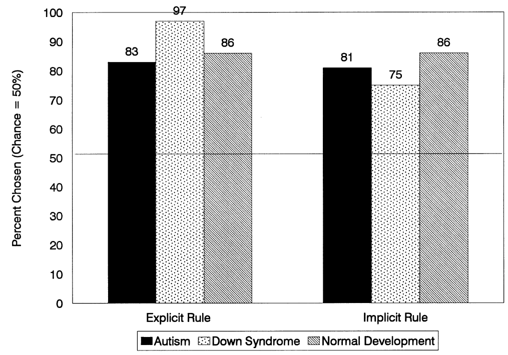


**Figure 5.** Percentage of trials that (a) the explicit and (b) the implicit rule stimuli were chosen during the rule-based category learning tasks.

Single-sample $t$ tests revealed that all three diagnostic groups chose the stimuli that followed the explicit rule at above-chance levels. Specifically, individuals with autism were accurate 83% of the time, $t(11) = 3.46$, $p < .01$, individuals with Down syndrome were accurate 97% of the time, $t(11) = 16.98$, $p < .002$, and individuals with normal development were accurate 86% of the time, $t(11) = 3.76$, $p < .01$.

Similarly, all three diagnostic groups chose the stimuli that followed the implicit rule significantly more often than chance. Specifically, individuals with autism were accurate 80% of the time, $t(11) = 3.53$, $p < .01$, individuals with Down syndrome were accurate 75% of the time, $t(11) = 2.46$, $p < .05$, and individuals with normal development were accurate 86% of the time, $t(11) = 3.76$, $p < .01$. Taken together, these data suggest that participants in all three diagnostic groups could learn and apply a rule that determined category membership. Additionally, at some level they were able to infer the rule when it was not explicitly stated.

Across diagnostic groups, performance on the rule-based conditions was related to receptive language mental age. Specifically, for explicit trials, participants with a higher receptive language mental age were more likely to choose an animal that followed the rule than participants with a lower mental age ($r = .35$, $p < .04$). A similar relationship was found between higher receptive language mental age and accuracy on the implicit rule trials ($r = .44$, $p < .01$). This suggests that the ability to learn and apply rules develops with mental age.

## Discussion

Results of this study suggest that persons with autism and persons with Down syndrome have difficulty forming abstract prototypic representations of their worlds. Prototype formation is considered to be a fundamental way in which infants learn to make sense out of their environment. Thus, an inability to learn categories through prototype formation may represent a very basic impairment that significantly disrupts the way in which individuals with autism and Down syndrome learn new information.

### *Implications for understanding typical development*

The results of this study can be used to make inferences about the normal development of categorization skills. Typically, research has shown that prototype formation is an early developing cognitive skill that precedes the ability to remember previously seen category members (Hayes & Taplin, 1993; Younger, 1990). Prototype formation has been documented within the first few hours of life (Walton & Bower, 1993) and is thought to develop independently of age and IQ. As expected, we did not find a relationship between prototype formation and receptive language mental age for any of the diagnostic groups. However, the developmentally delayed groups did not show the typical pattern of prototype learning.

Categorization based on specific features or rules is thought to be more closely related to age and IQ. As expected, we found that receptive language mental age was positively correlated with rule-based categorization ability for all groups of children. This finding suggests that, similar to typical children, children with autism and Down syndrome become more proficient at remembering specific pieces of information and forming appropriate rules based on that information as their ability level increases. It is surprising that the developmentally delayed groups showed rule learning without prototype learning. Typically, prototype learning is presented as a prerequisite to rule learning. This pattern of results suggests that rule-based category learning can occur without prototype learning.

It is important to note, however, that the rules used in this study were quite simple and based on a single feature. Therefore, the rule-based condition did not require the ability to integrate multiple pieces of information across experiences. It is possible that more complex rule learning would be impaired in the absence of prototype formation. Additionally, it is possible that because the rule-based task required attention to a single feature and the prototype task required attention to four different features, the prototype task may have been more difficult and required greater information processing demands than the rule-based task. However, because 10-month-old infants have been shown to demonstrate prototype formation using similar stimuli (Younger, 1985, 1990), it is unlikely that task difficulty can completely explain these findings.

### *Impairments in prototype formation are not specific to autism*

The finding that both groups of developmentally delayed children do not form prototypes during category learning suggests that this impairment is not specific to autism. The most parsimonious explanation of the current findings is that prototype impairments in persons with autism and in persons with Down syndrome are due to the lower mental age that often accompanies both disorders. This conclusion is consistent with prior research showing that persons with autism do not show a syndrome specific disturbance in categorization abilities (Tager–Flusberg, 1985a, 1985b; Ungerer & Sigman, 1987) but is inconsistent with research showing that categorization of representational information is specifically impaired in autism (Shulman et al., 1995). It is possible that mental age may not completely account for the disrupted prototype learning observed. Tager–Flusberg found that persons with autism and mental retardation had categorization abilities equivalent to their receptive language mental age. In the present study, persons with autism and Down syndrome showed impairments beyond what would be expected by their receptive language mental age. That is, their performance was below that of normally developing children matched on receptive language mental age. It is possible that nonverbal mental age may be a better predictor of the type of categorization skills assessed by this particular task. However, because children with autism typically have higher nonverbal than verbal mental ages, it is unlikely that nonverbal mental age can completely explain prototype formation impairments in autism.

Other aspects of mental retardation besides mental age, such as level of mental retardation or cognitive impairments associated with mental retardation, may explain the impaired prototype formation found in both developmentally delayed groups. Previous research has demonstrated intact prototype formation in persons with nonorganic mild mental retardation (Hayes & Taplin, 1993). The participants used in this study had more moderate mental retardation with an organic cause. It is possible that the prototype impairments observed in this study resulted from the greater level of mental retardation. However, some of the children with autism and Down syndrome received PPVT standard scores in the borderline and mild range of mental retardation (i.e., scores between 55 and 85) and even these participants did not show prototype learning.

It is possible that underlying cognitive impairments in children with autism and Down syndrome are linked to prototype impairments. Indeed both persons with autism and persons with Down syndrome have been reported to have difficulty disengaging their attention from a stimulus (Cohen, 1981; Courchesne, Townsend, Akshoomoff, Yeung–Courchesne, Press, Murakami, Lincoln, James, Saitoh, Egaas, Haas, & Schreibman, 1994; Wagner, Ganiban, & Cicchetti, 1990). Certainly, an attentional focus on a single feature of the novel animal (e.g., the legs) without attending to the other relevant features (e.g., the wings, horns, feet) might prohibit the ability to form a prototype.

Alternatively, given the small sample size and wide age span used in the present study, there may not have been sufficient statistical power to detect a more subtle difference between the participants with autism and Down syndrome. Future research with a larger number of participants is needed to examine this issue.

*Implications for understanding autism*

This study is consistent with several of the theories concerning cognitive impairments in autism. For example, Frith and colleagues (Frith, 1989; Frith & Happé, 1994) proposed that individuals with autism have a syndrome-specific impairment in their ability to integrate information across experiences to construct a higher level meaning due to a weak “central coherence.” It could be argued that prototype formation requires the ability to integrate information across experiences to form a central gestalt representation and therefore requires “central coherence” abilities. The present study raises the questions of whether an impairment in central coherence is specific to autism or whether it is also present in Down syndrome.

The present findings are also consistent with Minshew, Goldstein, and Siegel’s (1997) research demonstrating that persons with autism do not have global information processing impairments but show specific impairments in complex, not simple, information processing. In the present study, persons with autism were impaired on the more complex task that required integration of information across experiences (prototype formation task) but were not impaired on the simple task that required the processing of a single piece of information (rule-based task). Again, the present results suggest that impairments in complex information processing may not be specific to autism but may also be true of Down syndrome.

## *Summary*

The results from this study suggest that both children with autism and children with Down syndrome have impaired prototype learning abilities. An impairment in prototype formation fits within current theories of cognitive functioning in autism. These theories may also be applicable to underlying cognitive impairments in persons with Down syndrome. Future research needs to examine whether this task produces prototype impairments in other groups of persons with mental retardation (i.e., persons with mild and moderate mental retardation or other specific syndromes) and whether poor prototype formation abilities are related to impairments in underlying cognitive skills such as selective attention. Finally, future research needs to examine whether impairments in prototype formation are related to different factors in autism than in Down syndrome.

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