Children and Adults Learn Family-Resemblance Categories Analytically

Thomas B. Ward, Edward Vela, and Sally Duffin Hass

Texas A&M University

WARD, THOMAS B.; VELA, EDWARD; and HASS, SALLY DUFFIN. *Children and Adults Learn Family-Resemblance Categories Analytically.* CHILD DEVELOPMENT, 1990, **61**, 593–605. 3 experiments examined the modes of processing used by children and adults in learning family-resemblance categories. The materials were cartoon faces (Experiments 1 and 2) and bugs (Experiment 3) divided into categories that possessed no single defining attributes, but rather several characteristic attributes that were each partially predictive of category membership. The categories were structured so that a holistic mode of processing in which the individual did not selectively weight any given attributes could have led to success. Nevertheless, preschoolers (Experiments 2 and 3), first and third graders (Experiment 1), and adult college students (all experiments) all exhibited primarily analytic modes of learning that consisted of single- and dual-attribute approaches. Although the proportion of analytic learners among the preschoolers was lower than among the adults in Experiment 3, in no case were holistic modes of learning evident. The results are discussed in terms of their implications for young children's apparent relative success in learning natural categories. It is suggested that children's success in learning real-world categories may be based, in part, on an interaction between a basically analytic processing style and natural category structures that provide many partially informative attributes.

Young children tend to perform relatively poorly in laboratory studies of concept learning (e.g., Kendler, 1979; Tumblin & Gholson, 1981). In contrast, their real-world learning of simple object categories seems to be accomplished with relative ease and efficiency. Whether this discrepancy is real or only apparent, attempts to resolve it have led to two competing views of how children approach the learning of so-called family-resemblance categories. The modes of processing used in learning such categories are the focus of the present studies.

One suggested explanation of the real-world versus laboratory discrepancy is that the young child's preferred mode of processing is a holistic one, and that such a mode is manifested in and well suited to learning the structure of many naturally occurring categories (see, e.g., Kemler, 1983). That is, the holistic responses that young children make in simple classification tasks (e.g., Smith & Kemler, 1977) may indicate a general holistic mode of processing on their part. Combined with this idea is the observation that natural categories have family-resemblance structures in which members share different clusters of characteristic attributes, each of which are true of most but not all members (e.g., Mervis & Rosch, 1981; Rosch & Mervis, 1975; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). As a result, members of such categories tend to be more similar to one another in an overall sense than they are to members of other categories. Thus, the child presumably could determine membership in such categories by way of a holistic mode of processing without having to selectively weight any component attributes. This can be referred to as the *holistic processing* view. By this same view, there is also a mismatch between the child's tendency to focus on the holistic properties of objects and the structure of many experimenter-defined categories. Such categories require the child to analyze stimuli into their component dimensions and selectively attend to some components while ignoring others.

An alternate view of the real-world versus laboratory discrepancy is that young children approach concept-learning tasks, even ones involving family-resemblance category

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from adult learners. In addition, although attributes varied, in a formal sense, exactly as structures, as analytically as adults but are relatively unsophisticated at modifying their initial hypotheses (see Ward, 1989; Ward et al., 1989). The holistic processing that they exhibit in simple classification tasks may not apply in category learning situations because children may recognize that category learning requires a different mode of processing. In simple classification tasks there are no "correct" or "incorrect" groupings, whereas in category learning there are. Thus, when young children attempt to learn simple object categories, they may be analytic in the sense of selectively attending to single attributes in an effort to find the ones that will allow them to determine correct groupings. However, they may be less likely than older individuals to alter hypotheses about the importance of an attribute for category membership, even in the face of contradictory evidence (see, e.g., Tumblin & Gholson, 1981).

Such a tendency would lead to poor performance in laboratory situations in which a child might need to shift from a hypothesis about an initially preferred attribute to a hypothesis about the attribute that the experimenter has defined as correct. However, assuming a family-resemblance structure of natural categories, such an approach could lead to initial levels of performance that are well above chance. This is because many characteristic attributes exist, and any of those on which the child focused would lead to correct categorization of many instances and correct rejection of many noninstances. This view will be called the *attribute availability* hypothesis; with many partially informative attributes, the child need not find the single defining feature in order to perform well, even in cases where such a feature exists. For example, a child who attended to wings or feathers or beak would correctly identify many members of the category "bird" and would reject most nonmembers. The child's primary task thereafter would be to learn about exceptions that are category members but that do not possess the attribute in question.

A crucial difference between the *holistic processing* and *attribute availability* hypotheses concerns their predictions about developmental differences in the relative amount of analytic and holistic processing that will be observed in category learning situations. The holistic processing view, being rooted in the idea of a developmental progression from primarily holistic to primarily analytic modes of processing, predicts that young children will be more likely than adults to adopt holistic modes of processing and less likely than adults to adopt analytic modes of processing as they attempt to learn family-resemblance categories. In contrast, the attribute availability hypothesis predicts that young children will, like adults, adopt analytic modes of processing. It is these competing predictions that are of interest in the present studies. The validity of these views as complete accounts of the real-world versus laboratory discrepancy in children's category learning is not at issue in the present article—only the differing predictions for the modes of processing that ought to be observed.

Although both hypotheses are plausible, only a few empirical studies have been addressed to these issues. Of most relevance in the present article are those that have attempted to simulate the holistic properties of natural categories in the laboratory. In an ingenious study involving cartoon faces, Kemler Nelson (1984) demonstrated that young children can readily learn categories that have family-resemblance structures. She found that kindergartners learned holistically structured categories as readily as did fifth graders, but they performed much more poorly than the fifth graders on categories that required them to focus on a single defining feature. It appears, therefore, that young children can readily learn categories that have been set up in the laboratory to mimic the structure of natural categories.

Using materials that were very similar to those of Kemler Nelson (1984), Ward and Scott (1987) attempted to determine whether young children used holistic or analytic modes of processing when they successfully learned such family-resemblance categories. Table 1 displays the formal structure of the two categories used in the Kemler Nelson (1984) and Ward and Scott (1987) studies. Note that the members of category A have the characteristic values of straight hair, clipped mustache, small ears, and a tall-thin nose, whereas the members of B have the opposite characteristics. Thus, as with many natural categories, there are several characteristic attributes, each of which is partially predictive of category membership. Note also that each member of those respective categories possesses a different cluster of those characteristic attributes, and that no single feature can serve as a defining or criterial attribute. Finally, assuming an equal salience for all four attributes, the faces within a category are overall more similar to one another than they are to faces of the contrasting category.

TABLE 1

FORMAL STRUCTURE OF A FAMILY-RESEMBLANCE PROBLEM USED IN THE WARD AND SCOTT STUDY

Category A					Category B				
Face	Hair	Mustache	Ear	Nose	Face	Hair	Mustache	Ear	Nose
1	1	1	1	2	5	3	3	3	2
2	1	1	2	1	6	3	3	2	3
3	1	2	1	1	7	3	2	3	3
4	2	1	1	1	8	2	3	3	3

NOTE.—The faces denoted are ones presented during learning. The values 1, 2, and 3 refer, respectively, to straight, wavy, and curly for the attribute of hair, to clipped, medium length, and handlebar for mustache, to small, medium, and large for ears, and to tall-thin, medium, and short-fat for nose.

In using these materials, it was thus possible for the participant to learn the correct category assignments by adopting either a holistic or analytic mode of processing. With holistic processing, the comparisons could be made correctly on the basis of the overall similarity of the stimuli. No selective weighting of any component attributes would be required. In contrast, an individual could adopt an analytic, "attribute-plus-exception" mode of processing and also correctly assign category membership. Since all four attributes were partially predictive of category membership, an individual could selectively attend to any one and still be correct in making category assignments for most of the faces. For example, if a child focused on the mustache, faces 1, 2, 4, 5, 6, and 8 could be categorized easily and the learning task would be simplified to one of learning the correct category assignments of the two remaining exemplars (i.e., learning about the exceptions). If a child focused on the ears, faces 1, 3, 4, 5, 7, and 8 could be learned readily, and so on. Thus, as is true for natural categories, the problem of discovering the experimenter-defined attribute or shifting attention from a preferred attribute to a less preferred one was reduced.

Ward and Scott's (1987) results showed that almost half of the 5-year-olds tested could be classified as single-attribute learners, and this proportion was not significantly different from adult learners. In addition, although Ward and Scott (1987) originally used the label "holistic" to refer in a very general way to any of the individuals who did not show clear single-attribute patterns, subsequent reanalyses of the data from those subjects revealed that only two adults and one child showed clear holistic patterns of performance on the transfer items (see Ward, 1989).

The findings that children can be as analytic as adults in learning family-resemblance categories, and that neither age group showed a significant amount of holistic responding, seem counter to the holistic processing view of concept learning. Nevertheless, it is possible that the findings to date are limited to the particular types of analytic rules examined, the particular age groups tested, the learning criteria employed, and the types of materials used. With these ideas in mind, we conducted three studies. The first two were concerned with the possibility that older individuals are more analytic than younger ones but use more complex analytic rules that could not be identified with the set of transfer items used by Ward and Scott (1987). That is, even though the prediction of holistic category learning in young children was not supported, it is possible that the related claim of the holistic processing view, that adults will be more analytic than young children, still holds.

In Experiment 1 we also examined the tendency of children at intermediate age ranges (first graders vs. third graders) to exhibit holistic or analytic modes of learning. In addition, in Experiment 2 we investigated the possibility that degree of learning is related to the individual's mode of responding. Finally, in Experiment 3 we considered the possibility that the type of stimulus materials used would influence the tendency to adopt one or the other mode of learning. The materials used in that study were cartoon "bugs" whose attributes varied, in a formal sense, exactly as the "faces" used in the Ward and Scott (1987) studies.

Experiment 1

In the Ward and Scott (1987) study, nearly equal proportions of 5-year-olds and adults showed analytic patterns. These individuals appeared to have learned appropriate category assignments by focusing all or most of their attention on a single attribute. Unfortunately, the transfer items used in the Ward and Scott (1987) study did not allow a direct assessment of other analytic-type strategies, such as disjunctive approaches in which the individuals directed all or most of their attention to two attributes. For example, considering the items as shown in Table 1, an individual could achieve perfect performance by way of a disjunctive rule of the form "straight hair or clipped mustache or both" for category A, "curly hair or handlebar mustache or both" for category B. This issue is particularly important since more adults than children may have been analytic learners, but they may have used analytic approaches that were not readily identified with the particular set of test items that were used. Such a result could be predicted from previous work showing that multiattribute rules are more difficult to learn than single-attribute rules (Bourne, Dominowski, & Loftus, 1979). Adults would be expected to use the more difficult multiattribute rules more often than children. Thus the current study incorporated transfer items constructed to determine whether participants were using dual-attribute rules.

The subjects in this study were first and third graders and college students. First graders have been observed to be in a transitional phase between holistic and analytic modes of responding in simple classification tasks (e.g., Smith & Kemler, 1977). Thus, by the holistic processing view, it might be expected that some of them would exhibit holistic patterns and some would exhibit analytic patterns in the present category learning task. Since there is already evidence against holistic category learning in 5-year-olds (Ward & Scott, 1987), however, a more important aspect of the study was whether or not the older individuals would be more likely than the younger ones to adopt more complex analytic approaches.

METHOD

Participants

The participants were 28 first graders (mean age = 6-10) and 20 third graders (mean age = 8-7) who were recruited from classes in a parochial school in a suburban community and 66 college students who received course credit for their participation.

Stimuli

The materials consisted of cartoon-type faces that varied in terms of hair, ears, noses, and mustaches. Each of the four attributes had three possible levels, as indicated in Table 1. The faces were approximately 6 inches tall. The hair and mustaches were yellowish-blonde and the ears and noses were tan. The oval shape comprising the rest of the face was white.

Previous research indicated that none of the attributes were exceptionally salient with respect to the others (see Ward & Scott, 1987). That is, items that matched on one particular attribute were virtually never rated as more similar than items that differed on that attribute but matched on the other three. In addition, a more recent pilot study has revealed that differences along the component attributes are equally salient. In that study, subjects used a nine-point scale in judging the similarity of pairs of faces. Lower numbers indicated more similarity. There were three types of pairs—those in which a particular attribute was missing from both faces (feature-absent pairs), those in which the identical value of the attribute was present in both faces (feature match), and those in which different values of the attribute (1 vs. 3) were present in each face (feature difference). The attribute involved in these manipulations was varied as a between-subjects variable. The salience of the differences along the attributes can be measured by the relative changes in similarity ratings between the feature-different and other types of pairs. The mean ratings for the various pairs are shown in Table 2. As can be seen, feature-different pairs were rated as less similar than the other two types of pairs, and the effect of pair type was significant, $F(2,40) = 17.39$, $p < .001$. More important, however, the decrease in similarity for the feature-different pairs was roughly equivalent across the four attributes, and an analysis of variance revealed no effects or interactions of attribute type.

As a final preliminary measure, we conducted an oddity task with 10 preschoolers (mean age = 5-4) to determine whether the variations along the attributes were all dis-

TABLE 2

MEAN SIMILARITY RATINGS FOR FEATURE-ABSENT, FEATURE-SAME, AND FEATURE-DIFFERENT PAIRS FOR EACH FEATURE MANIPULATED

	ATTRIBUTE MANIPULATED			
PAIR	Hair	Mustache	Ears	Nose
Absent	6.61	6.44	7.28	6.78
Same	6.78	6.03	7.14	6.86
Different	8.14	6.97	7.92	7.78

criminable to young children. This age group was chosen because it represents the youngest age group tested in the present experiments. Children were shown triads of faces. Two of the faces in each triad were identical and one differed from the others by one or two levels on one of the attributes. The children's task was to indicate which face was different. On making a choice, they were then asked to indicate by pointing or labeling in what way the face was different. Across 16 trials, all possible single-level differences (i.e., 1 vs. 2 and 2 vs. 3 for each attribute) were sampled once, and the two level differences (1 vs. 3) were each sampled twice. Eight of the children performed perfectly on all 16 trials, correctly identifying the different faces and the nature of the differences. Two children made one error each. These children determined that all three items were the same when one of them differed by a one-step ear difference. Both of these children, however, correctly identified the other one-step ear difference on the trial on which it occurred.

Procedure

Learning phase.—Participants were tested individually in a small room at their school or in a laboratory room in the psychology department. All participants were instructed to imagine that a world existed in which they could tell who was a fire fighter and who was a police officer simply on the basis of appearance. They were asked to learn which faces were fire fighters and which were police officers. The correct category assignments for the faces used in the learning phase were determined according to the type of structure shown in Table 1.

At the beginning of the testing session with the children, the experimenter related the scenario while placing a toy fire truck and label "fire fighter" to one side of the table and a toy police car and label "police officer" to the other side. The college students were given the scenario, instructions, and labels only.

A trial consisted of the experimenter showing one of the eight faces to the participant and asking whether the face belonged to a fire fighter or a police officer. The college students responded verbally, and the children were allowed to indicate their decision verbally or by moving the face next to the fire truck or police car. The experimenter then informed the participant whether the response was correct or incorrect. Six different random orders of the eight faces were constructed, resulting in a total of 48 presentation trials.

TABLE 3

TRANSFER ITEMS USED IN EXPERIMENTS 1 AND 2

Face	Hair	Mustache	Ears	Nose
T1	1	1	1	1[a]
T2	3	3	3	3[b]
T3	3	1	1	2
T4	3	1	2	1
T5	3	2	1	1
T6	1	3	3	2
T7	1	3	2	3
T8	1	2	3	3
T9	1	3	1	2
T10	1	3	2	1
T11	2	3	1	1
T12	3	1	3	2
T13	3	1	2	3
T14	2	1	3	3
T15	1	1	3	2
T16	1	2	3	1
T17	2	1	3	1
T18	3	3	1	2
T19	3	2	1	3
T20	2	3	1	3
T21	1	1	2	3
T22	1	2	1	3
T23	2	1	1	3
T24	3	3	2	1
T25	3	2	3	1
T26	2	3	3	1

[a] Category A prototype.
[b] Category B prototype.

Transfer phase.—The transfer phase included 34 randomly presented trials consisting of a single presentation of each of the original eight faces (see Table 1), each of two prototypes (T1 and T2), and each of 24 test items T3–T26. Participants were asked to continue identifying each face as a fire fighter or police officer but were no longer given feedback. The prototypes and test items used in Experiment 1 are described in Table 3. Recall that the structure of the transfer items was designed so that it would be possible to determine whether participants were using some kind of disjunctive rule. For example, if a participant were using a hair/mustache disjunctive rule, then T15 and T21 would always be assigned to category A and T18 and T24 would always be assigned to category B because the values of the hair and mustache attributes both favor those category assignments. More important, T5, T11, T19, T20, T25, and T26 would be grouped in B and T8, T14, T16, T17, T22, and T23 would be grouped in A. Notice that for each of those 12 test items, only one of the two attributes thought to be involved in the disjunctive rule is informative with respect to category membership. The other always takes on an intermediate value. Thus, such a pattern of category assignments would be highly unlikely unless the person assessed both attributes. Notice also that T5, T8, T11, and T14 are strongly diagnostic because the values for the remaining attributes are consistent with category membership opposite to that chosen based on a disjunctive rule approach.

A hair/mustache disjunctive rule is only one out of six possible disjunctive rules that could be used. A participant could, for example, adopt an ears/nose disjunctive rule ("small ears or tall-thin nose or both" for category A and "large ears or short-fat nose or both" for category B). A careful examination of Table 3 shows that for each possible disjunctive rule there exists a set of 16 transfer items for assessing the use of this processing approach, and for each set, four of the 16 items are strongly diagnostic items. In order to be identified as using a given dual-attribute rule, a participant had to make 15 of 16 responses consistent with a particular pattern. As an additional restriction, all four responses to the strongly diagnostic items had to be consistent with the dual-attribute rule in question in order for the individual to be identified as using that rule.

It is important to note that the disjunctive rules described here refer to patterns of performance on a transfer task. It cannot be determined from the present procedures whether individuals truly use those attributes as rules or simply devote more attention to them than to the remaining attributes in making categorization decisions.

The test items shown in Table 3 also allow an assessment of the use of single-attribute and holistic approaches. For example, an individual who selectively weighted hair in determining category membership would classify T6–T10, T15, T16, T21, and T22 as A and T3–T5, T12, T13, T18, T19, T24, and T25 as B. Inspection of Table 3 reveals that there are also 18 particular responses that would be expected of individuals who selectively weighted each of the other three attributes as well. Seventeen of 18 responses had to be consistent with the use of a given attribute in order for an individual to be classified as a single attribute processor. In addition, for each attribute, six of the 18 responses involve *critical test* items that pit categorization based on the value of that one attribute against categorization based on the value of two of the other three attributes. For example, T3–T8 are critical test items for the attribute of hair. We imposed the additional criterion that responses to all six critical test items be consistent with the use of a particular attribute in order to classify the individual as having learned by way of that attribute.

A holistic responder who did not selectively weight any of the attributes would be expected to classify T3–T5, T9–T11, T15–T17, and T21–T23 as A and T6–T8, T12–T14, T18–T20, and T24–T26 as B. Twenty-three of those 24 responses had to be consistent with that pattern to identify the individual as a holistic responder.

It is important to note that the present transfer items were designed primarily to allow an examination of dual-attribute rules. As a result, in comparison with the transfer items used by Ward and Scott (1987), which were all "good" exemplars of the opposing categories, the present items might be described as "poor" exemplars. That is, the Ward and Scott items pitted a match on three attributes against a match on just one, whereas the present transfer items pit a match on two attributes against a match on just one. Since the attributes are roughly equally salient, the present items should still be more similar in an overall sense to the category that they match on two attributes than to the category that they match on just one attribute. Thus, a holistic pattern can be predicted. However, because the differences in overall similarity to the opposing categories would be smaller than in the Ward and Scott study, it might be more difficult for individuals to achieve a strict criterion for holistic processing. Thus, we also examined the effects of using more lenient scoring criteria.

Reaction-time measures.—Since response times were collected on each trial, it was possible to use reaction time as a converging measure to diagnose single-attribute responding. Assuming that the individual is attempting to learn the concept on the basis of one attribute, that attribute will lead quickly to the correct answer on six of every eight learning trials. The remaining two trials would presumably require more time since the learner can no longer rely on the information available from the favored attribute and must either guess or check the values of the other attributes. In either case, reaction time should be longer on those two trials. So, for example, an individual who focused either fully or mostly on hair as an attribute should learn to correctly categorize the three members of A that have straight hair (faces 1–3) and the three members of B that have curly hair (faces 5–7) in Table 1 relatively quickly. The individual should exhibit longer reaction times to the other two ambiguous faces (4 and 8). Note that the faces that are ambiguous depend on the attribute on which the learner has focused.

Results

The original eight learning items and the two prototypes were each presented once during transfer, and a criterion of 8 of 10 correct on those faces was used to classify an individual as a learner. Sixty-five of the 66 adults, 23 of the 28 first graders, and 19 of the 20 third graders were identified as learners. The proportion of learners was significantly related to age, $\chi^2(2, N = 114) = 9.19, p < .05$. Subsequent chi-square tests on each pairing of age groups revealed that the proportion of learners among the adults was significantly higher than among the first graders, $\chi^2(1, N = 94) = 8.79, p < .01$, but did not differ significantly from that among the third graders, $\chi^2(1, N = 86) = .82, p > .25$. There was no significant difference in the proportion of learners among the first and third graders, $\chi^2(1, N = 48) = 1.76, p > .10$. This last finding is consistent with Kemler Nelson's (1984) demonstration of equivalent amounts of learning in younger and older children. However, the findings with adults indicate that there may be improvements beyond childhood in the rate of learning family-resemblance categories. Thus, although young children may be competent in learning family-resemblance categories, they should not be thought of as being as competent as adults in doing so.

Of the individuals identified as learners, 30 adults, 10 first graders, and eight third graders were identified as single-attribute learners based on the procedures described above. An additional eight adults, three third graders, and two first graders showed disjunctive patterns of categorization. Including both single-attribute and disjunctive responders as analytic learners, the proportion of such learners varies only slightly from one group to the next, and a chi-square test revealed that, within the group of individuals identified as learners, assignment to the analytic versus other groups was independent of age group, $\chi^2(2, N = 107) = .28, p > .25$. None of the individuals in any of the age groups showed purely holistic patterns. Thus, among those individuals who showed clearly identifiable patterns, the most commonly observed mode of learning was an analytic one for all age groups.

For the adults, the numbers of individuals identified as using the attributes of hair, mustache, ears, and nose were 6, 14, 0, and 10, respectively, whereas the comparable numbers for first graders were 1, 5, 0, and 4, and for the third graders they were 0, 5, 0, and 3. Thus, in judging category membership, all age groups show a bias toward the more central features of the faces, even though the perceived differences along the four types of attributes were found to be roughly equivalent (Ward & Scott, 1987).

For individuals who showed a single-attribute pattern of transfer performance, mean reaction times for their ambiguous faces and unambiguous faces were computed across all correct learning trials. For adults, mean correct reaction time was longer for the ambiguous faces (1.64 sec) than for the other faces (1.21 sec), and the same was true for the first graders (2.67 vs. 1.95 sec) and third graders (2.29 vs. 1.52 sec). An analysis of variance confirmed that reaction time to ambiguous faces was significantly longer than to the other faces, $F(1,45) = 36.08, p < .01$, and the lack of a significant age × face type interaction indicates that the effect is roughly comparable across all age groups, $F(2,45) = 1.36, p > .25$. Thus, for all age groups, reaction time converged on the assignment of individuals to the single-attribute learning group.

It is possible that low levels of learning of the original items may result in an overestimate of the true proportion of analytic responders and an underestimate of the proportion of holistic responders in a given sample. For example, if category decisions during transfer are made on the basis of comparisons with known exemplars, and if only a subset of the original exemplars is known (e.g., faces 1, 2, 3, 5, 6, and 7 in Table 1), then a particular attribute (e.g., hair) may play a greater role than the others in category determinations. Thus, we compared the responses of individuals who performed perfectly on the original learning items during transfer with those who only met the more lax criterion of eight or nine out of 10 correct. Of the 30 adults who performed perfectly, 18 showed analytic patterns (single or dual attribute) and 12 showed ambiguous patterns. Of the 35 who met the more lax criterion, 20 showed analytic patterns and 15 showed unclear patterns. Of the third graders, six of the perfect performers showed analytic patterns and three showed unclear ones, whereas five of the less than perfect performers were analytic and four showed other patterns. For the first graders, the respective numbers were four analytic and one other for the perfect performers and eight analytic and 10 other for those who met the more lax criterion. As is evident from these distributions, there is no greater tendency for the less-than-perfect responders to be analytic in comparison to the perfect responders.

Since a large number of individuals showed unclear patterns of transfer performance, we analyzed the data from this group further. It is possible that their patterns of transfer performance approximate one or another of the rules, and that because of the strict criteria that we used (allowing only one violation of the rule) we were unable to classify these individuals. This is particularly problematic in the case of the holistic rule because 24 responses were relevant and because the transfer items are not "good" category exemplars. It may have been particularly difficult for a holistic responder to achieve a 23-out-of-24 criterion. To examine this issue, we set the criterion for single, dual, and holistic responding at 16 of 18, 14 of 16, and 20 of 24 consistent responses, respectively. In addition, for the analytic rules we allowed one of the two violations to be on the strongly diagnostic (dual attribute) or critical test (single attribute) items. In doing so, we identified an additional eight adults, five third graders, and five first graders as single-attribute responders. We also identified an additional six adults and one first grader as dual-attribute responders. However, even with this more lax criterion, we did not find any holistic responders in any age group. The percentages of learners who showed analytic patterns according to the less stringent criteria were 80, 84, and 78 for the adults and the third and first graders, respectively. Thus, it appears that among the learners, the most common approaches to the task are analytic ones.

Experiment 2

The results of the first experiment confirm and extend those of Ward and Scott (1987). In several age groups, among those who show clear patterns of performance, the most comonly observed modes of learning family-resemblance categories are analytic ones. These modes include the use of both single and multiattribute approaches. Most important, there is no evidence for either less analytic processing or more holistic processing in younger age groups even when more complex dual-attribute analytic rules are considered. It should be noted that the case against holistic responding is stronger in the Ward and Scott study, since the transfer items in that study were extremely "good" category exemplars, whereas in the present study, because of our interest in examining dual-attribute rules, they were less "good" according to holistic rules. Even in the present case, however, the transfer items always pitted matches on a single attribute against matches on more than one attribute. Thus, assuming approximately equal weighting of the attributes, there should always have been one category to which the items were more similar in an overall sense.

Since young children are found to respond holistically in other situations, it is important to consider the reasons why analytic patterns were observed in the first experiment. One possibility is that the youngest children tested (first graders) had all already made a transition to predominantly analytic modes of processing for most situations, and that only still younger children would be expected to exhibit holistic patterns of learning family-resemblance categories. Thus, in the second experiment, the performance of preschool children was observed.

Second, it has been suggested that low levels of learning for such category structures may result in an overestimate of the amount of analytic learning that has taken place (see, e.g., Kemler Nelson, 1988). Thus, even though the perfect performers from the first study provide evidence against this idea, the second experiment in this series used a training-to-criterion procedure rather than a fixed number of learning trials as a way of examining the issue further.

Method

Participants

The participants were 19 5-year-olds (mean age = 5-4) recruited from local preschools and 16 college students who received course credit for their participation.

Stimuli

The materials and category structures were the same as those described for Experiment 1.

Procedure

The procedure was identical to that of Experiment 1, except that individuals received learning trials until they reached a criterion of 12 in a row correct or until 96 learning trials had been presented, whichever came first. The learning trials involved randomly arranged presentations of each of the eight learning faces. After reaching criterion, participants were given the transfer task exactly as described in Experiment 1.

Results

All of the adults and 16 of the 19 children reached the 12-in-a-row criterion within the 96 learning trials, and the mean number of trials to criterion for the adults (24.75) was significantly less than that for the preschoolers who reached criterion (38.00), $F(1,30) = 5.37$, $p < .05$. The three preschoolers who did not reach criterion and one who subsequently failed to achieve the 8-of-10 criterion on the transfer task as described in the first experiment were excluded from further analyses. Of the remaining 15 preschoolers, six showed single-attribute patterns and one showed a disjunctive pattern according to the strict criteria as described in Experiment 1. Of the adults, five showed single-attribute patterns and three showed disjunctive patterns. The proportions of analytic responders in the two age groups are nearly identical and do not differ significantly, $\chi^2(1, N = 31) = .03$, $p > .50$. Among the adult single-attribute responders, the numbers identified as hair, mustache, ear, and nose learners were 1, 1, 2, and 1. The respective numbers for the children were 2, 4, 0, and 0. No individuals were identified as holistic responders. As in Experiment 1, there were no evident differences between those who achieved perfect performance with the original learning items during transfer and those who achieved only eight or nine out of 10 correct. The respective numbers of analytic and other types of responders for the perfect adults were 7 and 6, whereas for the nonperfect adults they were 1 and 2. For the children who achieved perfect transfer performance, there were 3 analytic responders and 1 other type, whereas for the nonperfect responders there were 4 and 7, respectively. Thus, analytic patterns are observed for preschoolers and adults even when the learning trials are continued to a 12-in-a-row correct learning criterion, and when only individuals who achieve perfect performance during transfer are considered.

As in Experiment 1, we determined the number of individuals who exhibited 16 of 18, 14 of 16, or 20 of 24 responses that were consistent with single, dual, or holistic approaches, respectively. An additional six adults and three children were identified as single-attribute responders, and one additional child was identified as a dual-attribute responder. No additional individuals in either age group were identified as holistic. Thus, in both age groups, a number of the individuals who had shown unclear patterns according to very stringent criteria were identified as showing patterns approximating single- or dual-attribute rules.

Experiment 3

In the first two studies we used cartoon-type faces as stimuli and found that most individuals who showed clearly identifiable patterns of performance learned family-resemblance category structures by way of analytic modes of processing. It is possible that the pattern of results obtained is specific to this type of material. For example, there is some research consistent with the idea that with development, individuals may become more sensitive to certain configural or holistic properties of faces (e.g., Diamond & Carey, 1977). Thus the materials themselves may be perceived more analytically by young children. In this case, it could be possible that properties of the materials obscure an otherwise greater holistic processing tendency on the part of young children.

In the third study, we used a different set of materials to determine whether or not the results obtained would generalize to materials other than the faces. The materials used in this study were cartoon "bugs" that varied in the attributes of wing size (large, medium, or small), facial expression (smile, neutral, or frown), number of body stripes (1, 2, or 3), and antenna length (long, medium, or short). As with the faces, each of the attributes had three levels, and, in a formal sense, the learning items can be represented exactly as the items depicted in Table 1 by replacing the label hair with wings, etc.

Since degree of learning did not appear to be an important factor in Experiment 2, we used a fixed number of trials. In addition, since the inclusion of transfer items to assess more complex rules did not reveal greater analysis by older individuals in the first two studies, only a smaller set of transfer items structured as shown in Table 4 was used. These were constructed to be consistent with the structure of those used in the original Ward and Scott (1987) study. The advantage of these transfer items is that they are all "good" category exemplars according to a holistic rule and thus provide a greater opportunity for holistic processing to be observed if it occurs.

Method

Participants and Procedure

The participants in the study were 24 5-year-olds (mean = 5-5) and 36 adult college students. They received a total of 48 learning

TABLE 4

TEST ITEMS FOR EXPERIMENT 3

Bug	Wings	Smile	Stripes	Antenna
T1	1	1	1	1[a]
T2	3	3	3	3[b]
T3	3	1	1	1
T4	1	3	3	3
T5	1	3	1	1
T6	3	1	3	3
T7	1	1	3	1
T8	3	3	1	3
T9	1	1	1	3
T10	3	3	3	1

[a] Category A prototype.
[b] Category B prototype.

trials with feedback and 36 transfer trials without feedback. The learning trials consisted of six different random orders of the eight learning items (formal structure given in Table 1). The transfer trials consisted of two presentations each of the eight learning items (Table 1), two prototype, and eight transfer items (Table 4). Individuals who made more than 13 correct transfer trial responses to the 16 presentations of the original learning items were identified as learners. The procedures for examining the convergence of reaction time on single-attribute learning were the same as described for Experiment 1. Assignment to single-attribute versus holistic learning groups was based on responses to the two presentations of each of the transfer items (T3–T10) shown in Table 4. Fifteen of those 16 responses had to be consistent with the use of a single attribute or with a holistic pattern (T3, T5, T7, and T9 as A and T4, T6, T8, and T10 as B) in order to classify a participant as an analytic or holistic learner.

RESULTS

Seventeen of the children and 35 of the adults were identified as learners. As in the first study, then, the proportion of learners among the adults is significantly higher than among the children, $\chi^2(1, N = 60) = 8.68$, $p < .01$. Of the child learners, eight were identified as analytic, single-attribute learners, whereas of the adults, 28 were identified as analytic. The respective numbers of individuals identified as responding to the antenna, wings, smile, and stripes were 13, 6, 5, and 4 for adults and 4, 1, 1, and 2 for children. Thus, although both age groups showed a bias toward the antenna, at least one individual in each age group was found to respond on the basis of each of the attributes. In contrast to the studies with cartoon faces, the proportion of analytic learners among the adults was significantly higher than that among children, $\chi^2(1, N = 52) = 5.82$, $p < .05$. Thus, to some extent, the age effects observed depend on the set of materials presented. However, it should also be noted that none of the children and only one adult exhibited purely holistic patterns of transfer performance. As was true for the faces, reaction times converge on the idea of analytic learning for both children and adults. Correct reaction time to the ambiguous and other bugs was 3.37 and 2.44 sec, respectively, for children and 1.40 and .89 sec, respectively, for adults. The effect of type of bug (ambiguous vs. other) was significant, $F(1,34) = 20.81$, $p < .001$, and did not interact significantly with age, $F(1,34) = 1.78$, $p > .15$.

As in Experiments 1 and 2, we examined approximations to rules. Using a 14-of-16 criterion, we found an additional two adults and three children to show single-attribute rules, and no additional individuals in either age group to show holistic patterns. Including these newly identified individuals, the adults are no longer significantly more likely than the children to exhibit single-attribute patterns, $\chi^2(1, N = 52) = 3.03$, $p > .05$. Finally, of the adults who responded perfectly, 10 were analytic and three showed other patterns. Of the less-than-perfect responders, 18 were analytic and four showed other patterns. For the children, the respective numbers were 2 and 2 for the perfect responders and 6 and 7 for the less-than-perfect responders. Thus, as in the first two experiments, there is no evident relation between analytic responding and the tendency to perform perfectly on the original learning items.

General Discussion

The present studies provide no support for the idea that children approach family-resemblance category learning tasks (at least the intentional ones used in these studies) with a holistic mode of processing. Rather, those children who exhibited unambiguous patterns of performance used single- and dual-attribute analytic approaches. The findings are more consistent with the idea that children approach category learning situations analytically, even when the materials to be learned have a family-resemblance structure that could conceivably lend itself to rapid learning by way of a holistic mode of processing. Thus, any advantage that young children have in learning real-world categories may stem from the availability of many partially informative attributes for natural categories rather than from category structures that lend themselves to holistic processing.

The proportions of young children who showed analytic patterns were roughly equivalent across the three studies. In contrast, the adults were more likely to show clear single-attribute patterns with the "bugs" in Experiment 3. The findings of that study illustrate the importance of using different sets of materials in an attempt to more clearly identify developmental patterns. There are apparently materials that will lead to higher proportions of analytic responding among adults than among children. However, even when a higher proportion of adults than preschoolers was found to show analytic patterns, the children were no more likely than the adults to show holistic patterns. Rather, they were less likely to show clear, unambiguous patterns. Whether materials exist that would lead to more holistic responding is unclear. However, there are no results from the present studies that suggest that holistic modes of learning by young children are likely to be observed.

The results are not entirely unexpected since young children have been found to exhibit higher levels of analytic responding when rule learning is emphasized (Smith, 1979), and they have often been found to exhibit hypothesis testing in concept-learning studies (see Tumblin & Gholson, 1981). It is in the nature of that hypothesis testing that developmental differences may emerge, and those differences may impact more on the learning of typical laboratory categories than on the learning of natural categories. Preschoolers' hypotheses are by no means as sophisticated as those of older children or adults, and they often take the form of response sets regarding particular dimensions rather than predictions regarding those dimensions (see Tumblin & Gholson, 1981). One of the major age-related changes seems to be in the tendency to alter hypotheses about the significance of particular attributes in the face of disconfirming information. Thus childen may be as analytic as adults in the sense that their responses are based on single features, and yet still not apply strategies as effectively. Such a mode of processing would be most detrimental to learning when only one attribute is informative with respect to category membership (as in many laboratory investigations) and less detrimental when many partially informative attributes exist (as in many natural categories). In the latter case, the child has a much higher probability of selecting an attribute that will be useful in categorizing.

Regarding any advantage that children may have with family-resemblance categories, it is important to note that the present studies were concerned only with the approaches that children take in learning such categories. They were not designed to determine whether young children are any more successful in learning such categories than they are in learning any other types. Nor were they specifically designed to replicate Kemler Nelson's (1984) demonstration that young children learn such categories as readily as older individuals. The high proportions of young learners across all studies and the results of the first study showing equivalent proportions of learners among first and third graders are consistent with the idea that even young children can be reasonably successful in learning family-resemblance categories. However, the greater success shown by adults indicates that young children do not possess some special mode of processing that puts them at an advantage with respect to other age groups in the learning of family-resemblance categories. Rather, they may apply the same modes of processing as adults, but possibly less efficiently.

An implication of the present findings is that there is no necessary link between the use of sophisticated strategies and the tendency to focus on a single attribute in performing a task nor between more primitive modes and the tendency to focus on the holistic properties of objects (see, e.g., Smith, 1983). In a related way, young children will not inevitably be found to respond more holistically than older children and adults. Whether children will be found to respond more holistically or less analytically appears to depend on a number of factors, including the nature of the task and the materials (see also Wilkening & Lange, in press). Thus, it is inappropriate to describe the young child as possessing a generally holistic mode of processing.

Despite the failure to find holistic responding by young children in the present studies, the results are not inconsistent with all interpretations of children's so called holistic processing. In particular, they are compatible with at least two recent formulations. First, Ward, Foley, and Cole (1986) have interpreted the developmental findings from simple classification tasks within the framework of an integral-to-separable model of processing. Within that model, information about overall similarity is available to the individual earlier in processing than is information about exact values of particular dimensions. Ward et al. suggested that one of the prime reasons that young children make many holistic responses in simple classification tasks is that they adopt rapid response tempos and thus respond before exact dimensional information is available. They went on to suggest that children approach such classification tasks "with the idea that an answer, any answer, will do" (p. 223).

More recently, Smith (1989) has presented the most comprehensive formulation of children's holistic responding to date. Within that model, one of the most important determinants of 4- and 5-year-olds' holistic-looking responses in simple classification tasks is the low value they place on identity as a special type of similarity relation. In contrast, adults place a high value on identity, and thus they selectively weight particular dimensions in order to achieve an identity match.

Although they were not designed to test these models of the classification process, the present results are quite consistent with these most recent formulations. When faced with a simple classification task in which any classification principles are allowed, the child need not use identity matches. However, in category learning situations in which groupings are not arbitrary, children may recognize that they must do something special in order to learn appropriate categorizations. Within the integral-to-separable model, one could argue that when children attempt to learn categories they are not satisfied with the holistic information available early in processing. Thus they delay responding until information about exact matches on particular dimensions or attributes is available. Within Smith's identity-valuing model, one could argue that in learning categories children place a higher value on identity than they do when simply classifying a set of objects into arbitrary groups.

Smith's (1989) model may also help in pointing out one of the limits on the present conclusions. Her work is consistent with the idea that still younger children than those tested in the present studies (e.g., 2- and 3-year-olds) do indeed distribute attention evenly across component dimensions. This, combined with the low value they place on identity, leads to "true" holistic, overall similarity responses in simple classification tasks. Perhaps if we had tested 2- and 3-year-olds we would have found some who fit the holistic rule response pattern. Thus, it is possible that there is a shift from holistic to analytic category learning, but that the shift takes place at an earlier age than has heretofore been described (e.g., Kemler, 1983).

In addition, the present results are not inconsistent with the idea that 4- and 5-year-olds may be more holistic in some situations with some sets of materials. For example, the present materials involve variations in the spatially separate component parts of objects. Such parts may be more separable from the whole object than are continuous perceptual dimensions (e.g., brightness) (see, e.g., Shepp, Barrett, & Kolbet, 1987). Perhaps if the latter types of variations are used a higher proportion of holistic responders will be found.

It is important to note that the present studies involved intentional learning of categories. Although children often deliberately attempt to learn categories, they also learn incidentally by way of daily interactions with objects in their environments. Since some research indicates that intentional learning may be more analytic than incidental learning (e.g., Kemler Nelson, 1984), it is useful to ask whether intentional learning instructions are necessary in order to observe analytic modes of category processing in young children. Recent research indicates that they are not (Ward et al., 1989). Ward et al. showed children novel objects and provided novel labels for those objects. The children were then shown variants and were asked to indicate whether or not the label also applied to those variants. The most common decision rule used by preschoolers was a match on a single attribute of the objects.

In the Ward et al. (1989) study, no explicit learning instructions were given, and thus the study is similar in some ways to simple classification tasks. However, in contrast to those tasks in which categories are arbitrary, the use of labels in the Ward et al. study clearly indicated that particular categories existed. It is reasonable to suppose that labels imply to the child that nonarbitrary categories exist and therefore that particular (analytic) categorization rules must be found. What the present results imply, then, in combination with other studies in the literature, is that children are quite sensitive to differences between tasks and that they use those apparent differences in determining which particular types of information to seek. Since children are faced with a number of different types of category-learning situations, this sensitivity to the need to alter their mode of processing for different situations may be an important contributing factor to their relative success in learning real-world categories.

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