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Complementary versus Contrastive Classification in Preschool Children

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We compare 3-year-old children's superordinate level classification under two experimental conditions. In the *Complementary* condition, children were instructed to sort a set of pictures three times, each time extracting a different "target" class (e.g., Animals) from the remaining items (e.g., Clothing and Food). In the *Contrastive* condition, they formed the three superordinate level classes simultaneously within a single trial (Animals vs Clothing vs Food). Because the probability of assigning items correctly by chance differs under these two conditions, we introduce statistical adjustments to take the different rates of chance success into account. Although children in the Contrastive condition had to divide their attention among three target classes, while those in the Complementary condition had to focus on only one target category per trial, there was no mean difference between these two experimental conditions. There was, however, a striking difference in the distributions under the two conditions: scores in the Contrastive condition were bimodally distributed, while those in the Complementary condition were more normally distributed. A second study, using different categories (Furniture, Vehicles, and Clothing), revealed the same effects. These data suggest that contrast in classification benefits some, but not all, preschool children.

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A considerable amount of recent research has been devoted to examining the young child's appreciation of taxonomic relations at superordinate levels (see Gelman & Baillargeon, 1983 and Markman & Callanan, 1983 for reviews). Although this issue remains somewhat controversial, researchers are united on at least one important point: The conditions of testing have profound effects on children's performance (Case, 1984; Gelman, 1978; Shatz, 1978; Siegler, 1986; Waxman & Gelman, 1986). In this paper, we focus on one performance factor in particular—the number of categories a child is required to form on any given classification trial. This issue has important theoretical and methodological implications for developmental work.

Consider the following problem: A child is presented with a deck of 12 cards (including pictures of Animals, Clothing, and Food) and instructed to sort them into different categories. There are several ways to structure this superordinate classification task. We might ask the child to go through the deck three times, each time extracting a different "target" class from the remaining elements (e.g., Animals vs Nonanimals). This is a *Complementary* approach: A different superordinate class is selected from the remaining elements on each of three successive trials. Alternatively, we might use a *Contrastive* approach, asking the child to form the three classes simultaneously within a single trial (i.e., Animals vs Clothing vs Food).

On intuitive grounds alone, one might expect that focusing on a single target class on each trial (as in the Complementary procedure) would be simpler than dividing one's attention among three classes (as in the Contrastive procedure). In fact, in Piagetian theory, Complementary classification (A vs Â) is the logical and ontogenetic precursor to classification in which more than one target class (e.g., A_1 vs A_2 vs A_3) can be considered simultaneously (Inhelder & Piaget, 1964). Indeed, the ability to shift attention among multiple classes may represent an important developmental advance (Sugarman, 1982). This view leads to the prediction that preschoolers will classify more successfully under Complementary than Contrastive conditions.

However, there is also support for a very different view—one that derives from recent theorizing regarding the benefit of contrast in establishing taxonomic systems of organization (Clark, 1987; Horton, 1983; Markman, 1984; Miller & Johnson-Laird, 1976; Shipley & Kuhn, 1983; Wales, Colman, & Pattison, 1984). Note that in the Contrastive condition, the three target classes (A_1 vs A_2 vs A_3) are contrastive, or equally detailed, at the superordinate level, while in the Complementary condition this is not the case. By definition, the "remaining items" in the Complementary condition (Class Ā) form a more general, miscellaneous group than the target class (Class A). Thus, if contrast clarifies class boundaries, then children in the Contrastive procedure may classify at least as well as those in the Complementary procedure, despite the fact that they must consider multiple classes within a single trial.

These different theoretical predictions present an interesting methodological problem. To adjudicate between them, one must compare children's classification under Complementary and Contrastive conditions. However, because the probability of assigning an item to the correct category *by chance* differs under the two conditions, a direct comparison of the results obtained in two conditions (e.g., mean number correct) is unwarranted. In the Complementary condition (A vs Ā), the probability of assigning an item correctly by chance is 1/2; in the Contrastive condition (A_1 vs A_2 vs A_3), the probability of assigning an item correctly by chance is 1/3. Therefore, in Experiment I, we develop a method which adjusts for these differences and enables a legitimate cross-task comparison. In Experiment II, we replicate our results with another group of children and a different set of stimuli.

EXPERIMENT I

Method

Subjects. Forty 3-year-old children (mean age = 3.6, ranging from 3.1 to 3.11) served as subjects and were randomly assigned to one of two experimental conditions. Children were drawn from several preschool programs serving racially mixed, middle-class populations in Philadelphia and the greater Boston area. Approximately equal numbers of boys and girls were included in each experimental condition (see below).

Stimuli. A set of 21 black-and-white line drawings were selected for typicality from Snodgrass and Vanderwart's (1980) standardized drawings.[1] Each was magnified to three times its original size and mounted on 11 × 15-cm cards. There were seven drawings from each of three superordinate level categories under investigation—Animals, Clothing, and Food (See Table 1). Nine of these drawings (3 per superordinate class) were used by the experimenter as clues; the remaining 12 were sorted by the children.

Procedure. Each child was tested individually, in a quiet, vacant room on the preschool premises. The experimenter introduced each child to three hand puppets and then pointed to three typical instances of a superordinate class to indicate ". . . the kind of thing each puppet likes. . . ." For example, to indicate the class Animal, the experimenter said, "This puppet only likes things like a dog, and a horse, and a duck, and other things like that," as she placed pictures of these instances below the puppet. These pictures remained in full view throughout the classification trials. Children were then asked to help the puppets find other things they would like. The Complementary and Contrastive conditions differed only in the manner in which children were instructed to sort.

In the Complementary condition, children were instructed to select a different superordinate class on each of three successive trials. The order in which these were classified was completely counterbalanced. On each such trial, the experimenter selected a different puppet, indicated the target class by reference to the typical instances (e.g., dog, horse, and duck for the category Animal), and instructed the children to place other members of the target class in one pile and all remaining items in a second pile. On each trial, all 12 stimuli were presented singly, in random order. The three typical instances remained in full view as the children classified.

In the Contrastive condition, children were instructed to form the three superordinate classes (e.g., Animals vs Clothing vs Food) within a single trial. The experimenter placed all three puppets in a row facing the child, referred to the typical instances for each superordinate level class, and instructed the children to sort the remaining 12 stimuli into the three target classes. The left–right position of the three classes was completely

[1] Typicality was assessed on a different set of children who were drawn from a comparable population. See Waxman and Gelman (1986) for details.

TABLE 1
EXPERIMENT I: COMPLETE LIST OF STIMULI

Category Items placed by experimenter	Items placed by child
Animal	
Dog	Cow
Horse	Rabbit
Duck	Kitten
	Bird
Clothing	
Pants	Dress
Jacket	Shirt
Blouse	Skirt
	Sweatshirt
Food	
Apple	Corn
Celery	Carrot
Grapes	Lemon
	Banana

counterbalanced. Stimuli were presented singly, in random order. The three typical instances for each class remained in full view as the children classified.

Scoring. We recorded the number of items each child placed correctly. Raw scores could range from 0 to 36 in the Complementary condition and from 0 to 12 in the Contrastive condition. We then adjusted each child's raw score using a standard correction for guessing:

Let $x_1, \ldots, x_{20}, y_1, \ldots, y_{20}$ be the proportion of correct answers by the 40 subjects, the x's from the Complementary condition and the y's from the Contrastive condition. We define transformations of the x's and y's as follows:

$$u_i = 2(x_i - \tfrac{1}{2})$$
$$w_i = -\tfrac{3}{2}y_i^2 + \tfrac{7}{2}y_i - 1.$$

The purpose of these transformations is to make the scores under the two conditions comparable by assigning perfect scores ($x_i = 1$ and $y_i = 1$) a common value of 1, scores of 0 ($x_i = 0$ and $y_i = 0$) a common value of -1, and scores expected under random guessing in each condition ($x_i = \frac{1}{2}$ and $y_i = \frac{1}{3}$) a common value of 0. For the Contrastive condition, this is performed by fitting a second-degree polynomial through the values $(0, -1)$, $(\frac{1}{3}, 0)$, and $(1, 1)$; the resulting polynomial defines the w's. For the Complementary condition, this can be performed by fitting a first-degree polynomial through the points $(0, -1)$, $(\frac{1}{2}, 0)$, and $(1, 1)$; the resulting linear transformation yields the u's. Thus the u's and the w's may range from -1 to 1; in both cases, a value of -1 corresponds to all answers incorrect, a value of 1 corresponds to all answers correct, and a value of 0 corresponds to the score expected under pure guessing.

Results and Discussion

Table 2 provides both raw and adjusted scores for each subject in each condition. When the scores have been adjusted by the method described above, we find no mean difference between the two conditions (Mann–Whitney test, $p > .20$).[2]

A careful inspection of Table 2 reveals that there is, nonetheless, a striking difference between the two conditions. Scores in the Contrastive condition appear to be distributed bimodally: one group (consisting of 10 of the 20 children) performed perfectly while another group (consisting of 7 of the 20) scored at or below the level expected by chance. Scores in the Complementary condition do not appear to be bimodally distributed. A Siegel–Tukey rank test reveals that significantly more subjects perform at the extremes in the Contrastive than in the Complementary condition, $p < .002$.

To further examine this apparent bimodality, we divide the 40 adjusted scores into quartiles and then form two groups—the extremes (scores from the top and bottom quartiles) and the midrange (scores from the two middle quartiles (see Table 3). Fischer's exact test reveals a significant difference between the extreme and the middle quartile distributions in the two experimental conditions, $p = .02$.

Finally, we tested the hypothesis that the bimodality obtained in the Contrastive condition was simply age-related. We found no correlation between age and performance in either condition; older 3-year-olds were as likely to benefit from contrast as were younger 3-year-olds.

The difference between the two distributions, and particularly the apparent bimodality in the Contrastive condition, was somewhat surprising; it could not have been predicted from any of the other reports concerning the role of contrast in cognitive development (e.g., Horton, 1983; Shipley & Kuhn, 1983). Therefore, we designed a second experiment to observe this phenomenon more closely. In Experiment II we asked another group of 3-year-old children to classify under either Contrastive or Complementary conditions. This time, however, we presented them with different categories (Furniture, Clothing, and Vehicles) and used colored photographs instead of black-and-white line drawings. Thus, Experiment II provides us with an opportunity to replicate the bimodality obtained in Experiment I and to extend these findings to a larger class of materials.

EXPERIMENT II

Method

Subjects. Forty 3-year-old children (mean age = 3.6, ranging from 2.11 to 3.11) served as subjects and were randomly assigned to one of

[2] We recognize that the transformation we employed may not perfectly characterize the strategies children use in classification tasks. One alternative approach is to assume the classification task is a binomial experiment, estimate success probabilities for each child, and use the normal approximation to the binomial to test the hypothesis that the average of the success probabilities under the Complementary condition (transformed exactly as the x_i's for precisely the same reason) equals the average of their transformed Contrastive counterparts. We did not follow this approach for two reasons: First, the assumption that each child randomly guesses on each trial with some unknown probability of success is questionable (particularly to those familiar with signal detection theory). Second, the normal approximations are apt to be quite poor; using the standard rule of thumb that the approximation is inadequate for np or $nq < 5$, we find inadequacies for over half of the children. Therefore, the nonparametric Mann–Whitney is more appropriate for these data. To satisfy ourselves that there was truly no mean difference between the conditions, we went one step further. Because the most plausible model of children's behavior in classification tasks may be one in which children behave according to a guessing model some (unknown) fraction of the time and according to a "no-guessing" model for the remainder of the time. We therefore calculated a different set of adjusted scores, based on a no-guessing, deterministic model. Like the standard correction for guessing, this no-guessing model revealed no mean difference between the conditions. Finding no mean difference under either of these two (extreme) models, there should be no mean difference using any combination of them.

TABLE 2

EXPERIMENT I: RAW SUCCESS SCORES, RAW PROPORTIONS CORRECT, AND ADJUSTED SUCCESS SCORES FOR SUBJECTS IN THE COMPLEMENTARY AND CONTRASTIVE CLASSIFICATION CONDITIONS

Complementary condition				Contrastive condition			
Subject number	Raw success score	Raw proportion correct (x_i)	Adjusted score (u_i)	Subject number	Raw success score	Raw proportion correct (y_i)	Adjusted score (w_i)
1	27	.75	.50	21	12	1.00	1.00
2	21	.58	.17	22	3	.25	−.22
3	30	.83	.67	23	2	.17	−.45
4	30	.83	.67	24	4	.33	0.00
5	24	.67	.33	25	5	.42	.21
6	30	.83	.67	26	4	.33	0.00
7	22	.61	.22	27	12	1.00	1.00
8	27	.75	.50	28	12	1.00	1.00
9	33	.92	.83	29	12	1.00	1.00
10	22	.61	.22	30	12	1.00	1.00
11	15	.42	−.17	31	7	.58	.53
12	36	1.0	1.0	32	3	.25	−.22
13	22	.61	.22	33	12	1.00	1.00
14	30	.83	.67	34	12	1.00	1.00
15	21	.58	.17	35	10	.83	.87
16	25	.69	.39	36	12	1.00	1.00
17	32	.89	.78	37	12	1.00	1.00
18	22	.61	.22	38	3	.25	−.22
19	22	.61	.22	39	2	.17	−.45
20	27	.75	.50	40	12	1.00	1.00
Mean:	25.9	.72	.44		8.2	.68	.52

TABLE 3

EXPERIMENT I: DISTRIBUTIONS OF ADJUSTED SCORES IN THE COMPLEMENTARY AND CONTRASTIVE CONDITIONS, DIVIDED INTO EXTREME (END QUARTERS) AND MIDRANGE (MIDDLE HALF) GROUPS

	Complementary condition	Contrastive condition
End quarters	8	16
Middle half	12	4

two experimental conditions. Children were drawn from several preschool programs serving racially-mixed, middle-class populations in the greater Boston area. Approximately equal numbers of boys and girls were included in each experimental condition (see below).

Stimuli. A set of 21 colored photographs was selected from magazines and books and mounted on 11 × 15-cm cards. There were seven photographs from each of three superordinate level categories under investigation—Furniture, Vehicles, and Clothing[3] (see Table 4). Nine of these (3 per superordinate class) were used by the experimenter as clues; the remaining 12 were sorted by the children.

Procedure. Children were randomly assigned to either the Contrastive or the Complementary condition. The procedures employed in these conditions were identical to those described in Experiment I.

Scoring. Scores were computed as in Experiment I.

Results and Discussion

The results of Experiment II replicate the effects reported in Experiment I and extend these to a new set of stimuli. Table 5 provides both raw and adjusted scores for subjects in each condition. As in Experiment II, a comparison of adjusted scores reveals no mean difference between 3-year-olds' performance in the Contrastive and Complementary conditions (Mann–Whitney test, $p > .07$). Yet once again, children in the Contrastive condition performed at the extremes of the distribution while those in the Complementary condition formed a more normal distribution, Siegel–Tukey rank test (one-tailed), $p < .01$. Further, Fisher's exact test (one-tailed) revealed that significantly more subjects in the Contrastive condition fell into the extremes than did their agemates in the Complementary condition, $p < .05$ (see Table 6). As was the case in Experiment I, the bimodality obtained in the Contrastive condition could not be

[3] In pilot work, we found only five superordinate level categories (Animals, Clothing, Food, Furniture, and Vehicles) with which 3-year-olds were consistently familiar. Therefore, to ensure that our youngest children were familiar with the materials, one category had to be included in both Experiments I and II. Although the superordinate category Clothing was included in both, different stimuli were selected to depict this category in Experiment II (see Tables 1 and 4).

TABLE 4
EXPERIMENT II: COMPLETE LIST OF STIMULI

Category Items placed by experimenter	Items placed by child
Furniture	
Chair	Couch
Bed	Kitchen table
Coffee table	Wardrobe
	Reclining chair
Clothing	
Dungarees	Raincoat
Jacket	Blouse
T-shirt	Skirt
	Dress shirt and tie
Vehicles	
Motorboat	Antique car
Station wagon	Bus
Airplane	Sailboat
	Helicopter

attributed to age: There was no correlation between age and performance in either experimental condition.

GENERAL DISCUSSION

In both Experiments I and II, we found no significant mean difference between preschoolers' classification in the Contrastive condition (where they had to divide their attention among three target classes) and the Complementary condition (where they had to focus on only one target category per trial). This, in itself, is an interesting finding. And although we fully recognize that the adjustment employed here is not the only one which might have been applied to our data, we note that any adjustment which focuses on mean scores will obscure the more provocative finding: For some children (in particular, those in the Contrastive condition with perfect scores), the explicit contrast appears to have offset any difficulty imposed by simultaneous consideration of multiple classes within a single trial. Yet for others, notably those earning scores at the opposite end of the distribution, contrast appears to offer no such advantage. Indeed, for some children, it may present an obstacle to successful classification.[4]

[4] There is additional support for the view that there are indeed two different populations of children within the Contrastive condition. Hoben Thomas has pointed out that the data in the Contrastive condition conform to a two-component mixture of binomials, while those in the Complementary condition conform to a single-binomial model.

TABLE 5
EXPERIMENT II: RAW SUCCESS SCORES, RAW PROPORTIONS CORRECT, AND ADJUSTED SUCCESS SCORES FOR SUBJECTS IN THE COMPLEMENTARY AND CONTRASTIVE CLASSIFICATION CONDITIONS

	Complementary condition				Contrastive condition		
Subject number	Raw success score	Raw proportion correct (x_i)	Adjusted score (u_i)	Subject number	Raw success score	Raw proportion correct (y_i)	Adjusted score (w_i)
1	28	.78	.56	21	9	.75	.78
2	26	.72	.44	22	10	.83	.87
3	31	.86	.72	23	6	.50	.38
4	22	.61	.22	24	12	1.00	1.00
5	28	.78	.56	25	12	1.00	1.00
6	31	.86	.72	26	12	1.00	1.00
7	28	.78	.56	27	12	1.00	1.00
8	33	.92	.83	28	11	.92	.95
9	32	.89	.78	29	1	.08	−.73
10	19	.53	.06	30	12	1.00	1.00
11	36	1.00	1.00	31	11	.92	.95
12	30	.83	.67	32	11	.92	.95
13	30	.83	.67	33	11	.92	.95
14	17	.47	−.06	34	3	.25	−.22
15	27	.75	.50	35	10	.83	.87
16	11	.31	−.39	36	12	1.00	1.00
17	27	.75	.50	37	3	.25	−.22
18	19	.53	.06	38	6	.50	.38
19	12	.33	−.33	39	3	.25	−.22
20	21	.58	.17	40	2	.17	−.45
Mean:	25.4	.71	.42		8.5	.70	.59

TABLE 6

EXPERIMENT II: DISTRIBUTIONS OF ADJUSTED SCORES IN THE COMPLEMENTARY AND CONTRASTIVE CONDITIONS, DIVIDED INTO EXTREME (END QUARTERS) AND MIDRANGE (MIDDLE HALF) GROUPS

	Complementary condition	Contrastive condition
End quarters	9	15
Middle half	11	5

While it is clear from these experiments that contrast among classes does not benefit all children under all experimental conditions, the data do not permit us to ascertain precisely why this bimodality emerged. The bimodality cannot be attributed to age, for older 3-year-olds were as likely to benefit from contrast as were younger 3-year-olds. Another possibility is that individual differences in children's existing knowledge or appreciation of the superordinate classes under consideration distinguish the two groups of children in the Contrastive condition. As a group, 3-year-old children have considerable difficulty imposing superordinate level relations in classification tasks (Markman, Cox, & Machida, 1981; Rosch, Mervis, Gray, Boyes-Braem, & Johnson, 1976; Waxman & Gelman, 1986), but there are marked individual differences which appear to be related to the child's knowledge about the classes under consideration (Chi, 1978). Perhaps contrast can only benefit those children who appreciate the superordinate level classes and for whom the contrast is therefore apparent. This possibility may be tested by conducting a posttest interview to determine whether a child's knowledge about the classes predicts their performance in the Contrastive condition.

Another possible explanation for the bimodality obtained in the Contrastive condition involves the strategies which the children adopt in the classification task itself. Two different strategies are possible. In the first, placement is determined within a single three-way comparison. When presented with a given target item, the child simply judges which of the three classes before her is most appropriate. In the second strategy, placement involves an exhaustive series of two-way comparisons. When presented with an item, the child judges its appropriateness for each of the three superordinate classes individually. For example, she first checks to see if it is an appropriate member of Class A_1; she then checks to see if it is an appropriate member of Class A_2; she finally checks to see if it is an appropriate member of Class A_3; only then does she decide where to place it. Because this second strategy may require more sustained attention, more memory, and more coordination, it may produce more errors. This hypothesis is difficult to test, for 3-year-old children have difficulty articulating their problem-solving strategies (Brown, Bransford, Ferrara, & Campione, 1983). However, one might attempt

to impose each of these strategies onto different groups of children and then to compare the performance of these groups in a contrastive classification task.

In conclusion, additional research specifically designed to distinguish the children who fall into one extreme in the Contrastive condition from those in the other and to pinpoint the mechanisms responsible for the bimodality is warranted. Theories regarding the role of contrast in cognitive development await such information.

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