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AUTHOR Isen, Alice M.; And Others
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ABSTRACT

This paper reports two experiments which examined processes involved in children's ability to solve class inclusion problems of the form, "Are there more A' (subclass) or more A (class)?" In the first experiment a total of 216 children in age groups 5, 7 and 9 years were placed in three conditions which were designed to distinguish performance on single and double class inclusion problems (involving implicit and explicit partitioning) and to examine subsequent transfer of experience with the double class display procedure when the child returned to the traditional one-class setting. Findings support the position that certain perceptual contexts are more likely to induce the child to perceive the class rather than merely the subclasses. Overall transfer results also showed improvement but gave no significant effects for explicit compared with implicit partioning of the double class display. Experiment 2 placed into two conditions a total of 120 children in age groups 5, 7 and 9 years, each condition comprising three consecutive tests designed to test the effect of intervening double class problems on Test 2 performance and on Test 3 transfer effects. Anticipated improvements were demonstrated. Comparison of data from each experiment suggests that class inclusion is not what is at issue in part-whole comparisons. A general process description of what occurs in class inclusion problems is offered. (GO)

The facilitation of class-inclusion by use of multiple comparisons and two-class perceptual displays

Alice M. Isen

University of Maryland, Baltimore County

Christine A. Riley

Princeton University

Teressa Tucker

University of Maryland, Baltimore County

and

Tom Trabasso

Princeton University

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In the "standard" class-inclusion problem, a child is shown a single class of objects which may be partitioned into two subclasses. Consider the array shown in the left side of Figure 1. Here the class, animals, is subdivided into D's, dogs, and C's, cats; and the question is asked: "Are there more dogs or more animals?" The well known finding is that children younger than 7 years typically respond "dogs", i.e., they name the major subclass rather than the class.

According to Inhelder & Piaget (1964), preoperational children fail to solve a class inclusion problem because they are unable to compare a subordinate class simultaneously with its super-ordinate class. Further, they are presumed to lack the logical operations of addition and subtraction of classes.

Other explanations identify either perceptual or linguistic factors as sources of difficulty. Wohlwill (1968) showed that children were more successful when the physical display was absent than when it was present and put forth a perceptual hypothesis. Here the child partitions the single-class display into two subclasses; the display does not lend itself to a perceptual interpretation of the subclasses as a class (e.g., the dogs do not resemble the cats). On the linguistic side, Markman (1973) notes that interpreting the connective "or" exclusively--the most common usage--would reinforce the tendency towards subclass division; and she demonstrated that when the class name did not apply to either of the subclass members (e.g., "family" cannot be used to describe "children"), performance by young children who fail the standard question was markedly improved.

The present study builds upon Wohlwill's (1968) perceptual set interpretation and offers a novel method for the study of the child's understanding of part-whole relations.

In his Experiment III, Wohlwill (1968) facilitated performance by adding a few objects that were not members of either subclass. Presumably, these additional objects allowed the child to perceptually contrast the class in question with other objects. We sought to enhance this effect by providing another class as a contrast to the one being queried. Wohlwill did not, however, include transfer tests to single-class problems, and success could have occurred through the child treating all objects other than the named subclass (A_1) as the named class (A). A transfer test on single-class problems does not allow this strategy.

On the right-hand side of Figure 1, a two-class display is shown. Each class may, in turn, be subdivided into two subclasses. One class is animals, the D's are dogs and the C's are cats; the other class is fruits, the A's are apples and the O's are Oranges. You can see that one can perceptually group the elements in the display into two classes as well as four subclasses. The double-class display allows simultaneous perceptual comparison of classes and subclasses.

In Figure 2, we let these classes be represented as A and B, the subclasses as A_1 and A_2, B_1 and B_2, respectively. Note that the ratio of the major subclass to the class in A is 6:8; in B, it is 4:8. Wohlwill's (1968) procedure reduced the ratio of major subclass objects in a similar fashion and we included this variable for systematic study. Ahr & Youniss (1970) have found that as the major/minor ratio is reduced, the solution rate increases. They did not reduce the ratio below 1.00 since the named subclass in the question would then become a minority perceptually. Under the perceptual hypothesis, the failure to find a subclass which is larger would lead to a perceptual interpretation of the display as a class.

Returning to Figure 2, we can query the child on comparisons at the level of class and/or subclass both within (which is the traditional class-inclusion problem) and between classes. That is, we can ask which is more, A_1 or A? or which is more, A_1 or B? Note that both of these questions entail common logical operations of addition of subclasses and comparisons of their outcomes as well as simultaneous comparison of class with subclass. Hence, the use of two class displays, multiple partitioning and questioning allows one to study part-whole comparisons without some of the awkwardnesses of class-inclusion problems. For example, it makes sense to ask whether there are more apples than more pets; the class-inclusion question, however, is ungrammatical given an exclusive interpretation of the "or" connective.

We studied some consequences of these ideas on children in age groups of 5, 7, and 9 years.

In our first experiment, we contrasted three conditions which are summarized in outline in Figure 3. In Figure 3 you can see that for condition 1, the children solved 4 single class-inclusion problems and then were retested on 4 similar and 4 unrelated single class-inclusion problems. This is a control condition.

In condition I2, where I stands for Implicit partitioning and 2 for double-class context, the first 4 problems occur as in condition 1 in a double-class context and in condition E2, when E stands for Explicit partitioning, the first 4 problems plus all other comparisons are queried in the double-class context. Both groups are then transferred to the same set of related and unrelated class-inclusion problems in a one class context as in condition 1. A related problem is one involving the same class, though not the exact problem previously solved, and an unrelated problem involves a new class.

We tested 216 children in Exp. I; there were 3 age groups X 3 conditions with 24 children per cell, half of whom were boys and half of whom were girls. The children were from two schools in the Baltimore City and Baltimore County School Districts and represented a wide socio-economic and racial distribution.

Eight different kinds of problems were used. Figure 4 lists these as well as their overall relative difficulty for each age group. The problem subsets, which subclass or class was mentioned first, ratios, which problems were related and served as specific transfer and which ones were new and served as general transfer were completely counterbalanced over the subjects.

Let us consider the test results first. In testing, double-class contexts and the lower (major/minor subclass) ratio each facilitated performance ($F(2,179) = 15.15$ and 33.12, respectively, $p < .01$). The main results, plotted as the percentage of correct answers as a function of age for the three context conditions and the two ratios are shown in Figure 5. We note, comparing the two figures that these factors interacted ($F(2,179) = 5.11$, $p < .01$):when the major subclass was large i.e., 6 vs. 2 in the 6:8 ratio, the double-class contexts were superior; when the sublcasses were equal, i.e., 4 vs. 4 in the 4:8 ratio, overall performance for all groups improved and the effect of double-class context was reduced. Both main effects and the interaction are consistent with the interpretation that certain perceptual contexts are more likely to induce the child to perceive the class rather than just the subclasses although the basis for this perception differs.

In the transfer to single-class problems (the traditional class-inclusion situation), there was no difference ($F\ (1,179) < 1$) between specific and general transfer, as can be seen in Figure 6. This result obviates an interpretation that the children were using a perceptual strategy based upon a combination of the minor subclass and the unnamed class when both classes were present.

The overall transfer results are summarized in Figure 7. In looking at "transfer", we are examining the carryover effect of experience with our double-class display procedure when the child returns to the traditional one-class setting. The average improvement is 13 percent and compares favorably with Wohlwill's (1968) results (10 to 15 percent). Figure 8 shows that this transfer depended on the double-class displays ($F\ (2,179) = 4.29$, $p < .01$) and the ratio since the two factors also interacted ($F\ (2,179) = 7.76$, $p < .01$). There was no net transfer effect of having explicitly partitioned all classes and subclasses of the double-class display, i.e., I2 and E2 showed about the same transfer; a finding contrary to our expectations since we thought that all possible comparisons would promote counting and combining operations.

Experiment II used an intervention procedure, and its design is summarized in Figure 9. Again we studied 5, 7 and 9 year old children in two conditions with the same factors as before. There were 2 X 3 X 24 = 120 children in all; 24 per cell. Both groups were initially tested on 4 single-class-inclusion problems. The children in condition 1 were retested on a related set and then were tested a third time on 4 related and 4 new problems, all in single class displays. For condition 2, the second test occurred in the double-class context and all possible class/subclass comparisons were made. Then the children were tested in a single-class context for specific and general transfer.

Figure 10 summarizes the main findings for the three tests. The double-class context improved testing in phase 2 by 4.2% and in transfer, phase 3 by 13.6%, the latter being equivalent to the finding of Exp. I and Wohlwill's Exp. III (1968). In the analysis, only Age, $F(2,120) = 12.66$; phase, $F(2,240) = 18.15$; and the condition X phase interaction, $F(2,240) = 3.70$ were statistically reliable ($p < .05$). All other factors were not significant (this particular analysis excludes ratio effects which were reliable throughout all three phases and did not interact with any other variable). Figure 11 shows that there was no specific versus general ~~transfer~~ difference.

We now turn to an examination of some of the multiple partition comparisons for conditions E2 of Exp. I and 2 of Exp. II. In Figure 12, we have averaged the percent correct for the two conditions and compared the class-inclusion results. The N's per data point are 48 children. In effect, as the major to minor subclass ratio decreases, the percent correct increases. These results replicate Ahr & Youniss (1970). If the children are using subclass comparisons to answer class-inclusion questions, then these results follow. In the top curve, the unnamed class is larger and if it is identified with the class named, the child can be correct but for reasons other than comparing a class with its subclass. In B_1 vs. B, the ratio is 1.00 and he cannot find a larger subclass.

The most important finding is shown in Figure 13 which contrasts class versus subclass comparison results within (A vs. A_1 or class-inclusion) and between (A_1 vs. B or non class-inclusion) classes. The nearly identical results for A_1 vs. A and A_1 vs. B shows that class-inclusion is not what is at issue in part-whole comparisons. Rather, one gets the same results on comparison of a subclass with a class, regardless of whether or not that class contains the subclass. However, the same logical operations are involved. $A > A_1$ entails $A = A_1 + A_2 = 6 + 2 = 8$ and $A_1 = 6$, and since $8 > 6$, $\therefore A > A_1$. Likewise $B = B_1 + B_2 = 4 + 4 = 8$, $A_1 = 6$, since $8 > 6$, then $B > A_1$. Identical counting, adding and comparison operators would have to occur in both conditions. If comparisons are made at the subclass level, A_1 will be selected since it is larger than B_1 or B_2 alone. When the children err, they state A_1, not B_1 or B_2. Thus these results are consistent with the perceptual hypothesis.

Within-subclass and between-class comparisons are summarized in Figure 14. Again ratio effects are observed since A_1 vs. A_2 is better than B_1 vs. B_2. However, the poor performance of B_1 vs. B_2 and the worse performance of A vs. B results from the fact that there are equalities and there is a conflict between the combining of classes and the inequality called for in the question. We note that while in the B_1 vs. B_2 question, the children were random in their answers whereas in A vs. B, they gave A as the answer presumably because A_1 is the largest subclass. The age results were 69, 58, and 47 percent A answers respectively. Thus older children are able, to some slight degree overcome the conflict and say that the classes are equal when asked which is more? However, they also, to a very large extent fall back on a perceptual subclass reply when they don't answer "equal".

We may, at this point, suggest a general process description of what occurs in class-inclusion problems. Given the question, "Are there more A_1 or more A?" and a perceptual context of only A_1 and A_2 (the traditional single-class-inclusion context), we begin by assuming that the child, as listener, has to figure out what the speaker means by the question. The perceptual subclass, A_1, is coded as A_1 since that is stated in the question. The other subclass is coded as A since "or" may be correctly interpreted exclusively. Then, the quantities of A_1 and A (actually A_2) are determined. This can occur by counting, area, length or density. It does not matter which, since all operations lead to the output $A_1 > A$. Consequently, from the adult's point of view, the child has failed to read his intentions properly and is "incorrect."

However, if the label A cannot be applied to A_2 (as in Markman's 1973 study), then the child might well employ a counting operator (cf. Klahr & Wallace, 1972) and make a proper comparison of $A > A_1$. Likewise, if the subclass quantities are equal, as in our B_1 and B_2, the child cannot find a larger subclass and is forced to re-interpret the label for the class in terms of both subclasses. Having done so, he can employ counting operations and combine the subclasses so that $B > B_1$. Finally, interpretation of A_1 and A_2 as A is facilitated if A_1 and A_2 are perceptually contrasted with other objects, here another class and in Wohlwill's (1968) study, simply other objects. If the subclasses are so interpreted and coded, proper counting operations yield the desired result.

Language, then, when viewed as communication, is shown to be highly context dependent for children and the interaction of language and perception in class-inclusion contexts leads to a misinterpretation of the question and a subsequent failure to employ the correct operations.

References

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Inhelder, B. & Piaget, J. The early growth of logic in the child. New York: Harper, 1964.

Markman, E. The facilitation of part-whole comparisons by use of the collective noun "family". Child Development, 1973, 44, 837-840.

Wohlwill, J.F. Responses to class-inclusion questions for verbally and pictorially presented items. Child Development, 1968, 39, 449-465.

Figure Captions

Figure 1. Examples of single and double class displays. D=Dog, C=Cat, A=Apple and O=Orange.

Figure 2. The structure of a two class context. A and B are classes; A_i and B_i are subclasses; 2, 4 and 6 are the number of members per subclass.

Figure 3. Outline of Experiment I.
I refers to Implicit partitioning;
E refers to Explicit partitioning;
1 and 2 are for single- and double-class contexts.

Figure 4. Percentage of Correct Answers for each concept for each age group averaged over all conditions and experiments. The concepts are ordered in difficulty for the 5-year-old children on the abscissa.

Figure 5. Double Class and Ratio Effects in the first test phase, Experiment I.

Figure 6. Specific and general transfer results, Experiment I.

Figure 7. Single- and double-class transfer results, Experiment I.

Figure 8. Double Class and Ratio Effects in transfer, Experiment I.

Figure 9. Outline of Experiment II.

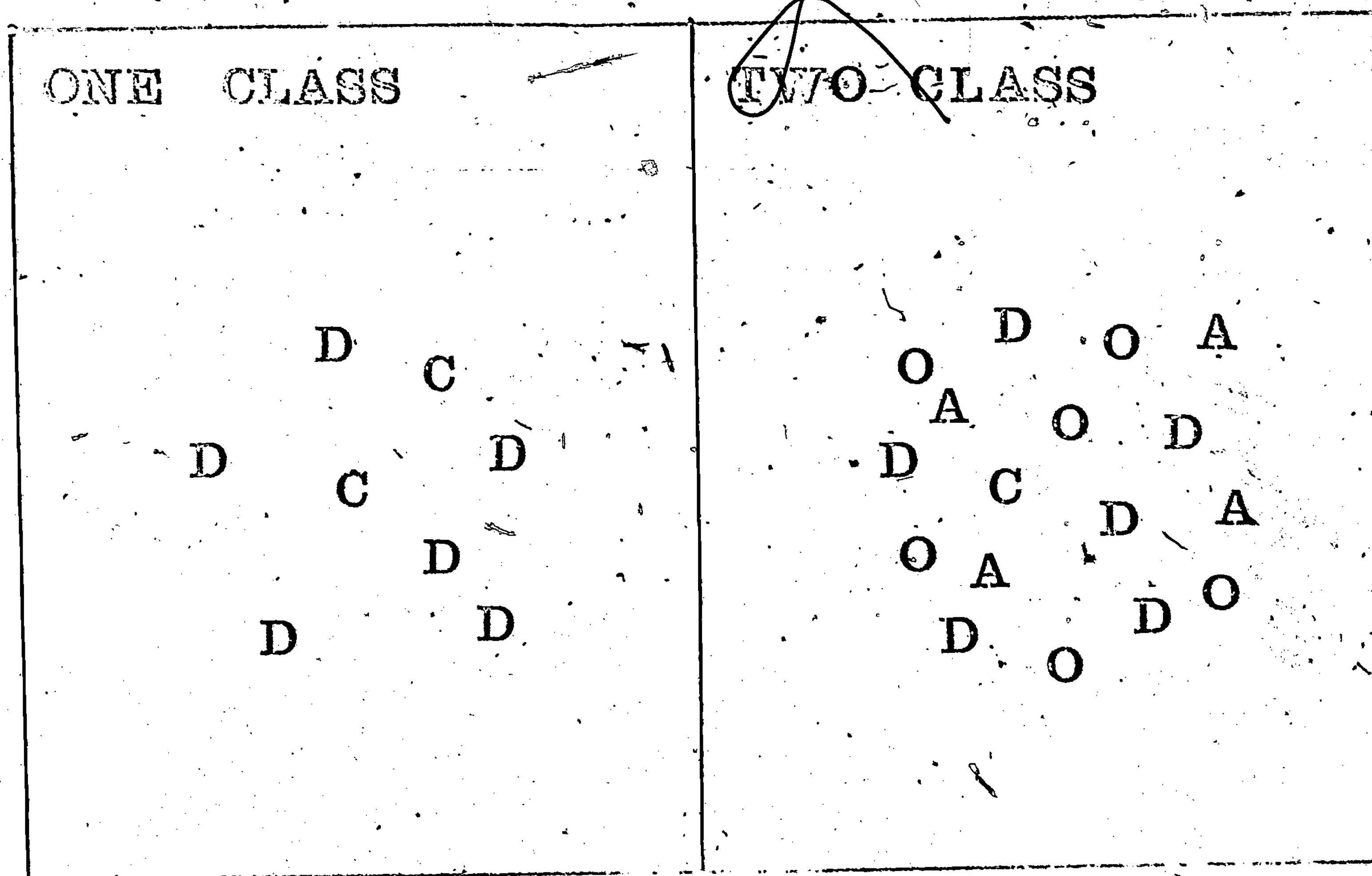
Figure 10. Group Results for all three phases of Experiment II.

Figure 11. Specific and general transfer results in Experiment II.

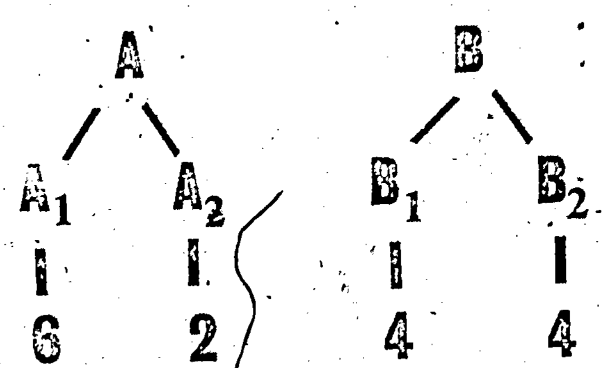
Figure 12. Within class, class versus subclass comparisons in double-class contexts. The data are from Groups E2 of Exp. I and 2 of Exp. II.

Figure 13. Class versus subclass comparisons in two-class contexts.

Figure 14. Within class and equality effects in two-class contexts.


ONE CLASS
D C
D C D
D
D D
TWO CLASS
D O A
O A O D
D C D A
O A D O
D O

two class structure

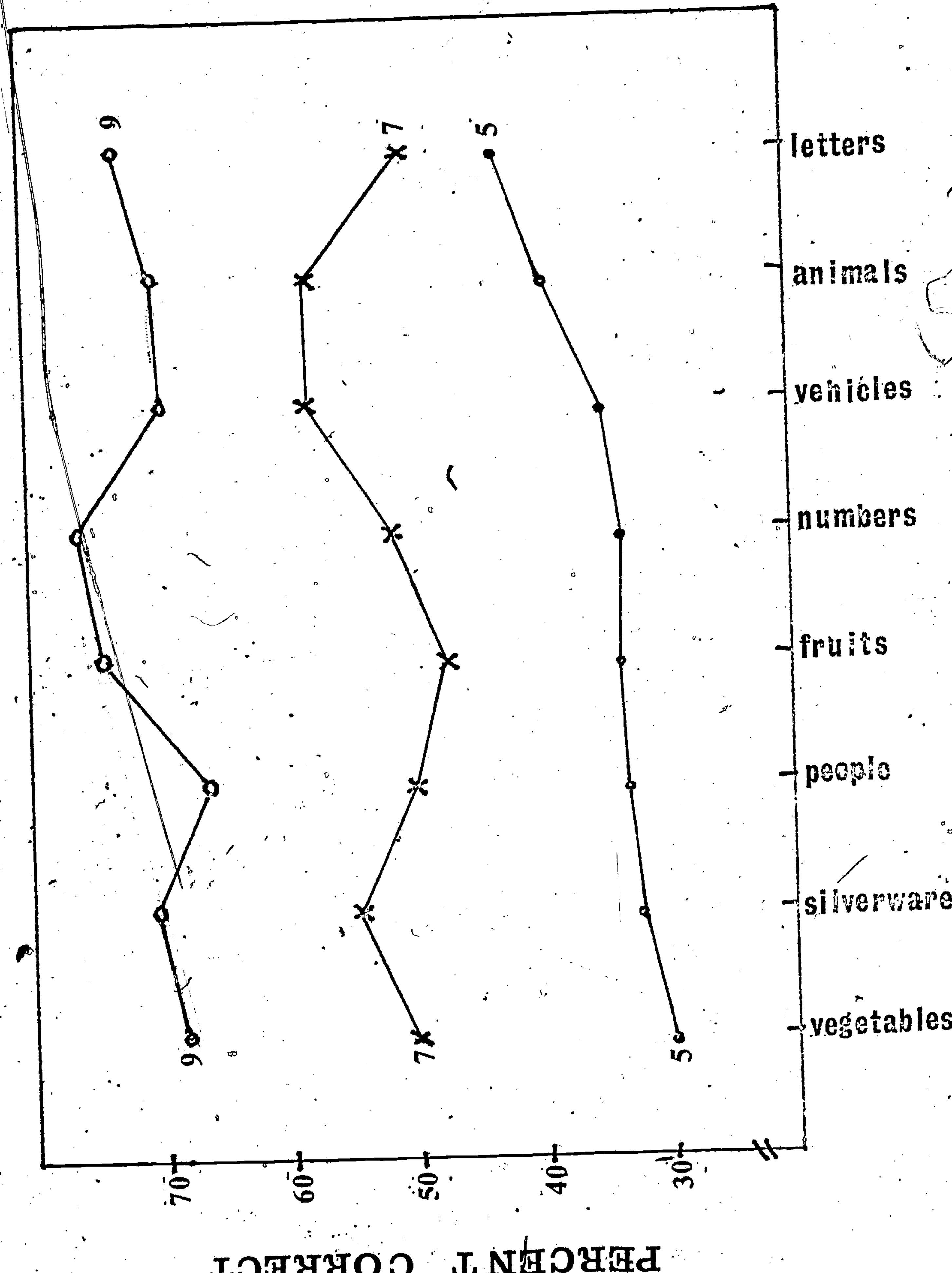


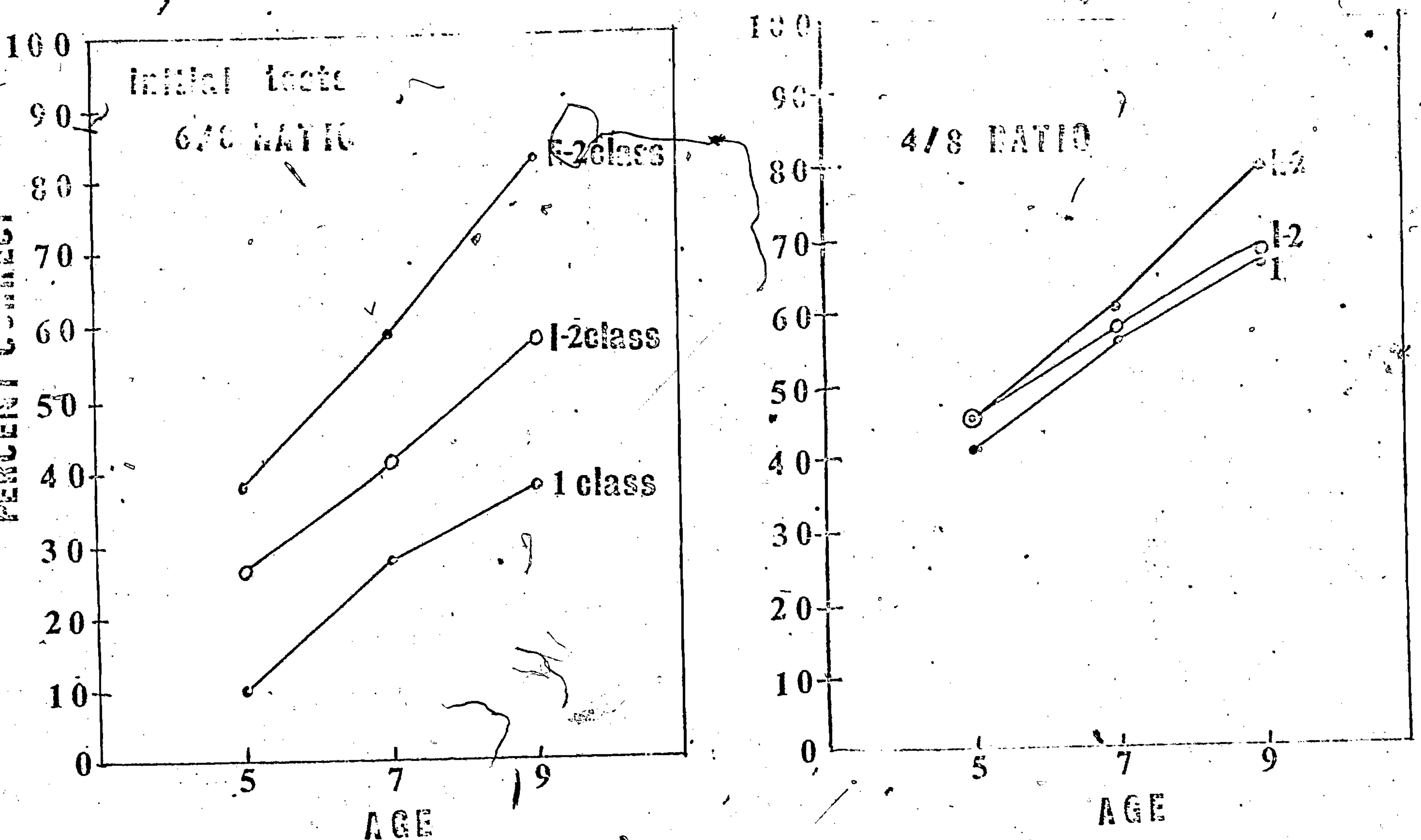
EXPERIMENT I

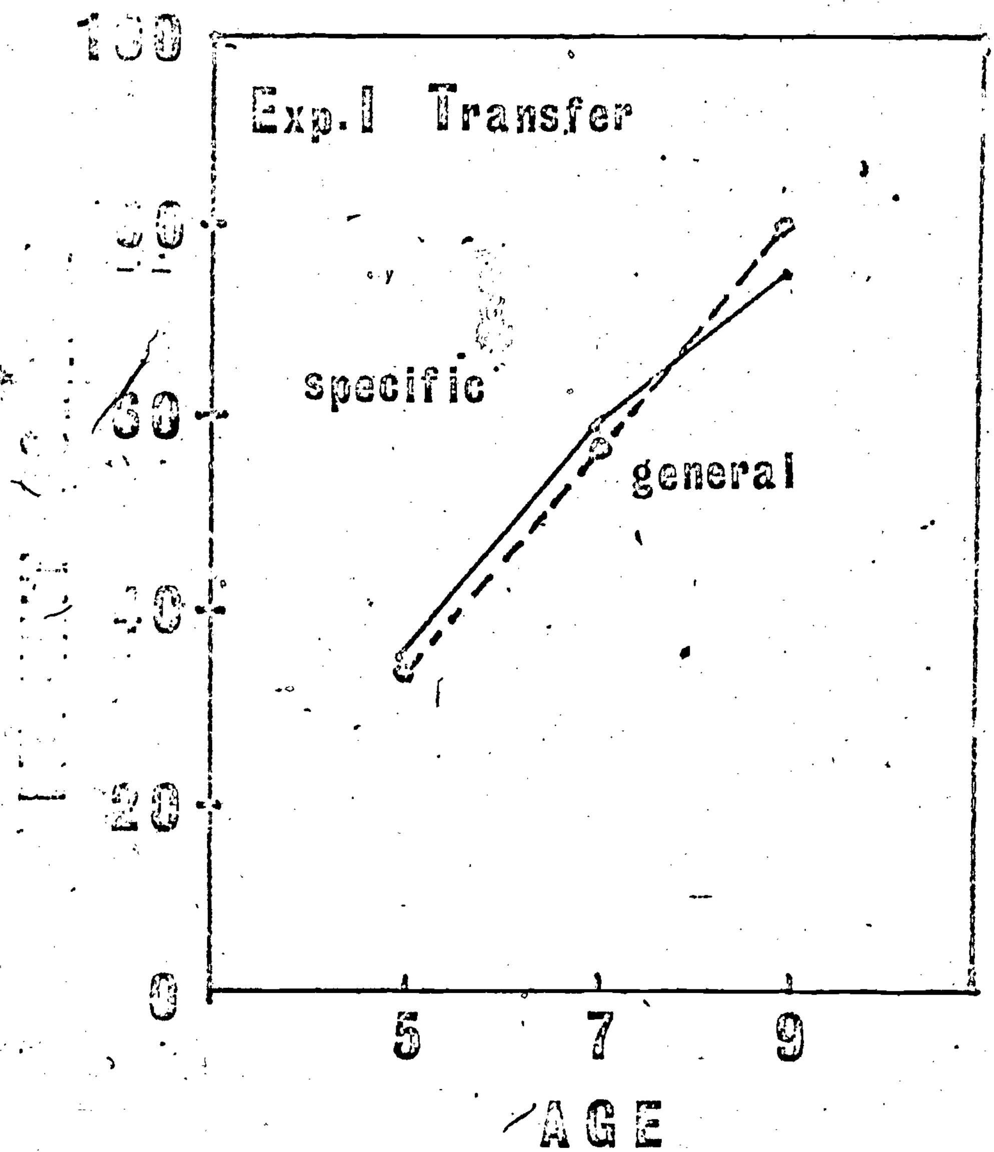
GROUP	PROCEDURE	PHASE TEST	PHASE TRANSFER
1	single class–inclusion only	4 problems	4 old 4 new
I2	same with double-class context	"	"
E2	all questions in test	"	"

EXPERIMENT I

GROUP	PROCEDURE	PHASE TEST	PHASE TRANSFER
1	single class–inclusion only	4 problems	4 old 4 new
I2	same with double-class context	"	"
E2	all questions in test	"	"


letters
animals
vehicles
numbers
fruits
people
silverware
vegetables
9
7
5
70
60
50
40
30
PERCENT CORRECT


Initial tests
K-2class
I-2class
1 class
4/8 RATIO
I-2
1
PERCENT CORRECT
AGE
AGE


Exp. I Transfer
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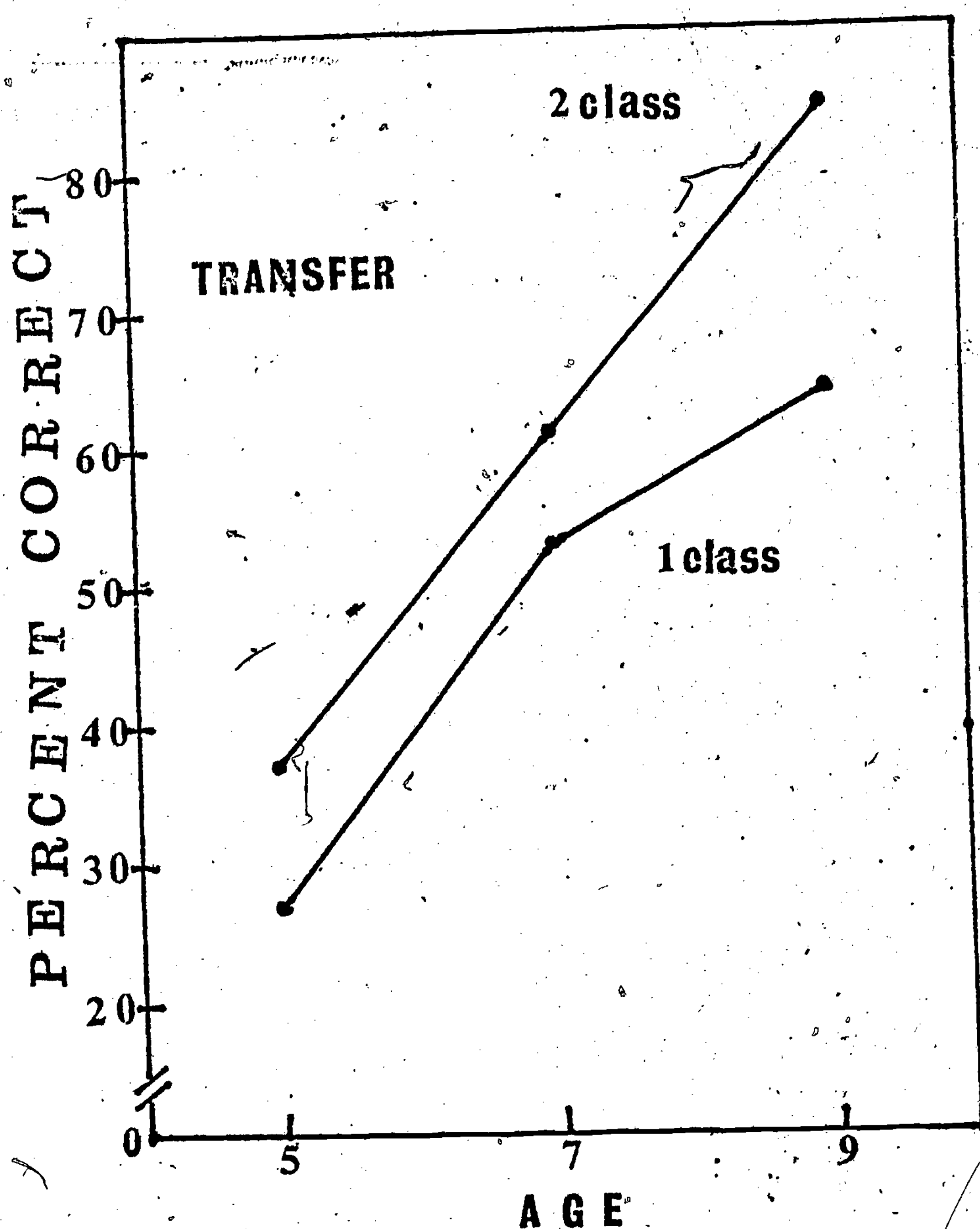
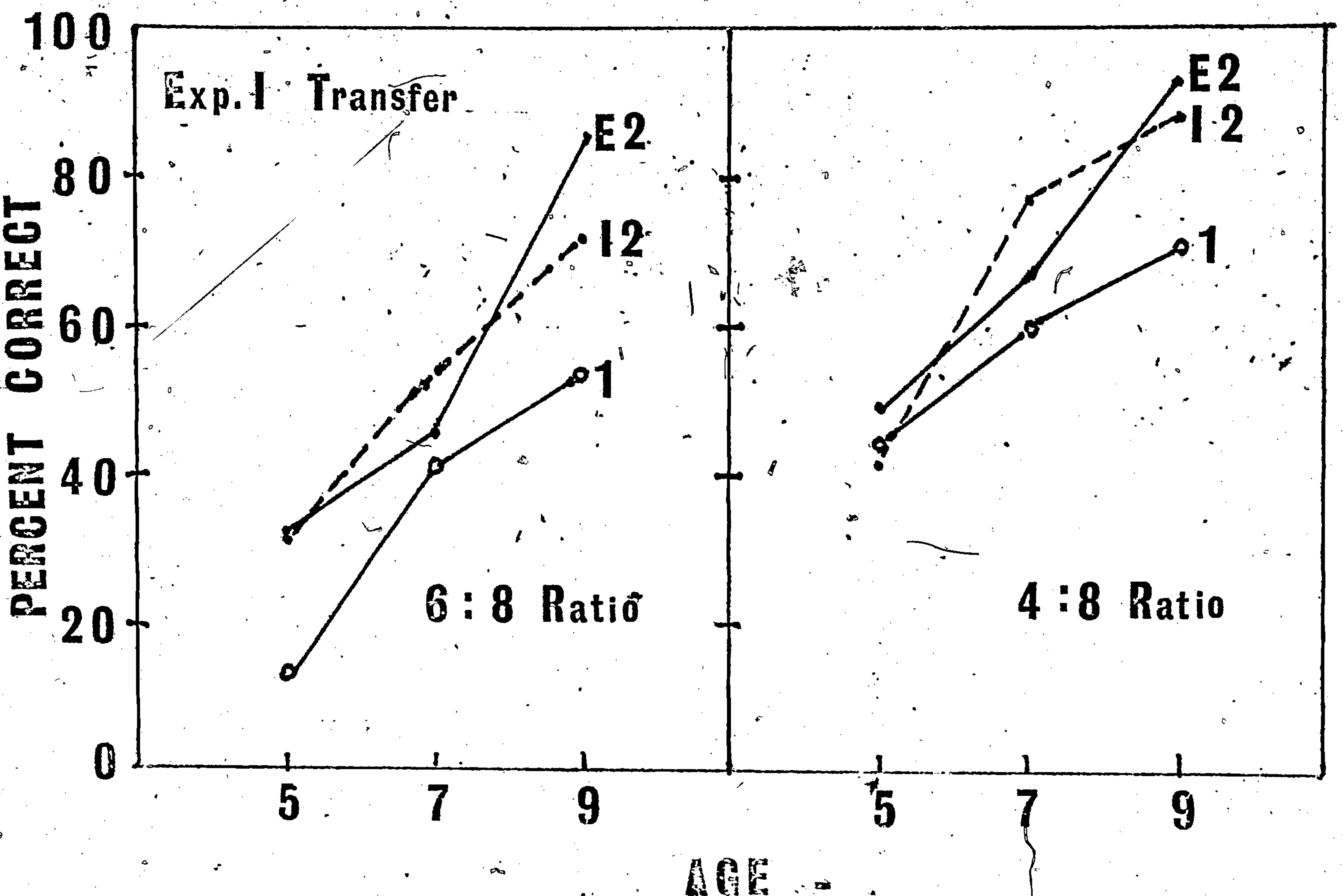
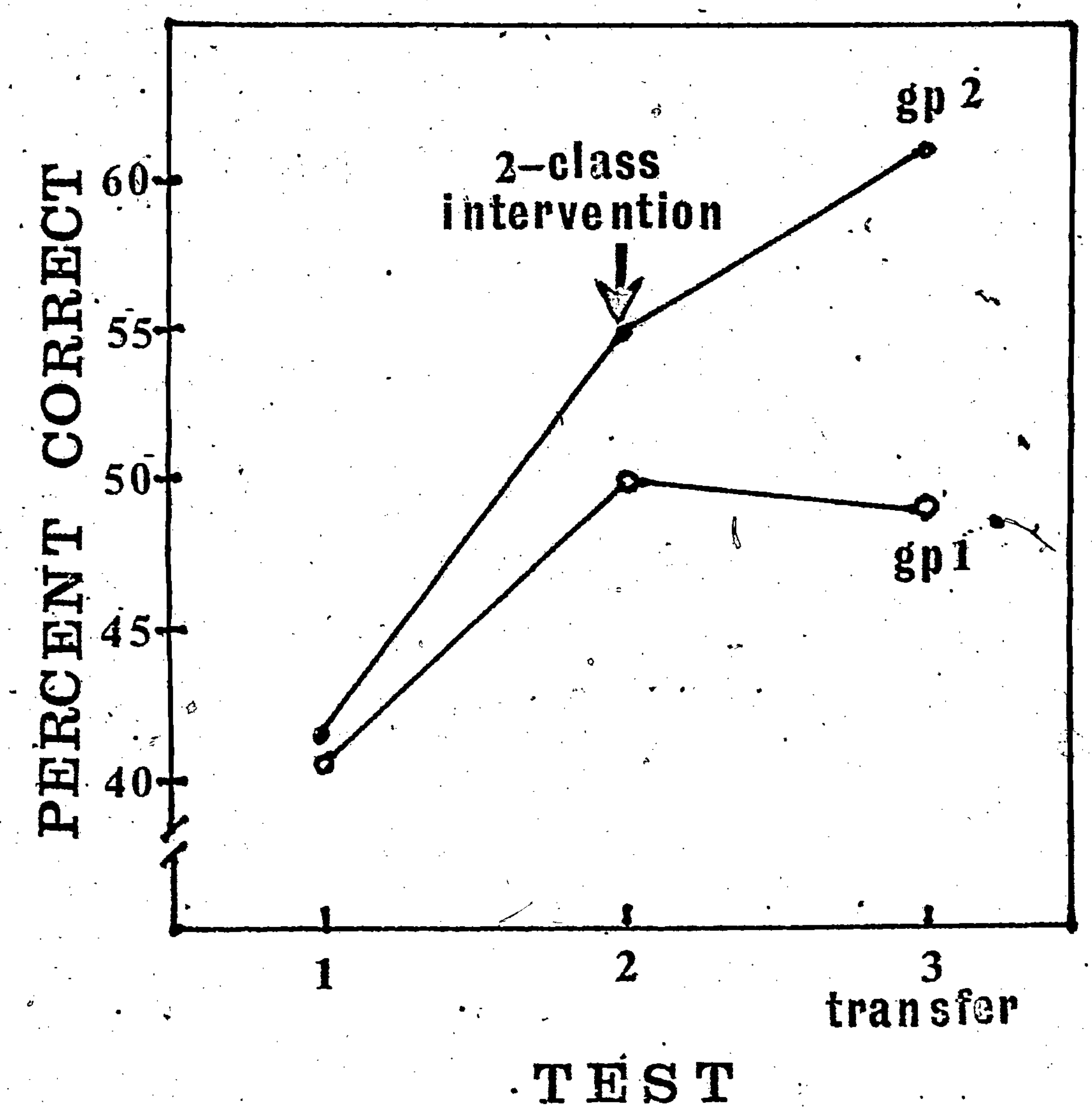
80
60
40
20
0
specific
general
5
7
9
AGE


2 class
TRANSFER
1 class
PERCENT CORRECT
80
70
60
50
40
30
20
0
5
7
9
AGE


Exp. I Transfer
100
80
60
40
20
0
PERCENT CORRECT
E2
I2
1
6:8 Ratio
4:8 Ratio
5
7
9
AGE

EXPERIMENT II

GROUP	TEST 1	TEST 2	TRANSFER TEST 3
1	4 single class-inclusion probiems	4 old	4 old & 4 new
2	same	same with double-class context	same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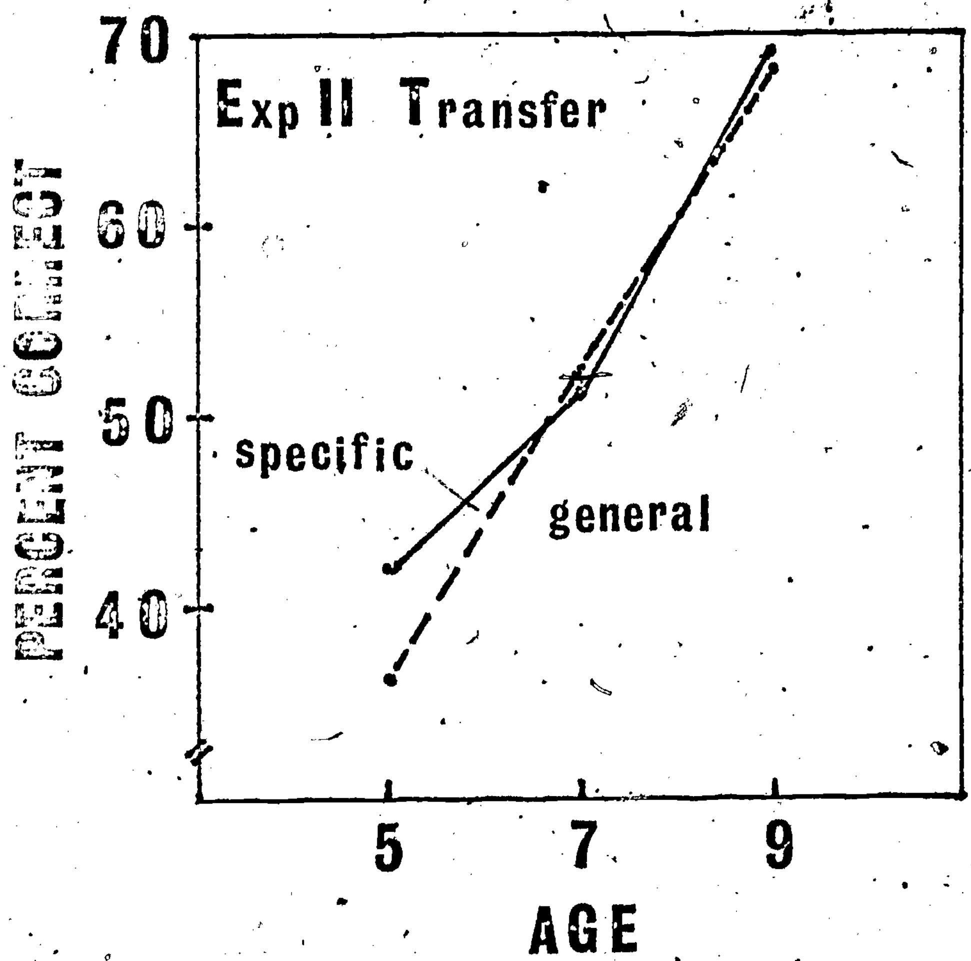
55
50
45
40
2–class
intervention
gp 2
gp 1
1
2
3
transfer
TEST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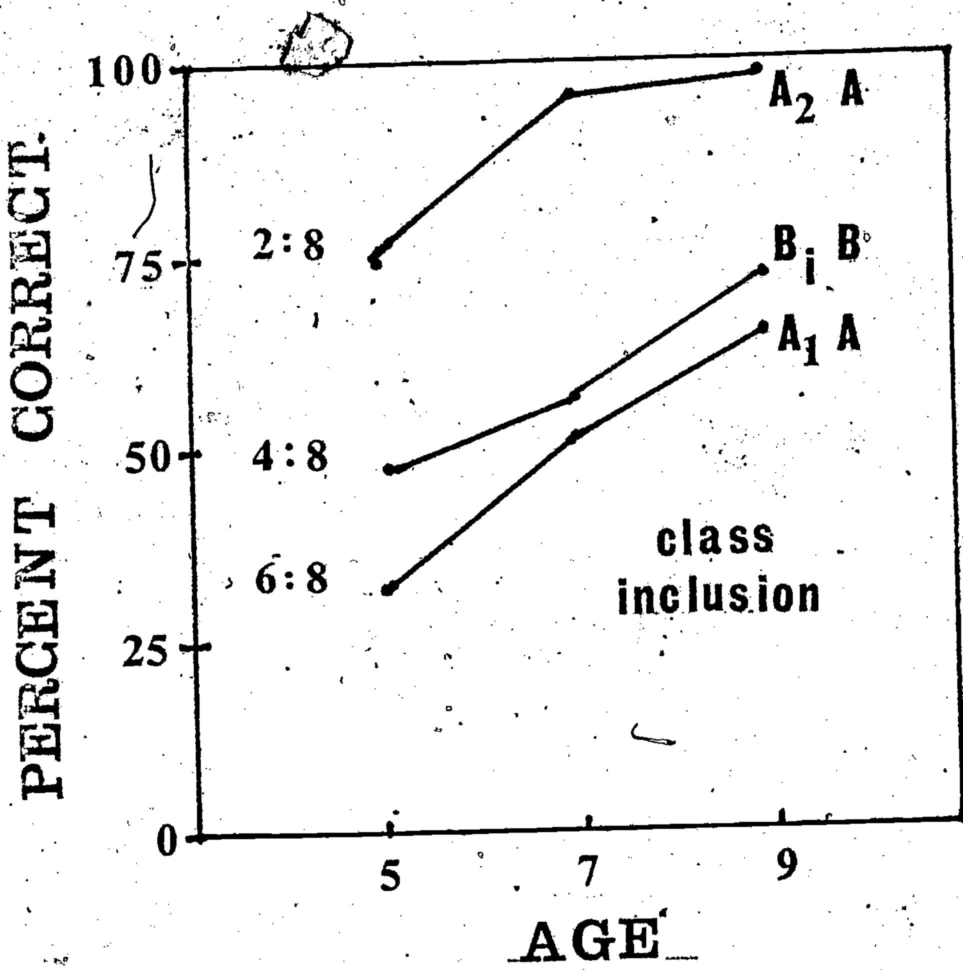
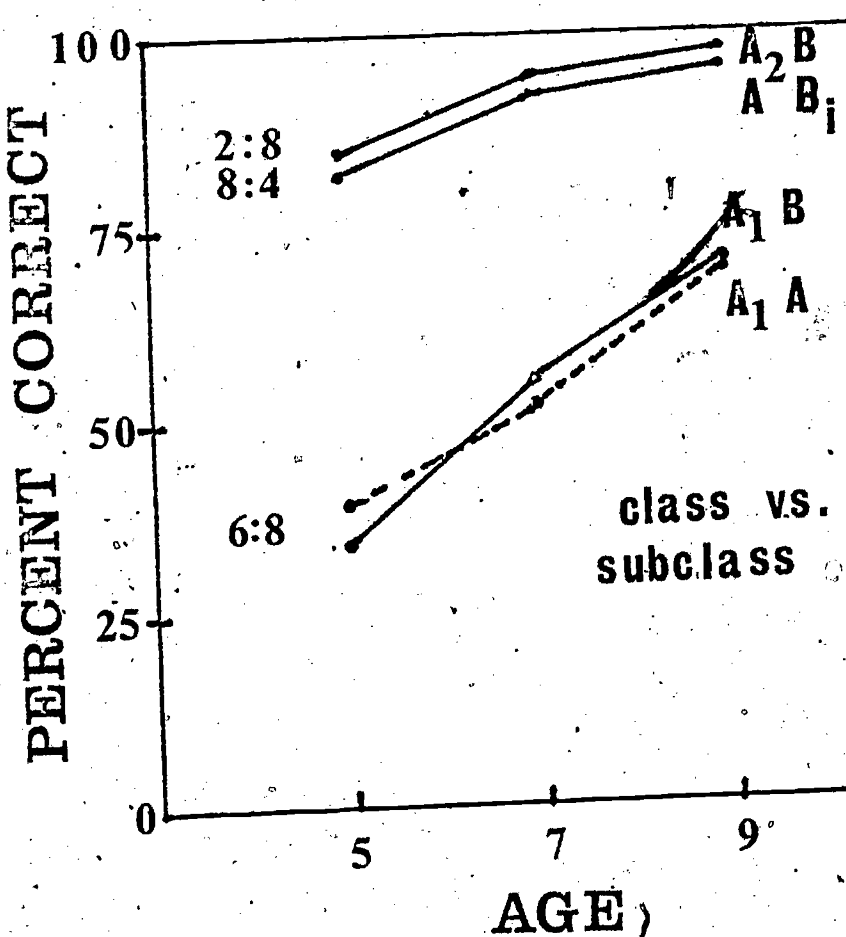
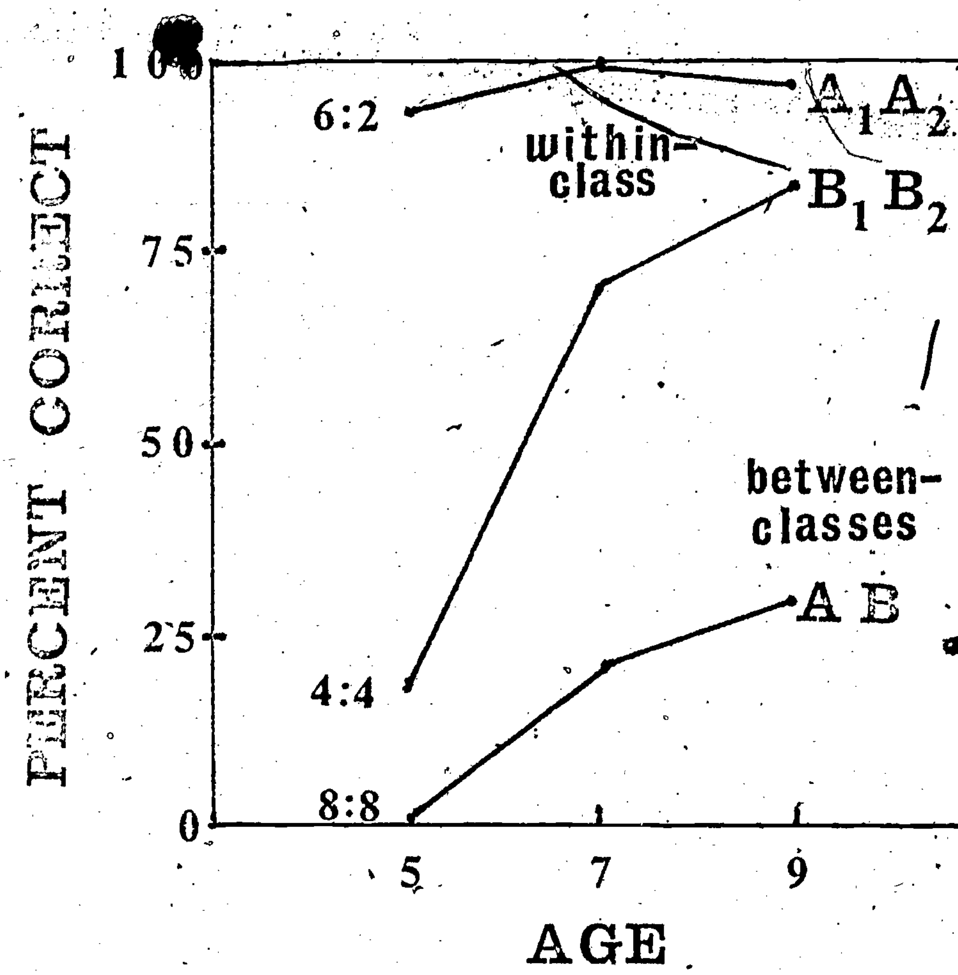
60
50
40
PERCENT CORRECT
Exp II Transfer
specific
general
5
7
9
AGE


100
75
50
25
0
PERCENT CORRECT
2:8
4:8
6:8
A_2 A
B_i B
A_1 A
class inclusion
5
7
9
AGE


PERCENT CORRECT
100
75
50
25
0
5
7
9
AGE
2:8
8:4
6:8
A_2B
AB_i
A_1B
A_1A
class vs. subclass


PERCENT CORRECT
100
75
50
25
0
6:2
4:4
8:8
within-class
$A_1 A_2$
$B_1 B_2$
between-classes
A B
5
7
9
AGE