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ABSTRACT

Recent theoretical analyses have implied that there may be age differences in children's tendency to exercise component selection, i.e., to attend selectively to a single component of stimulus objects in a learning situation. In the present study, 6 experiments were conducted, each designed to investigate developmental changes in component selection across ages 4, 8, and 12. In the first of 2 principal experiments, children's tendency to exercise component selection was found to decrease from ages 4 to 8, and this result contrasted with a lack of change over this age range in children's incidental learning. These results suggest that, by age 8, children tend to utilize redundant stimulus information when it is a useful aid for learning as in a component selection task, but are also able to ignore such information when it is nonfunctional or "incidental." The second of the 2 major experiments examined component selection at varying levels of training. As the children learned the task, they were found to maintain attention to secondary stimulus information as well as to the more salient component of the stimuli; thus, the children's attention did not appear to become more selective as learning proceeded to criterion. Also, overtraining did not generally tend to "broaden" attention as expected. (Author/TA)

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HEALTH, EDUCATION, AND WELFARE

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U. S. DEPARTMENT OF
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Preface

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Summary

Recent theoretical analyses (Gibson, 1963; Wohlwill, 1962) have implied that there may be age differences in children's tendency to exercise component selection--i.e., to attend selectively to a single component of stimulus objects in a learning situation. The present study introduced a new method for examining component selection in children, and six experiments were conducted, each designed to investigate developmental changes in this process across ages 4, 8, and 12 (excluding age 4 in Experiment 3 and including age 10 in Experiment 1). The first experiment was intended primarily to develop the measure, and the results led to the selection of tasks appropriate for use in subsequent experiments. In the first of two principal experiments (Experiment 2), children's tendency to exercise component selection was found to decrease from ages 4 to 8, and this result contrasted with a lack of change over this age range in children's incidental learning. These results were interpreted to suggest that, by age 8, children tend to utilize redundant stimulus information when it is a useful aid for learning as in a component selection task, but are also able to ignore such information when it is nonfunctional or "incidental."

The second of the two major experiments (Experiment 4) examined component selection at varying levels of training, and several results of interest emerged. As the children learned the task, they were found to maintain attention to secondary stimulus information as well as to the more salient component of the stimuli; thus, contrary to a recent hypothesis (James & Greeno, 1967), the children's attention did not appear to become more selective as learning proceeded to criterion. Also, overtraining did not generally tend to "broaden" attention as expected, as children of ages 4 and 8 acquired little stimulus information beyond the point at which criterion had been reached. The 12-year-olds, however, continued to acquire stimulus information with overtraining, suggesting an age difference in the effects of this variable on attention.

Other experiments of the study aided in interpreting the above results. Experiment 3 demonstrated the importance of a stimulus variable that frequently differentiates the component selection measure from the typical incidental learning task--the degree of integration among stimulus components. Experiment 5 assessed the relative difficulty of the two major stimulus components used in this research (shape and color) as independent cues for learning, and Experiment 6 further examined the effects of overtraining in connection with a modified component selection task. The results of the research as a whole were interpreted in terms of theories relating to the development of selective attention, and some implications for models of learning and instruction were discussed.

Introduction

The concept of selective attention implies that an individual cannot "take in," or process into memory, all of the information contained within a complex stimulus; he must select a portion of it on which to concentrate his thought (Broadbent, 1958; Neisser, 1966). Several theories have suggested that the nature of children's attention undergoes basic changes over the early school years. Eleanor Gibson (1963), for example, views cognitive development as involving a continual differentiation process; with increasing age a child develops the ability to recognize the critical features on which stimulus objects differ. The theory implies that a young child perceives objects as stimulus compounds, or combinations of attributes, while an older child may tend to distinguish among stimuli on the basis of a selected component dimension (see also Tighe & Tighe, 1966). In a related analysis, Wohlwill (1962) posits that as a child grows older he requires fewer redundant cues to discriminate among stimulus objects. In general, these analyses suggest a developmental increase in the extent to which children exercise "component selection"--that is, the natural tendency to differentiate among objects on the basis of a selected stimulus component.

The present study examined the validity of this hypothesis by comparing children of various age levels in performance on a new measure of component selection. Unlike more widely used tasks which reflect children's <u>ability</u> to attend selectively to critical information, the present measure was designed specifically to assess children's <u>disposition</u> to attend selectively to component aspects of stimuli. This distinction is critical to the present analysis and will be elaborated further in connection with a brief overview of research relating to attention in children.

Three popular topics of research in this area are "concept identification," including various "discrimination shift" transfer paradigms, "incidental learning," and "dimension preferences." The <u>concept identification</u> and <u>discrimination shift</u> problems measure the facility with which children can detect, and maintain an orientation to, a dimension designated as relevant for classification of stimuli. An increase in this ability from preschool to middle childhood has been indicated by this research (see review by Wolff, 1967). In the <u>incidental learning</u> problem, instructions or training ensure attention to a critical component of stimulus objects during an initial learning phase, and other components are thus designated as "incidental." Comparison of performance on the initial learning phase with subsequent recall of incidental information reflects the relative amount of attention a child has directed to the critical and incidental information, respectively, during learning. Several studies have indicated an increase from middle childhood to early adolescence in the ratio of initial learning to incidental recall, suggesting a developmental increase in children's ability to attend to information critical for learning and to ignore incidental information (e.g., Hagen, 1967; Maccoby & Hagen, 1965). In the <u>dimension preference</u> research, a subject is presented stimuli that differ simultaneously on two or more component dimensions and is required to sort or match the stimuli on the basis of a single dimension. Age differences have been observed in the number of children who tend to classify stimuli on the basis of one dimension rather than another--for example, shape rather than color (e.g., Brian & Goodenough, 1929; Corah, 1964; Suchman & Trabasso, 1966)--suggesting developmental changes in the particular stimulus component to which children naturally direct their attention.

While each of these areas of research has provided valuable information relating to children's selective attention, this evidence bears only indirectly on the issue of component selection. In each case, a procedure has been used that forces the subject to direct his attention to a given stimulus component. For example, the concept identification and incidental learning procedures require that attention be directed to an experimenter-defined relevant component of stimuli. These measures, then, reflect a child's ability to attend selectively to critical information rather than his disposition or natural tendency to attend selectively to a single component of stimuli. The dimension preference tasks, while allowing some degree of choice, also require a subject to choose, on each trial, a single dimension on which to focus his attention. None of these methods, therefore, has addressed the question at issue in the present analysis--namely: To what extent do children of various age levels naturally attend selectively to a single component in differentiating among stimulus objects?

To answer this question, a new measure was devised for use in the present research. Analogous to tasks used with adults (Richardson, 1971; Trabasso & Bower, 1968), and similar in principle to problems used with retardates (House & Zeaman, 1963), the measure was designed specifically for studying component selection in normal children over a wide range of ages. Performance on this task was examined at three developmental levels--ages 4, 8, and 12. Comparison between the first two age levels was intended to provide data bearing on the hypothesized increase in component selection across the early school years. The oldest group was included to test for further changes in component selection beyond middle childhood, parallel to the developmental changes in ability to attend selectively suggested by research on incidental learning.

General Method

The initial phase of the component selection problem requires a child to learn the spatial position associated with each of several stimuli that differ on two redundant dimensions--e.g., shape and color, as in the present experiments. In a subsequent test, an attribute of only one of the component dimensions is presented on each trial--for example, a colorless triangle or a blue card--and the subject is asked to identify the spatial position that had been associated with the attribute shown. All attributes of each dimension are represented in the test, and scores indicating the number correct for each dimension separately comprise the major data of the measure. These scores form the basis for inferring component selection, according to a rationale that may be summarized as follows. It is assumed that the amount of information retained about each dimension separately reflects the degree to which attention has been directed to each of these stimulus components during learning. Thus, if a subject performs perfectly on the test trials for one dimension but at a chance level on the other dimension, he has presumably exercised component selection in learning the task--that is, attended selectively to a single dimension of the stimuli. However, to the extent that his test scores indicate recall for information about both dimensions, his attention has been less selective, as he has apparently discriminated among the stimuli on the basis of a combination of components.

Outline of the Study

The study was comprised of six experiments, designed to investigate a number of issues related to the development of selective attention. While these issues will be discussed in detail in separate introductions, a brief description of the experiments at this point provides a general overview of the research. Age of Subject was a major variable throughout, as each experiment involved children of ages 4, 8 and 12 (excluding age 4 in Experiment 3 and including age 10 in Experiment 1). In Experiment 1, a pilot study designed for developing the component selection measure, children were given problems of varying levels of difficulty, and the results led to the selection of tasks appropriate for use in subsequent experiments. Experiment 2 was the first major assessment of age differences in children's performance on the component selection measure. In addition, the results from this problem were compared with data from two variations designed to represent incidental learning tasks, to examine the validity of the distinction drawn above between children's disposition to attend selectively and their ability to do so. To further understand differences between the component selection measure and the typical incidental learning task, Experiment 3 assessed the effects of a stimulus variable that frequently differentiates these two measures--the degree of integration of the stimulus components (an incidental learning paradigm was used in this case).

Experiment 4 examined component selection at varying levels of training, to provide a more complete picture of the manner in which children employ selective attention in learning. Children were given varying degrees of training prior to the test of component selection, including two levels of undertraining, a weak and strong criterion, and two levels of overtraining. To aid in interpreting the results obtained, Experiment 5 assessed the relative difficulty of shape and color as independent cues for learning, and Experiment 6 examined the effects of overtraining in connection with a modified component selection task.

Experiment 1: Development of Measure--Effects of Task Difficulty

The purpose of this experiment was to develop a measure that would be optimally suited for studying component selection in children from preschool to early adolescence. To this end, the component selection task described below was presented under several levels of difficulty, manipulated by varying the number of stimuli in the task. A given subject received a problem involving either three, five, or seven stimuli, and tasks of each level of difficulty were administered to subjects at four age levels, 4, 8, 10, and 12 years. The 10-year-old group was included in this experiment to test for a possible nonlinear developmental trend in component selection beyond age 8, analogous to that found in certain studies of incidental learning (e.g., Maccoby & Hagen, 1965).

Subsidiary information was provided by a task involving three stimulus dimensions, shape, color and pattern, to be described following presentation of the results for the standard two-dimensional problem. Although subsequent experiments focus on the latter measure, the three-dimensional task was included here primarily to determine the suitability of the component selection procedure for later research on hierarchies of attention to stimulus dimensions. (In this respect, the present task is similar to Kagan, Moss and Sigel's (1963) measure of visual analysis.)

Method

Subjects

The experiment included a total of 160 subjects at four age levels, averaging 4.3, 8.6, 10.5, and 12.5 years (ranges = 3.0-6.2, 7.8-9.8, 9.8-12.7, and 11.9-14.0 years, respectively). The three oldest groups were drawn from third-, fifth-, and seventh-grade classes in two elementary schools and a junior high school in a middle class area of Bucks County, Pennsylvania. The youngest group was drawn from three nursery schools in the same general vicinity, which contributed the same proportions of subjects to each subgroup of the experiment.

Materials

The stimuli for the standard two-dimensional task were colored shapes, each approximately 8 cm. x 8 cm., placed on black cards and enclosed in transparent envelopes. The colors used were blue, green, orange, yellow, tan, pink, and gray, and the Munsell (1966) values which most closely matched these colors were, respectively, 2.5B-8.5/2, 5G-9/2, 2.5YR-7/12, 5Y-9/6, 10YR-7/7, 10RP-8.5/6, and Neutral-8.5/0. The seven shapes that were used are pictured in Figure 1 (the patterns shown in the figure will be explained below in connection with the three-dimensional task--see Results). For the seven-stimulus problem, all shapes and colors were employed, and four different sets of stimuli were created, differing in the color that was associated with each shape. For the three- and five-stimulus problems, the four sets of stimuli differed in (a) the

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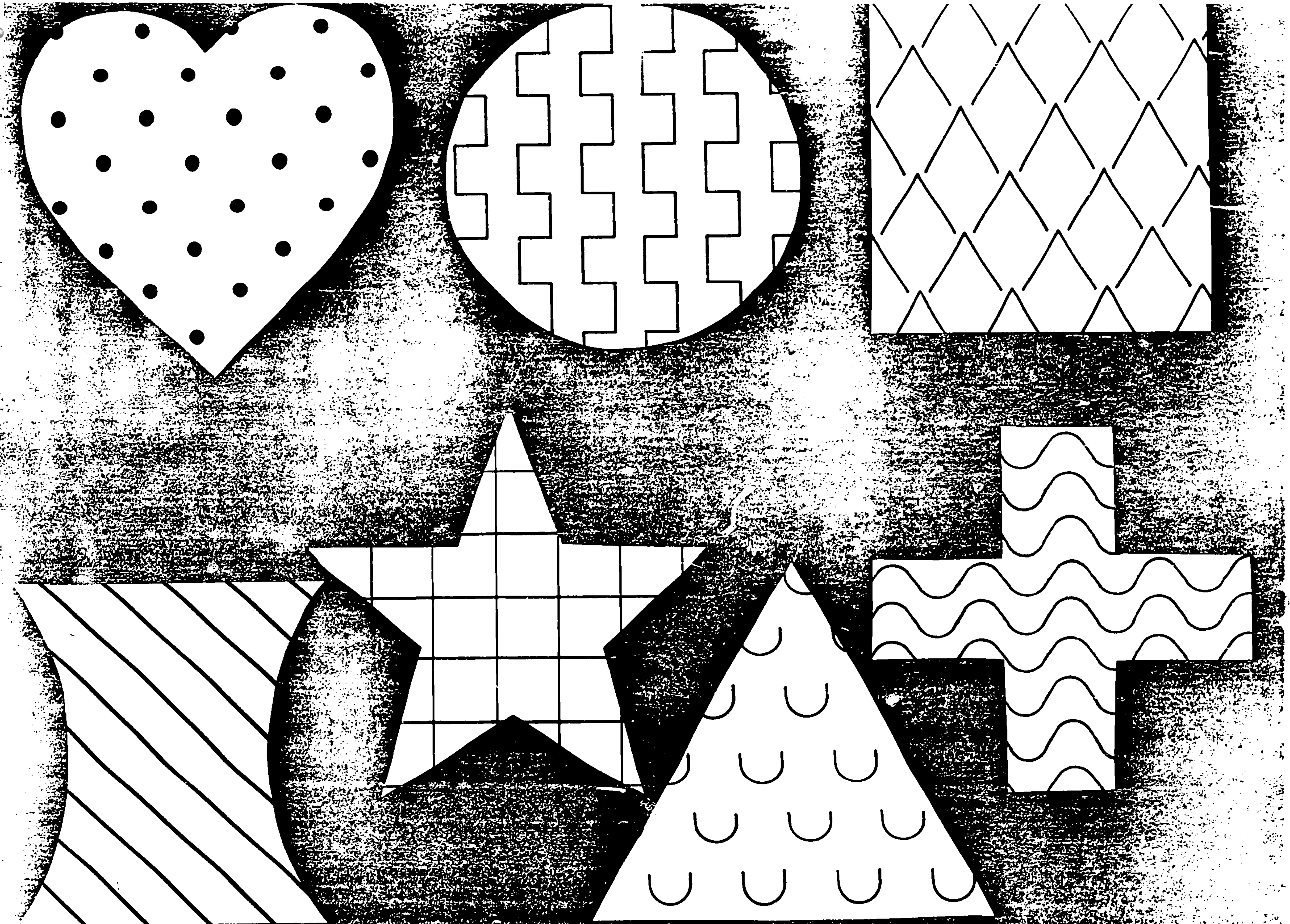

Figure 1. The shapes and patterns used in stimuli of Experiment 1.

shape-color associations and (b) the particular subset of shapes and colors that were employed. The task was administered with the use of metal file-card boxes, each containing a slot into which the cards could be placed.

Procedure

The subject was seated at a table directly opposite the experimenter, and before him was a row of three, five, or seven unlabeled boxes. The subject was told that he would be shown some cards that belonged in the boxes and his job would be to learn which card belonged in each box. The cards contained stimuli differing in shape and color, and these dimensions were redundant, so that for any subject, a given shape was always of a particular color. Thus, for example, the task might have required the subject to learn that yellow squares belonged in the first box, green circles in the second box, and so forth. Reference was never made, however, to the dimensionality of the stimuli.

To begin the task, the experimenter placed an example of each stimulus upon the box in which it belonged, left the cards to be viewed for five seconds, then placed them behind the boxes to be used as "feedback cards." The subject was then given, face down, a pile of "cue cards," which contained stimuli identical to those just shown. He was required to turn over the cue cards, one by one, examine each card for a minimum of three seconds and then place it in the box in which he thought it belonged. The 4-year-olds were handed each cue card separately. Each time a card had been placed in a box, the experimenter indicated the correct box by briefly holding the appropriate feedback card above it. The cue cards were arranged according to trial blocks, each containing one example of each stimulus, with a different random order of stimuli in each successive block. The subject performed the task until he had reached a criterion defined as either (a) two errorless trial blocks in succession or (b) two errorless trial blocks with an intervening trial block containing a single error. Subjects who did not reach criterion within 10 trial blocks were eliminated from the final sample.

After criterion had been reached, test trials were introduced to determine the amount of information which the subject had acquired about each stimulus dimension separately. On each of these trials, the experimenter held up a "test stimulus" containing a white shape or a solid color. The subject was instructed, "One of the cards that you saw had this shape (color). Try to remember which box you put it in and point to that box." No feedback was given during the test trials. Every attribute within each dimension was presented, and the dimensions were systematically intermixed across test trials. For each subject, the number of correct responses on these test trials was determined for each dimension separately, and these two scores constituted the major component selection data.

Experimental Design

The independent variables were Age of Subject (4, 8, 10, and 12) and Level of Difficulty (3, 5, or 7 stimuli). Tasks of each level of difficulty were randomly assigned to subjects at a given age level, and the final sample consisted of 10 subjects per experimental subgroup. The four stimulus sets were represented in identical proportions across the subgroups (3:3:2:2). Each subgroup contained an equal representation of (a) the two sexes, (b) two different sets of assignments of stimuli to spatial positions, (c) two different orders in which the cue cards were presented, and (d) two different orders in which the test stimuli were presented. All subjects were tested by a single experimenter (J. S. M.).

Results and Discussion

The initial data to be considered are the number of trials required to reach criterion in the learning phase of the task, as these data bear upon selection of an optimal measure to be used in subsequent research. In this regard, the seven-choice problem proved to be extremely difficult; the proportions of subjects reaching criterion at ages 8, 10, and 12 were 25%, 65%, and 92%, respectively; the task was therefore not administered to the 4-year-old subjects. Except for the oldest subjects, then, the component selection data from the seven-choice task are based on restricted samples and will not be considered. The problem involving three stimuli, on the other hand, proved to be extremely easy for all age levels, as all but 3 of the 40 subjects given this task reached criterion immediately. Since an ideal component selection measure is one which is difficult enough to allow "room" for learning to take place at all age levels, the three-choice problem may also be considered inappropriate for the developmental comparisons of the study. It can be argued, in fact, that the mere presentation of the number of trials required to establish criterion on the three-stimulus problem may, in a sense, have provided the older subjects with overtraining, which could affect interpretation of age differences in component selection scores. The five-choice task, however, was learned by 100% of the subjects tested at all age levels except age 4 (74%), and the proportions of subjects at ages 8, 10, and 12 who reached criterion immediately were 2/10, 1/10, and 7/10, respectively. Except for some degree of sample restriction at age 4, then, and the fact that the problem was still of less than optimal difficulty level for the oldest subjects, the five-choice task appears to have been the best suited of the three for assessing age differences in component selection. Therefore, developmental comparisons in test data were based primarily on the five-stimulus problem.

The test trials of the component selection task yielded two separate scores, indicating the total number correct for shape and color test stimuli, respectively. Preliminary examination of these scores revealed that the shape component was consistently selected over the color component at all age levels, as 76 of the 80 subjects given the three- and five-stimulus tasks received a shape test score that exceeded or equaled the color test score. For this reason, the data were subsequently examined in terms of the mean number correct on shape, across all subjects in each group, in comparison with the mean number correct on color. For statistical analysis, a score was derived for each subject representing the difference between the shape and color test scores. A second measure was also computed which was designed to take into account the total test performance for every subject; the number correct on the shape test trials for each subject was expressed as a proportion of the total number correct on all test trials. However, with only one exception, analyses based on these two scores in the present experiment and Experiment 2 yielded essentially identical results. Except where noted, then, only the statistics based on the shape-color difference scores will be reported.

Table 1 presents the mean shape and color test scores for the five-stimulus task, and Figure 2 summarizes these data graphically, with the scores expressed as percentages. The slopes of the lines in the figure reflect the shape-color difference scores at the four age levels, and developmental changes in component selection may be detected through visual comparison of these slopes. To provide further information regarding the nature of the data obtained with this measure, Table 2 presents the frequencies of subjects receiving all possible shape-color difference scores for the five-stimulus task. An analysis of variance was performed, to determine the overall effect of age on these shape-color difference scores. This effect proved to be nonsignificant ($\underline{F}(3,36) < 1$), suggesting little developmental change in the degree to which the subjects attended selectively to the shape component of stimuli differing in color and shape.

For the three-stimulus task, the percentages correct for shape and color test trials, respectively, were: age 4, 87-47; age 8, 100-50; age 10, 87-57; and age 12, 97-90. The overall change across age levels in shape-color difference score on this task was significant ($\underline{F}(3,36) = 4.19$, $\underline{p} < .05$), although the results merely approached significance for the score expressing the ratio of shape score to total test performance ($\underline{p} < .10$). Examination of the data indicates the developmental trend in difference scores in this case to be due primarily to high scores for color as well as shape for the oldest group. As was noted above, this three-stimulus task was learned immediately by subjects at all age levels, and a type of "overtraining" may therefore have been provided to the oldest subjects. If it is true that attention tends to become less selective with overtraining (James & Greeno, 1967), then such an artifact alone could account for the age differences observed for the three-stimulus problem.

A three-dimensional task analogous in design to the two-dimensional, five-stimulus problem was also administered to 10 subjects at each age level. The initial phase entailed learning of spatial positions associated with five stimuli that differed on three redundant dimensions, shape, color and pattern (Figure 1 depicts the patterns used). Subsequent test trials assessed recall

Table 1

Means and Standard Deviations (in Parentheses) of Test Scores for Two-Dimensional, Five-Stimulus Problem and Three-Dimensional Problem in Experiment 1 (N = 10 in each group)

	Two-dimensional, five-stimulus problem			
Stimulus component	Age 4	Age 8	Age 10	Age 12
Shape	3.90 (0.99)	4.40 (0.70)	4.40 (0.70)	4.80 (0.42)
Color	1.90 (1.37)	3.10 (1.60)	2.50 (1.18)	3.20 (1.87)
	Three-dimensional problem			
Stimulus component	Age 4	Age 8	Age 10	Age 12
Shape	3.60 (0.84)	3.70 (1.25)	3.70 (1.25)	4.30 (0.82)
Color	2.30 (1.25)	2.80 (1.48)	2.40 (1.17)	2.20 (1.55)
Pattern	1.60 (1.43)	1.90 (1.66)	2.30 (1.70)	2.50 (1.27)

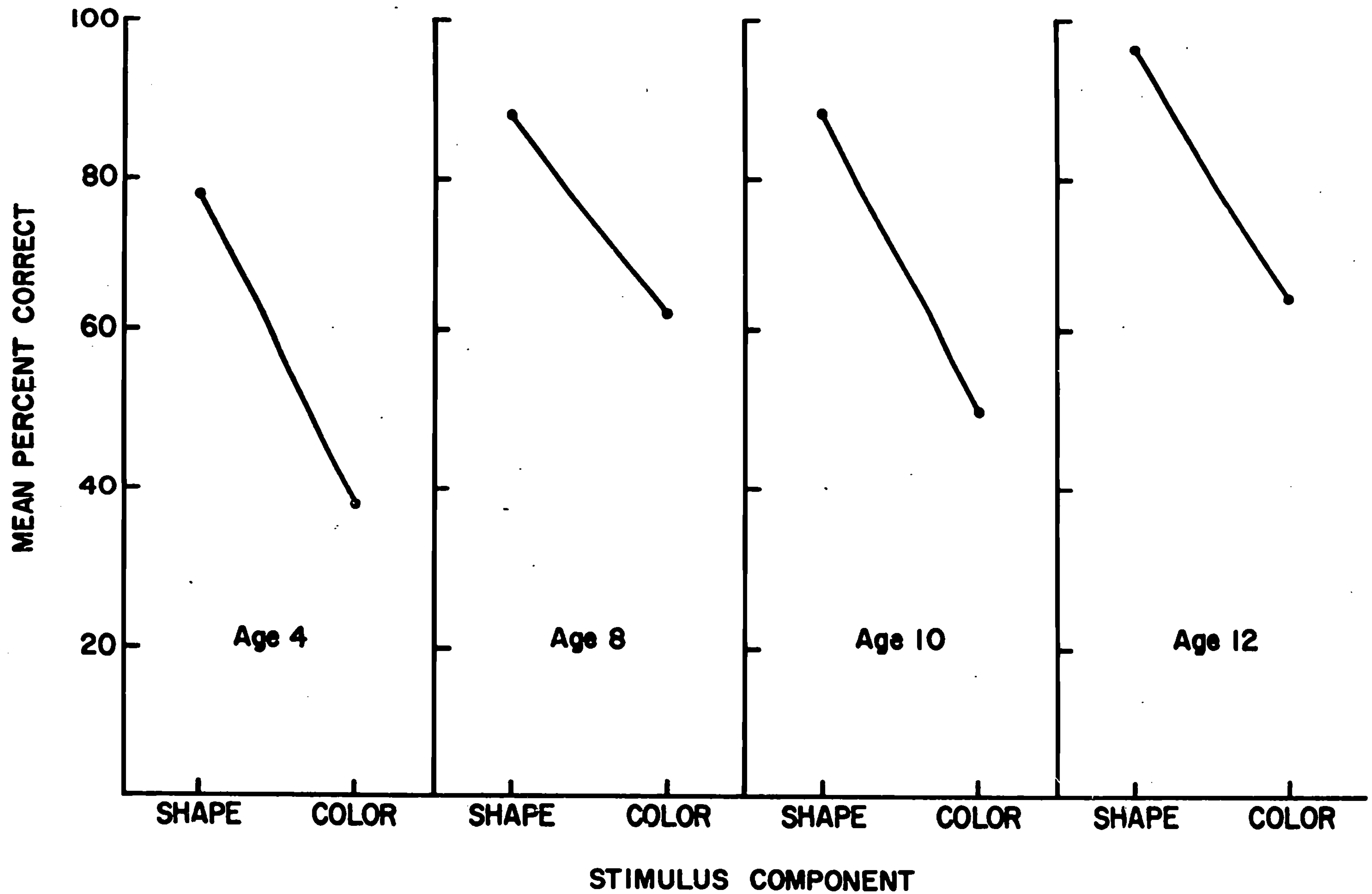

Figure 2. Mean percent correct on shape and color test trials for each subgroup given the two-dimensional, five-stimulus problem in Experiment 1.

Table 2

Number of Subjects Receiving Each Shape-Color Difference Score in Two-Dimensional, Five-Stimulus Problem of Experiment 1 and in Standard Task of Experiment 2

		Difference score						
		-1	0	1	2	3	4	5
Experiment 1: Two-dimensional, five-stimulus problem								
	Age 4	0	3	0	2	4	1	0
	Age 8	2	2	1	2	2	1	0
	Age 10	0	1	4	1	3	1	0
	Age 12	1	3	1	1	2	2	0
Experiment 2: Standard task								
Five-stimulus problem	Age 4	1	3	0	5	5	2	0
	Age 8	0	7	6	1	2	0	0
Six-stimulus problem	Age 8	2	6	4	1	1	1	1
	Age 12	1	3	4	3	1	2	2

for the position associated with each shape, color and pattern separately; for the last dimension, each test stimulus was a white card covered by a pattern. Four different sets of stimuli were constructed, which differed both in the subset of five patterns selected for presentation and in the shape and color paired with each pattern. The results for this problem, which are presented in Table 1 and Figure 3, were consistent with those for the two-dimensional task in indicating generally higher scores for shape than for the other components. For statistical analysis, a score was derived for each subject representing the difference between (a) the total for shape and (b) the average of the color and pattern totals, as the latter scores generally fell within the same range. An analysis of variance indicated little developmental change in these difference scores ($\underline{F}(3,36) < 1$). Thus, the subjects generally attended selectively to the shape component of these stimuli, and approximately the same degree of shape selection was manifested at all age levels. The data also appear to suggest a developmental change in the rank-ordering of the three dimensions, as manifested in a decrease across age levels in the difference between the color and pattern scores. Although this decrease proved to be nonsignificant, the results from this preliminary sample at least suggest the value of further research into the hierarchy of attention to stimulus dimensions such as these.

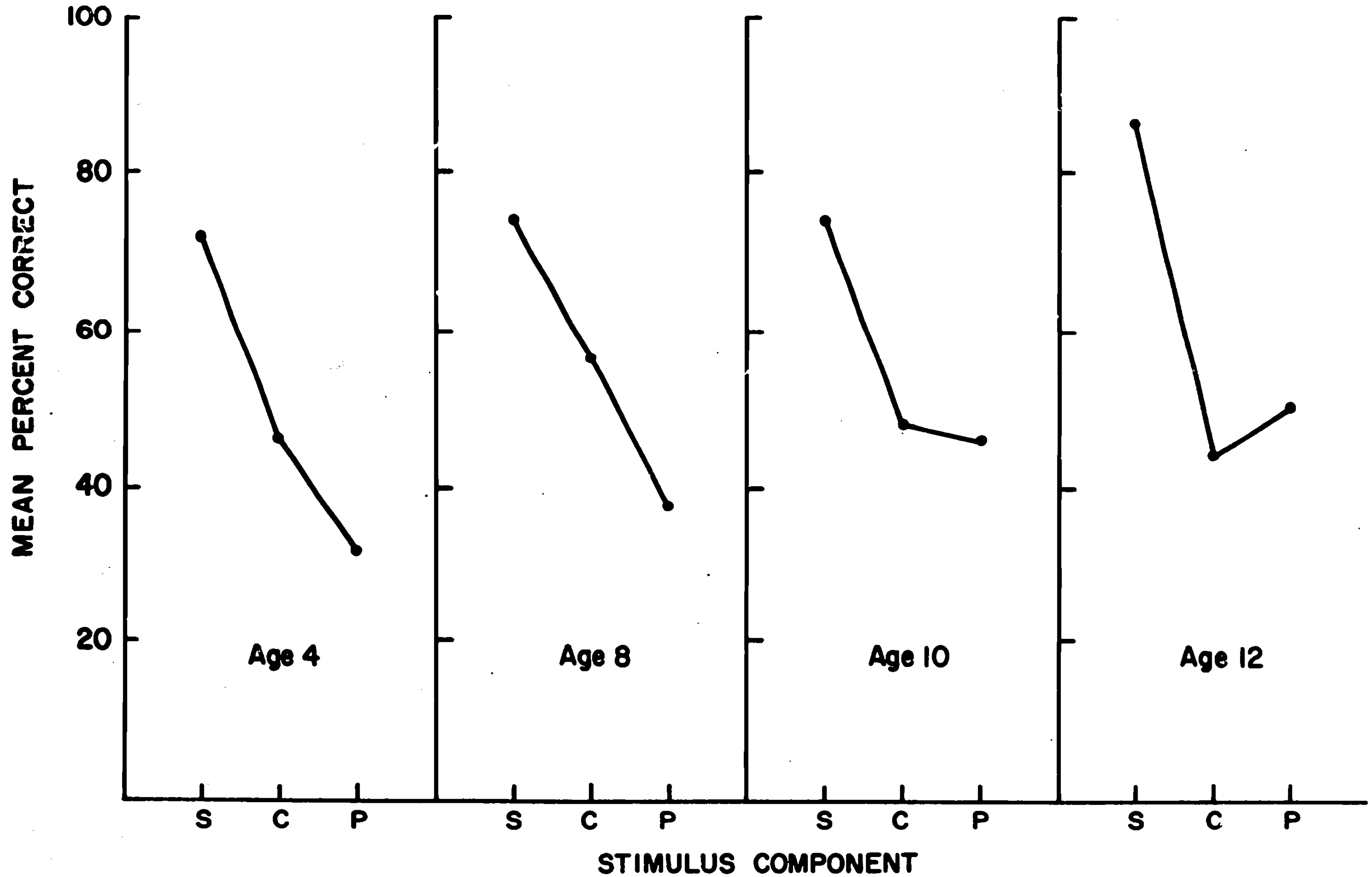

Figure 3. Mean percent correct on shape (S), color (C), and pattern (P) test trials for each subgroup given the three-dimensional problem in Experiment 1.

Experiment 2: Comparison of Component Selection and Incidental Learning

The data of Experiment 1 suggested that the degree to which children exercise component selection with stimuli differing in shape and color may not change appreciably from preschool age to early adolescence. This conclusion must be regarded as tentative, however, as it was based on the task that had been selected a posteriori as the best measure to be used for the developmental comparison, the five-choice problem. Therefore, one of the major purposes of the second experiment was to replicate these results, using a measure chosen in advance to be optimally suited for the age levels included in the study. To increase the effectiveness of the developmental analysis, the experimental design was modified in such a way that subjects of ages 4 and 8 were compared in performance on a problem of one level of difficulty (five stimuli), while 8- and 12-year-olds were compared on a measure of slightly greater difficulty (six stimuli). (Two separate groups of 8-year-olds were used in the two comparisons.) In this case, direct statistical contrasts were made between pairs of successive age levels, and developmental trends across the entire range of ages in the study were inferred by subjective combination of these analyses. This "overlapping-age-levels" design appeared to provide an effective solution to the problems of sample restriction for the youngest subjects and "overtraining" for the oldest subjects, as discussed above. Alterations in the procedure also served to make the task somewhat less abstract for the youngest subjects, thereby further reducing the number of subjects at this age level who were unable to learn the task.

The second purpose of this experiment was to furnish evidence relating to the strength or "completeness" of the component selection process. A major question arising from the results of Experiment 1 is whether the tendency to discriminate among stimuli on the basis of a single dimension is as strong under the free-choice circumstances of a component selection task as would be true in a situation which demanded that attention be directed to a given dimension. To answer this question, the standard component selection problem was compared with two variations that involved the same basic materials and procedure but required that attention be directed to shape. The first variant, while identical in format to the standard component selection task, included an instruction that recall for the position associated with each shape would be tested following the learning phase. In the second variant the stimuli used as feedback cards during learning differed in color and shape, as in the standard problem, but the cue cards contained information about shape alone (white shapes); thus, the subject was forced to attend to shape in order to learn the task, as in the typical measure of incidental learning. Following the learning phase of both variants, test trials identical to those of the standard problem were presented. The degree of component selection manifested on each of these tasks was examined across age levels, according to the "overlapping-age-levels" design described above.

Method

Subjects

A total of 198 subjects from three age levels were tested, averaging 4.6, 8.8, and 12.8 years (ranges = 3.3-6.0, 7.6-10.5, 11.4-14.4 years, respectively). The two oldest groups were drawn from third- and seventh-grade classes in two elementary schools and a junior high school in a middle class area of Bucks County, Pennsylvania. The youngest group was drawn from four nursery schools in the same geographic area, which contributed the same proportions of subjects to each experimental subgroup.

Materials

The stimuli used in the standard two-dimensional task of Experiment 1 were employed here with the exception of the following changes. The sample of shapes and colors was reduced to six by eliminating the fourth shape pictured in Figure 1 and the color yellow. As the colors blue, green and gray used in Experiment 1 had been less salient than was desirable, more saturated shades of these colors were adopted, with Munsell (1966) values of 5PB-7/7, 2.5G-8.5/6, and Neutral-7/0, respectively. Two sets of stimuli were used, which differed in the color associated with each shape. For the five-choice problem the heart was eliminated from both sets, thus eliminating the colors gray and blue from the two sets, respectively. In place of the boxes used in Experiment 1, the task was administered by means of a Plexiglas screen (13 cm. high and 79 cm. long) against which the feedback cards were rested.

Procedure

Standard component selection task. Although the basic format of the task remained as described in the General Method, the means of presenting the stimuli was altered to the form outlined below. The subject was seated at a table across from the experimenter with the Plexiglas screen before him. The feedback cards, containing colored shapes as described in Experiment 1, were rested against the screen facing the experimenter, so that the subject could see only the backs of the cards through the Plexiglas. The subject was told, "In front of you are five (six) cards, which I am going to turn around in just a moment. Look at them carefully when I do, because I am going to see if you can remember where each one is when I turn them back around again." Each feedback card was turned and the entire array was exposed for five seconds. Cue cards with colored shapes identical to those on the feedback cards were then presented one by one, with the instruction, "I want you to look at the card (being presented) and then point to the card in front of you which you think is like the one I am holding up." Each cue stimulus was presented for a minimum of two seconds, and approximately two to five seconds were required for a response. For each cue card, after the subject had made his choice, the correct feedback card was turned and displayed briefly above the Plexiglas. After the subject had reached criterion (as defined in Experiment 1, except that a maximum of 12 trial blocks were allowed), a series of test stimuli, each containing a white shape or solid color, were presented in a manner analogous to that of Experiment 1. In this case the feedback cards remained in position against the

Plexiglas screen, and for each test stimulus the subject was told, "One of the cards that you saw had this shape (or color). Try to remember where you saw it, and point to the card that you think it is."

Variant 1. The procedure of the Standard task was used in this variant, with the addition of the following instructions immediately after the initial five-second exposure to the feedback cards: "Remember that one of the things you saw had a shape like this (showing a white shape), one had a shape like this, etc. After the first part of the test ("game" for the 4-year-olds) I am going to see if you can remember where you saw each of the shapes like this, so try to remember where the shapes are."

Variant 2. This variant included the instructions described in the previous paragraph and followed a procedure identical to that of the Standard task, with one exception: the cue cards used in the learning phase were white shapes rather than colored shapes. Thus, the subject was forced to attend to the shape of each stimulus in order to learn the task.

Following the learning phase, both variants included test trials identical to those presented in the Standard task. In addition, a second test was administered immediately following the major test trials for subjects in all groups, which was designed to assess the degree to which a subject could identify the color that had been associated with each shape. Cards containing all of the colors were placed on the table as the experimenter said, "Remember that each of the shapes was a particular color. Now (holding up the white shapes, one by one) try to remember which color this shape was and point to that color."

Experimental Design

The major variables of the experiment were Age of Subject (4, 8, and 12 years) and Task (Standard and Variants 1 and 2). Subjects of ages 4 and 8 were compared in performance on five-stimulus problems, and subjects of ages 8 and 12 were compared in performance on six-choice problems. The design thus consisted of two "sub-experiments," each containing six experimental groups. Each group contained 16 subjects, with an equal representation in each group of (a) the two sexes, (b) the two stimulus sets, (c) four arrays of feedback cards (stimulus-position pairings), (d) two orders in which the cue cards were presented, and (e) two orders in which the test stimuli were presented (in each test). The data were collected by two experimenters (J. S. G. and J. S. M.), each of whom tested half the subjects in each group.

Results and Discussion

The learning data attest to the appropriateness of the tasks used in these developmental comparisons. No more than two subjects in each 4-year-old subgroup failed to learn the five-choice problem and no more than one subject in each 8-year-old subgroup failed to learn the six-choice problem. Furthermore, the numbers of subjects in each group who reached criterion immediately were not inordinately high; e.g., for the Standard task these frequencies were 3, 6, 3, and 6 (out of 16) for the 4- and 8-year-old five-choice, and 8- and 12-year-old six-choice subgroups, respectively. Comparable frequencies were observed for the subgroups receiving Variants 1 and 2. Analyses of variance indicated that the decrease from ages 4 to 8 in trials to criterion on the five-choice problem, with the Standard task and variants combined, was significant for both the final sample ($F(1,90) = 4.19$, $p < .05$) and the full sample including nonlearners, who were given a score of 12 ($F(1,101) = 7.67$, $p < .01$, unweighted-means analysis). The decrease in trials to criterion from ages 8 to 12 on the six-choice task was not significant ($F(1,94) = 2.49$, $p > .10$, for the full sample).

Table 3 presents the shape and color test data for each subgroup, and Figure 4 depicts these data graphically, with the scores plotted as percentages. As in Experiment 1, a score was also derived for each subject representing the difference between the totals for shape and color, and frequencies of subjects obtaining all possible difference scores for the Standard task are presented in Table 2 (see above). Analyses of variance on the shape-color difference scores were performed separately for the five- and six-choice problems. Since developmental changes for each task separately were of primary theoretical interest, the analyses were constructed not in terms of a standard crossed-factor format but rather in terms of comparisons between age levels for each task separately (Age within Tasks) and comparisons between tasks. The overall effect of Tasks was broken down into two nonorthogonal contrasts--between the Standard and each variant--as the major concern in this case was to determine the effect of each procedural variation separately in relation to the basic component selection procedure.

For the five-choice problem, analyses of age differences indicated a significant decrease in the shape-color difference score from age 4 to age 8 for the Standard task ($F(1,90) = 4.97$, $p < .05$) but not for either of the variants. As is the case for each of the effects to be reported, this decrease appears to have been due primarily to a difference in performance on the color test trials, as the shape scores remained relatively high across all subgroups of the study. Of the two comparisons between tasks, only the difference between the Standard and Variant 2 was significant, the shape-color difference score being higher in the latter case ($F(1,90) = 6.01$, $p < .05$). For the six-choice problem, a developmental increase in difference score from ages 8 to 12 was observed for Variant 2 ($F(1,90) = 6.27$, $p < .05$) but not for either the Standard task or Variant 1. As was true for the five-choice problem, comparisons between tasks indicated the mean difference score for the Standard to be significantly lower than that for Variant 2 ($F(1,90) = 17.94$, $p < .01$) but not significantly different from that for Variant 1.

Although the data in Figure 4 appear to suggest a slight increase in component selection from ages 8 to 12 on the Standard task, data from Experiment 3 to be presented indicate nearly identical patterns of results for these two age levels. In that experiment, the Standard

Table 3

Means and Standard Deviations (in Parentheses) of Test Scores for All Subgroups of Experiment 2 (N = 16 in each group)

Task and Stimulus component	Five-stimulus problem		Six-stimulus problem	
	Age 4	Age 8	Age 8	Age 12
Standard				
Shape	4.19 (1.05)	4.38 (0.88)	5.38 (0.96)	5.50 (0.89)
Color	2.19 (1.22)	3.50 (1.26)	4.38 (1.63)	3.62 (1.59)
Variant 1				
Shape	4.44 (0.89)	4.44 (1.09)	5.50 (0.82)	5.56 (0.73)
Color	3.06 (1.48)	2.75 (1.77)	4.62 (1.36)	4.00 (1.63)
Variant 2				
Shape	4.44 (0.89)	4.44 (0.73)	5.69 (0.60)	5.94 (0.25)
Color	2.25 (1.29)	2.00 (1.26)	3.25 (1.61)	2.06 (1.65)

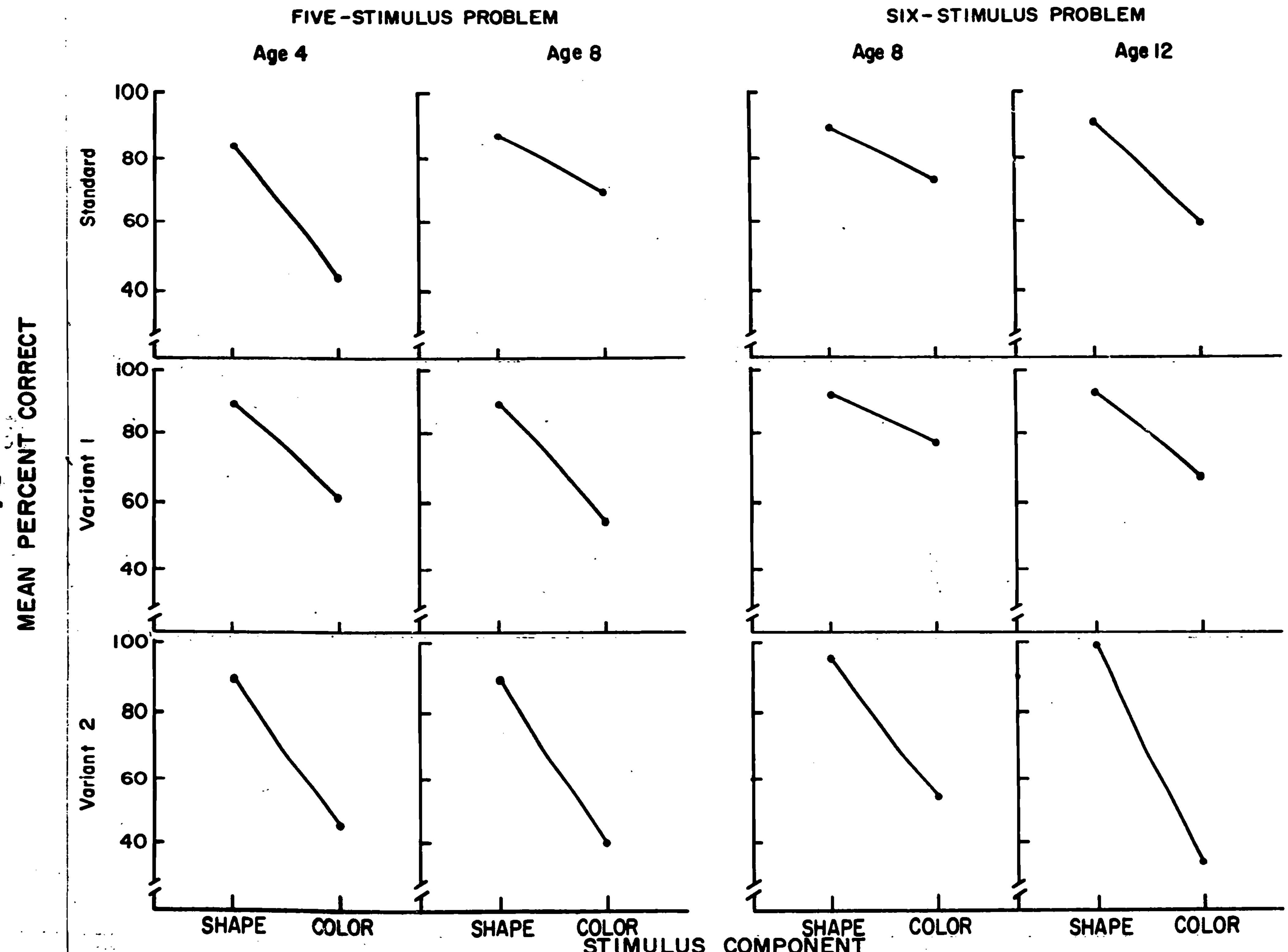

Figure 4. Mean percent correct on shape and color test trials for each subgroup of Experiment 2.

six-stimulus task was administered to 20 subjects at each of ages 8 and 12 from samples similar to those described above. The resulting mean percentages correct for shape and color, respectively, were 92 and 71 at age 8, and 89 and 73 at age 12.

Information concerning the relation between learning rate and component selection in the present study was provided by correlations between trials to criterion and shape-color difference scores, computed separately for each subgroup. The correlations for the 4- and 8-year-olds given the five-choice problem, and the 8- and 12-year-olds given the six-choice problem, respectively, were: for the Standard task, .38, -.26, -.50, .00; for Variant 1, -.44, -.36, -.18, .18; and for Variant 2, .24, -.23, .22, .27. No consistencies are readily apparent in these correlations.

Developmental changes in attention from ages 4 to 12 may be inferred by a subjective combination of the results obtained for the five- and six-choice problems. Most importantly, data from the Standard measure did not indicate a developmental increase in component selection, as had been expected on the basis of the theoretical analyses presented earlier. Rather, where an age difference was found, it was in the direction of a <u>decrease</u> in component selection—from ages 4 to 8. This result cannot be attributed simply to an increase with age in children's preference for attending to color rather than shape, as research on stimulus matching in children has generally indicated a developmental trend in the opposite direction (e.g., Corah, 1964; Suchman & Trabasso, 1966). Thus, the age differences observed for the Standard task appear to reflect developmental changes in the more general process of component selection rather than in aspects of attention related to these specific dimensions. The results indicate that, while the 4-year-olds exercised a relatively high degree of component selection with these materials, the older children were apparently less selective, as they attended to both shape and color in learning the task. Further implications of these results will be discussed below.

No overall differences in degree of component selection were found between the Standard measure and Variant 1, in which the subjects were instructed to attend to shape. Similarities in data for these two tasks are obvious in the case of subgroups given the six-choice problem. For the five-stimulus problem, however, the results are less clear-cut, as a possible differential effect for the 4- and 8-year-old subjects is suggested. While these last effects can only be clarified through replication, it is nevertheless possible to offer the following summary description of the present results. For three of the four comparisons between these two tasks (except the 8-year-old five-choice subgroups), the shape-color difference score was at least as high for the Standard component selection task as for Variant 1. In the majority of cases, then, selective attention to shape was apparently as great under conditions that allowed the subject a free choice of the means by which to differentiate among stimuli as was true in a situation involving instructions to attend to shape.

Interpretation of certain results involving Variant 2 must take into account the influence of a confounding factor, the number of stimulus exposures. One such result is the difference in component selection scores between Variant 2 and the Standard task. It must be pointed out that subjects given Variant 2 were exposed to only half the number of cards containing colored shapes as were subjects given the Standard task, since the cue cards were white shapes in this case; therefore, these subjects received fewer opportunities to learn the color associated with each shape. Assuming that performance on the color test trials is partially influenced by recall for the shape-color associations, this difference in stimulus exposure alone could account for the lower color scores, and thus greater difference scores, for Variant 2 than for the Standard task. A related factor must also be considered in interpreting the decrease from ages 8 to 12 in shape-color difference scores for Variant 2. Since the older subjects learned the initial phase of this task more rapidly than did the younger subjects, they also received fewer exposures to the stimuli. This age difference in amount of stimulus exposure in itself could explain the older subjects' lower amount of recall for color information.

Despite these difficulties of interpretation, however, the data from Variant 2 are valuable in one important respect. The developmental trend in performance on this variant may be compared subjectively with that observed on the Standard task, as a means of assessing the degree of similarity in the attentional processes employed in these two situations. Age differences in exposure duration are not critical in such a comparison, as such differences are presumably equal for the two tasks. In this regard, it will be observed that the decrease from ages 4 to 8 in shape-color difference scores on the Standard task was not paralleled in the data for Variant 2. Also, the increase from ages 8 to 12 in difference scores on the latter task contrasts with the absence of such an effect for the Standard measure. An *a posteriori* analysis of the interaction between Age and Standard-versus-Variant 2 yielded an F value of 4.55 for the comparison between 4- and 8-year-olds ($df = 1, 60$, $p < .05$, using standard significance level). Of course, this analysis is entirely *post hoc*, and the strength of the above-mentioned interaction must ultimately be determined through replication of the present results. Tentatively, however, it may be said that component selection scores on the Standard task appeared to follow a developmental course somewhat different from that observed for Variant 2. It is possible that the attentional processes reflected in a component selection measure are quite unlike those employed in a situation that requires attention to be directed to a given stimulus component, and these processes may differ in the developmental changes which they undergo.

The second set of test trials, administered immediately following the first test, determined the subject's ability to identify the color that had been associated with each shape. The most notable aspect of the scores obtained is their similarity to the number correct on the color trials of the first test. These two scores fell within six percentage points of each other, with no consistent directionality, for every subgroup but one (for the 4-year-olds given Variant 2, the percent correct on the second test was 10 percentage points lower than the color score). In addition correlations between these two scores, computed for each of the 12 subgroups of the experiment, were moderate to high; for the Standard, Variant 1, and Variant 2, respectively, the median correlations derived from the four subgroups given each task were .50, .45, and .72. Thus, the data suggest some degree of relationship between a critical aspect of the component selection measure, the color score, and a measure indicating retention of the shape-color associations. While several explanations might account for this relationship, one likely possibility is that the ability to identify the position in which each color appeared may have been mediated by recall of the shape associated with each color, or vice versa. Because of the constant order in which the two tests were presented, however, further speculation in this regard must await additional research designed specifically to test this interpretation.

Experiment 3: Assessment of a Critical Stimulus Variable

This experiment was designed to provide further information regarding differences between the component selection measure and the typical incidental learning task, to supplement the results obtained in Experiment 2. The major independent variable in this case was the type of stimulus material used, often a critical dimension of difference between these measures. In the incidental learning problems which have been most commonly used in developmental research, the stimuli are complexes of spatially distinct pictures (usually pairs), and the child is required to attend to only one of the pictures in each complex (e.g., Hagen, 1967; Siegel and Stevenson, 1966). The present component selection task, on the other hand, was conceived as a means of identifying dimensions to which children typically attend in discriminating among objects; this necessitated the use of stimulus components that are contained within a single unit--features such as shape and color along which objects commonly differ. Current theoretical analyses of selective attention have failed to distinguish between these two types of stimulus material. However, it is reasonable to posit that the process of attending selectively to a feature that is an integral part of a stimulus is quite different from the process of orienting to one of several spatially distinct elements of a complex. The former case necessarily involves a central selection process--that is, selection of information on which to concentrate one's thought; the latter involves the more peripheral process of orienting one's gaze toward a particular stimulus element and away from others. To determine the importance of this distinction for developmental theories of attention, the present experiment included tasks in which the stimuli were either pairs of pictures, as in the typical incidental learning measure, or colored shapes, as in the component selection measure used in other experiments of the present study.

Since a major purpose of this experiment was to aid in interpreting the results of previous incidental learning studies, an incidental learning measure was used to assess the effects of this stimulus variable. One group of subjects was given a task involving pairs of pictures, in which they were required to attend to one picture in each pair, followed by a test of their ability to identify the pictures that had been depicted together. Another group was given an analogous task involving colored shapes, in which the subjects were required to attend to the shape of each stimulus during a learning phase, followed by a test of their ability to identify the color associated with each shape. A third group given the standard component selection task (with colored shapes) was also included, to allow direct comparison of the results obtained with the incidental learning and component selection measures. Since developmental studies of incidental learning have typically focussed on children beyond middle childhood, the present experiment also concentrated on developmental changes occurring in this age range and included children of ages 8 and 12.

Method

Subjects

A total of 122 subjects were drawn from third and seventh-grade classes in the same population that contributed subjects to Experiment 2 (mean ages = 8.7 and 12.7 years).

Materials

For the Pictures task, the primary stimuli were pairs of line drawings on cards (ea. 9 x 13 cm.), each pair consisting of an animal and a household object. The pictures on each card (each approximately 5 cm. square) were adjacent to each other, with the animal shown above the object in three cases and below it in three cases. The animals were: dog, cat, bear, deer, camel, and horse; the household objects were: television, chair, lamp, clock, table and cup. Additional cards, used as cue or test stimuli, contained a single animal or a single household object. For the Shapes task, the major stimuli were colored shapes on black cards, as described in Experiment 2, and additional cards containing a color or a white shape served as cue or test stimuli. Materials similar to those of the Shapes task were also used for the Component Selection problem.

Task and Procedure

The two major groups of the study, Pictures and Shapes, were given an incidental learning problem of the type described by Hagen (1967). The task consisted of two parts, a central learning phase and an incidental learning test. In the first phase six cards, each containing an animal and a household object (or a colored shape), were simultaneously turned face up and exposed for five seconds (the cards were affixed to a long piece of cardboard, in a row). After this period, the cards were turned face down, and the subject was shown an animal (or a white shape) and asked to point to the position in which that animal (shape) had appeared. The next trial was then administered, in which the same pairs of pictures (colored shapes) were presented, but in a different spatial arrangement, following which the child was shown an animal (shape) and asked to identify the position in which it had appeared. Twelve such trials were presented and the animal (shape) presented as a cue on each trial was randomly determined, with the restrictions that each animal appear twice within the entire task and no position be correct less than once nor more than three times. The number correct on these 12 trials comprised the "central learning score" for a given subject. It will be observed that the animal (shape) component in each stimulus was designated as critical for correct performance, while the household object (color) was deemed "incidental." To aid in defining this relationship, a one-trial warm-up problem preceded the main task, along with instructions to pay attention to the animals (shapes). (The stimuli used in the pretest were two pairs of pictures, or two colored shapes, different from those to be encountered in the main task).

Following the 12 trials of the initial learning phase, the subject was given an incidental learning test, to determine whether he could identify the household object (color) that had been paired with each animal (shape). For this test, all six household objects (colored cards) were placed on the table face up, and the child was shown each of the animals (white shapes) one by one, and asked to point to the household object that went with each animal (or the color that went with each shape). The number correct on this test constituted the subject's incidental learning score. For subjects given the Component Selection Task, shape and color scores were derived as indicated in Experiments 1 and 2.

Experimental Design

There were three tasks, entitled Pictures, Shapes, and Component Selection administered to children at each of ages 8 and 12. Each of the six resultant subgroups contained 20 subjects and an equal representation of (a) the two sexes, (b) two sets of materials, differing in the household object associated with each animal (or color associated with each shape), (c) two orders in which the cue cards were presented, and (d) two orders in which the test stimuli were presented. All subjects were tested by a single experimenter (J.S.M.).

Results and Discussion

The central and incidental learning scores for the Pictures and Shapes tasks are presented in Table 4. It will be observed, first of all, that the central learning scores increased from ages 8 to 12 in both cases. This is consistent with the results of previous research and is to be expected, as it reflects an increase in children's general ability to learn critical stimulus information. An analysis of variance for these central learning scores indicated the main effect of Age to be significant $(F(1,76) = 31.41, p < .01)$ with neither an effect of Tasks nor an interaction between Age and Tasks $(F(1,76) < 1)$.

Of greater importance for the present analysis are the incidental learning scores, as these reflect the degree to which subjects are attending to the incidental features of the stimuli. For the Pictures task, these results replicated those obtained in previous studies with a similar measure (Druker & Hagen, 1969; Hagen, 1967) in indicating little difference across age levels in incidental learning. For the Shapes task, however, a marked increase in incidental learning was observed across these age levels, and this result, in contrast with that obtained with the Pictures task, suggests that somewhat different attentional processes may be involved in these two situations. This interpretation is supported by an analysis of variance for the incidental learning scores indicating a significant interaction between Age and Tasks $(F(1,76) = 6.80, p < .025)$ as well as a main effect of Age $(F(1,76) = 7.57, p < .01)$.

Table 4

Means and Standard Deviations (in Parentheses) of Scores for Pictures and Shapes Tasks of Experiment 3

(N = 20 in Each Group)

	Pictures task		Shapes task	
	Age 8	Age 12	Age 8	Age 12
Central learning	3.70 (1.30)	6.40 (2.37)	4.15 (1.66)	6.45 (2.42)
Incidental learning	1.70 (1.08)	1.75 (1.62)	1.45 (1.47)	3.30 (1.89)

While these two types of material differ in several respects, it is proposed that the factor responsible for the divergent results is the degree of integration of the stimulus components. In the case of the geometric figures, the color and shape components are integral features of each stimulus, and a child likely perceives these components as inextricable parts of a whole. With the pictorial materials, on the other hand, the two components are conceptually and spatially distinct, and a child might logically regard them as separate entities. Assuming, then, that the degree of integration among components is the critical factor underlying the differential results observed in the present study, the following general hypothesis can be offered. In learning tasks involving stimulus components contained within a unit, such as shape and color, children at all age levels will attend to both components to an extent in learning the task. Thus, acquisition of information about incidental features will proceed apace with central learning, causing incidental learning scores to increase with age along with central learning scores. However, when the components are separate and distinct elements, younger children will attend to both components to an extent, while older children will attend primarily to critical stimulus elements and ignore incidental information; in the latter case, incidental learning will remain relatively constant across age levels, while central learning increases.

The results for the Component Selection task are consistent with those obtained in Experiment 2, in that the component scores did not differ significantly as a function of age (the shape and color scores, respectively, were 92% and 71% for age 8 and 89% and 73% for age 12). While scores for this task cannot be contrasted directly with those of the incidental learning tasks in the experiment (Pictures and Shapes), some insights regarding differences between these methods may be derived through informal comparison of the incidental learning and component selection data. The most useful comparison in this regard involves developmental trends in (a) color scores from the Component Selection task and (b) incidental learning of color in the Shapes task. As has been noted, the former scores differed little between ages 8 and 12 while the latter increased markedly across these age levels. Although the reasons for this difference are not immediately apparent, one possibility involves the amount of exposure to the stimuli provided by each method. In the Component Selection task, a given stimulus was exposed for roughly 3 seconds on each trial; in the incidental learning procedure, on the other hand, the entire array of six stimuli was exposed for 5 seconds per trial, thus affording only 5/6 seconds viewing time for each stimulus. It is possible that the older children were particularly adept at acquiring color information under the rapid exposure conditions of the incidental learning task but lost their advantage over the younger children in a task in which the stimuli were exposed for a longer duration. Other interpretations of the present results are possible as well, and additional research with component selection and incidental learning measures will help to identify the critical methodological differences between these approaches.

Experiment 4: Component Selection as a Function of Degree of Training

It has been proposed that a subject's disposition to attend selectively in a learning task will depend upon the particular learning stage in question. James and Greeno (1967), for example, have posited that subjects will attend to several stimulus components in the early phases of learning, then begin to attend more selectively as learning progresses toward criterion, and finally relax the selective mechanism again with overtraining. If such an analysis is correct, it was reasoned, then the pattern of results observed across stages of learning might serve as a valuable unit of analysis, as contrasted with a single component selection score. Developmental comparison of these patterns could provide a relatively comprehensive picture of the manner in which children of various ages utilize selective attention throughout the course of learning. For this purpose, as well as to test the validity of the James and Greeno formulation, the present experiment examined component selection at six different levels of training, ranging from undertraining to overtraining, and the effects of this variable were assessed in children at each of ages 4, 8 and 12.

Method

Subjects

The study included a total sample of 84 children at age 4, 152 at age 8 and 72 at age 12 (mean ages = 4.6, 8.7, and 12.9, respectively). The two oldest groups were drawn from third- and seventh-grade classes in a middle-class area of Somerset County, New Jersey, while the youngest group was drawn from nursery schools in the same general vicinity. As in Experiment 2, an "overlapping-age-levels" design was used, such that 4- and 8-year-olds were compared in performance on a five-stimulus task, while a six-stimulus task was used in the comparison of 8- and 12-year-olds.

Task and Materials

The primary stimuli were colored shapes on black cards, of the type used in Experiments 2 and 3; in this experiment, however, the colors yellow and brown were substituted for gold and gray, respectively. Excluded from the five-choice task were: (a) the color brown for all subjects and (b) the circle and heart, each for half the subjects. The component selection task was administered as described in Experiment 2, with the learning phase continuing through as many trial blocks as were necessary to meet one of the criteria defined below.

Experimental Design

The study consisted of four "subsamples": 4- and 8 year-olds given the five-stimulus task, and 8- and 12-year-olds given the six-stimulus task. Subjects in each subsample were randomly assigned to one of six training groups given different levels of training on the component selection task, with a final sample of 12 in each group (after exclusion of subjects for failure to reach the appropriate criterion). The first four groups differed in the stringency of the criterion to be reached before the learning phase was terminated and the component selection test begun; these criteria were chosen to represent clearly differentiated levels of learning, according to data from earlier experiments. For the Undertraining 1 group, a trial block with three or fewer errors was required for termination of the learning phase (for both the five- and six-stimulus tasks), while for Undertraining 2, a trial block with one error or less was needed. For Criterion 1, subjects were required to attain one errorless trial block, while subjects in Criterion 2 had to reach one perfect trial block followed by two blocks containing no more than one error. Subjects in Overtraining 1 and Overtraining 2 were trained to the latter criterion, followed by three and six additional trial blocks, respectively, prior to receiving the test phase.

Each of the six training groups contained an equal representation of (a) the two sexes, (b) two stimulus sets, differing in the color associated with each shape, (c) two arrays of feedback cards, (d) two orders in which the cue cards were presented, and (e) two orders in which the test stimuli were presented (in each test). All subjects were tested by one experimenter (S.S.T.).

Results and Discussion

Initial Considerations

Relative salience of shape and color. The number of correct responses on the shape and color trials of the component selection test was determined for subjects in each of the six training groups. As in earlier experiments, the shape component proved to be generally more salient than color, in that the shape score was equal to, or higher than, the color score for 92% of the subjects. Thus, it appears that children in all training groups directed their attention primarily to the shapes of these materials, and color was a "secondary component," in a sense. The mean shape and color scores for each training group are plotted in Figure 5, and differences in these scores across groups will be discussed below under "Effects of Training on Component Selection."

Learning data. The total number of trial blocks received by each training group is listed at the bottom of Figure 5, to indicate the overall amount of exposure to the stimuli that subjects in each group were given (the numbers of trial blocks prior to reaching the appropriate criterion in each case are listed in parentheses). It is useful to inspect these scores, before considering the component selection data in the figure, to determine whether the groups in this study were given differential amounts of training as expected. In this regard, a difference of at least one trial was observed for all successive pairs of training groups except the two levels of undertraining; in the case of the 12-year-olds and the 8-year-

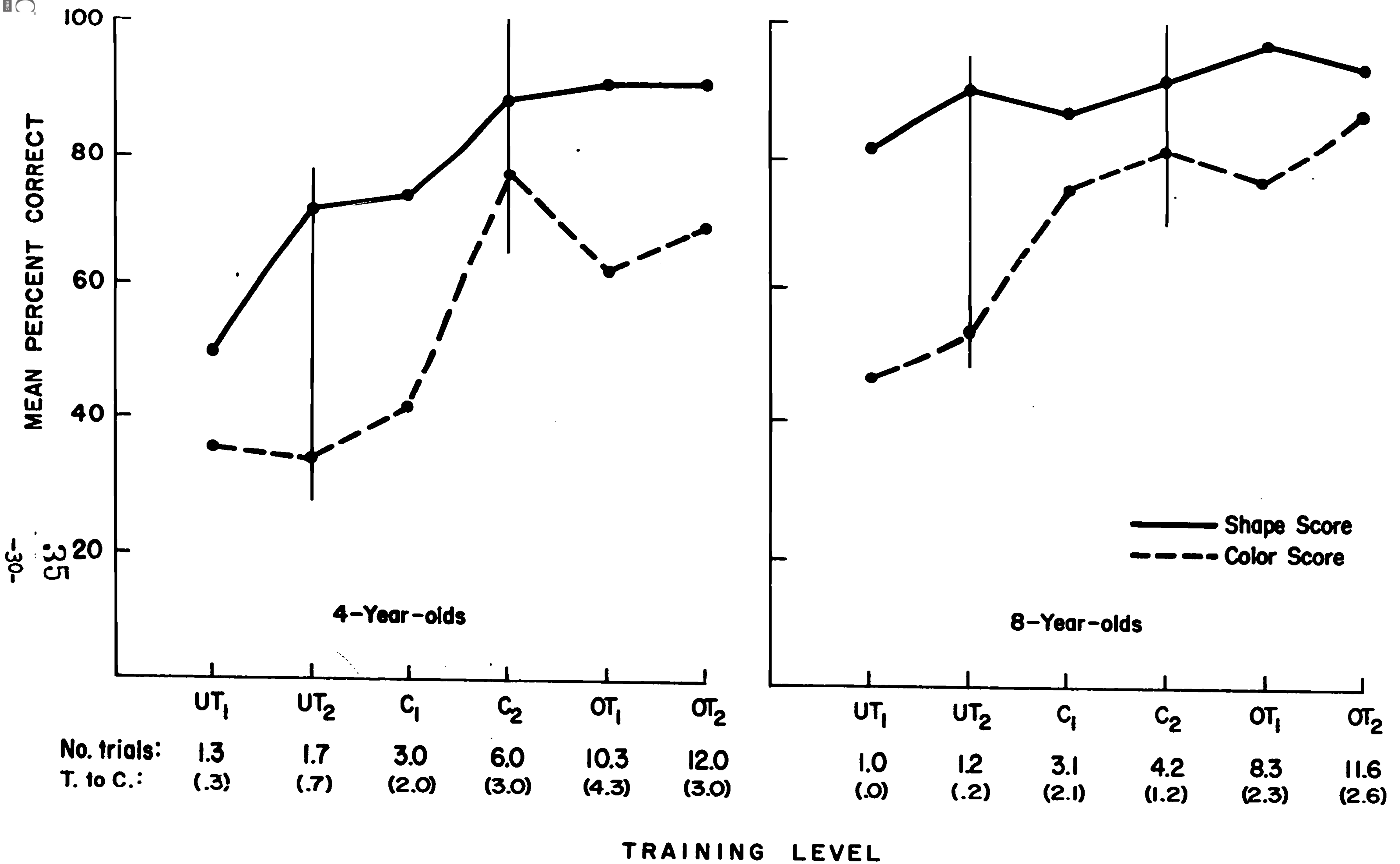

Figure 5a. Mean percent correct on shape and color test trials of five-stimulus task, for each training level from Undertraining 1 (UT 1) to Overtraining 2 (OT 2). The mean number of trial blocks received by subjects at each training level, as well as the mean number of trial blocks prior to reaching criterion, are listed below the abscissa.

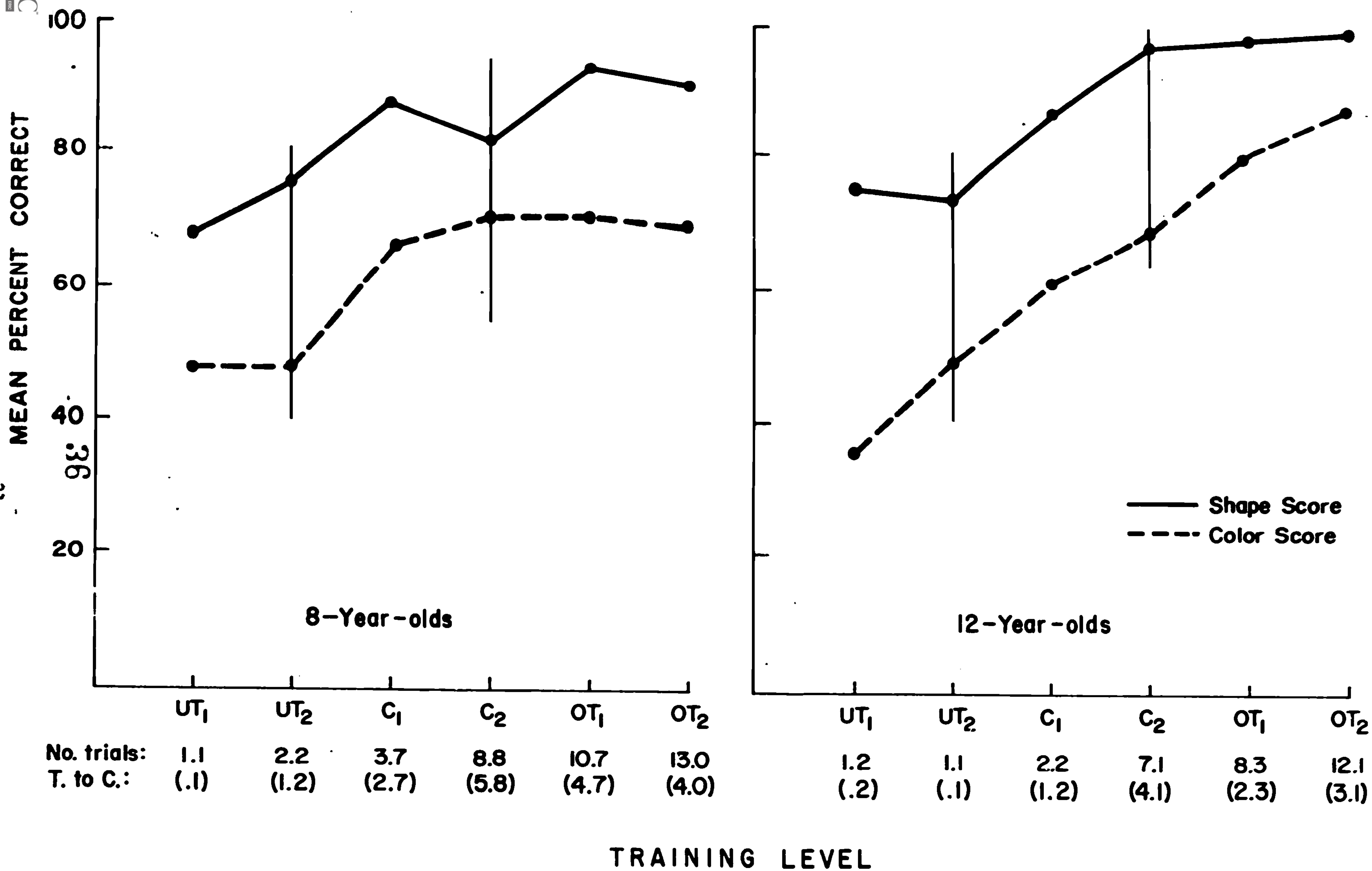

Figure 5b. Mean percent correct on shape and color test trials of six-stimulus task, for each training level from Undertraining 1 (UT 1) to Overtraining 2 (OT 2). The mean number of trial blocks received by subjects at each training level, as well as the mean number of trial blocks prior to reaching criterion, are listed below the abscissa.

olds given the five-choice task, the two undertraining groups received nearly identical amounts of training, as most subjects in these groups reached the necessary criterion in a single trial. Thus, of the levels of training included in this study, only those beyond the second level of undertraining apparently represent clearly differentiated amounts of training for subjects at all age levels. Therefore, discussion of the component selection data will focus primarily on changes occurring beyond the second level of undertraining.

It was critical in this study to employ tasks that were reasonably difficult, in order that different stages of learning could be identified; however, this necessitated that some subjects fail to reach the criterion appropriate for their group and additional subjects be tested in order to arrive at a final sample of 12 children per group. The number of nonlearners for the six training levels, in order beginning with Undertraining 1, were: for the 4-year-olds, 0,0,1,5,5,1; for the 8-year-olds given the five-stimulus task, 0,0,0,0,0, and 1; for the 8-year-olds given the six-stimulus task, 0,0,1,1,2 and 3; and for the 12-year-olds, none. While these figures are generally reasonable for most subgroups, the numbers for the 4-year-olds were greater than expected from the data of earlier experiments. This latter fact raises the possibility that sample restriction may have been involved in the comparison between Undertraining and Criterion groups for the young children, and analyses to be presented will attempt to piece out the influence of this factor. Examination of the effects of overtraining for these young children, however, and comparisons involving other age groups do not appear to be affected by gross sample selection.

Effects of Training on Component Selection

Initial level of shape and color scores. While the data presented in Figure 5 are complex, some conclusions bearing on the effects of training level may be derived by examining three general aspects of these data: the magnitude of the component scores at undertraining, changes in the scores from undertraining to strong criterion, and changes in the scores with overtraining. Regarding the first aspect, it will be noted that, at all ages, the mean shape score was higher than that for color even at the initial level of undertraining. Thus, the expected greater attention to shape than color was observed at the earliest stage of learning, as well as at criterion level and beyond. Apparently, the disposition to attend selectively (to the more salient of two components) is operating from the moment that learning begins.

Changes prior to reaching criterion. Of even greater importance for the present study, however, is variation in the component scores across levels of learning. The first changes of interest are those occurring as subjects are approaching the point of mastery of the task, during which time attention is hypothesized to become most selective, according to the James and Greeno (1967) analysis discussed above. While it is impossible to identify the precise juncture at which a learning problem has been mastered, the strong criterion of the present study (Criterion 2) represents a point at which it could be said with relative certainty that the (initial phase of) the present task has been learned. Also, Undertraining 2 is felt to represent the point at which subjects have begun to approach mastery of the task. The present analysis therefore concentrates upon changes in the component scores occurring between Undertraining 2 and Criterion 2, the period during which subjects presumably approach and reach a hypothetical "point of mastery."

The most notable result in this regard (as seen in Figure 5) is that the color scores increased markedly during this period, a pattern that appears to be true of children at all age levels. (The shape scores increased as well, although more gradually, having reached a relatively high level for most subgroups at Undertraining 2.) These results tend to contradict the hypothesis that attention should be most selective during the period in which a subject is mastering the task. If such a hypothesis were correct, scores for the "secondary component" (color) should have remained relatively constant or increased only gradually during this period. However, the marked increase in color scores suggests that the subjects continued to attend to this component as well as to the primary component (shape) during this learning stage.

The reliability of these effects is indicated in analyses of variance performed on the component data. Two sets of analyses were conducted in this experiment; the first of these involved the three training levels from Undertraining 2 to Criterion 2, and results of these analyses will be presented in this section. The other set involved the three levels from Criterion 2 to Overtraining 2, and results of these analyses will be considered below under "Effects of Overtraining." It was deemed most useful to separate the data into two units in this fashion, since the two major foci of the study involved children's use of selective attention (a) during learning, and (b) after reaching criterion.

Analyses involving the color scores are the most pertinent to the hypotheses of the experiment and will be considered initially. Separate analyses were performed for the five- and six-stimulus tasks, and the independent variables in each case were Age and Training Level, the latter variable consisting of the three levels from Undertraining 2 to Criterion 2. The most critical result was a significant main effect of Training Level for both the five-stimulus task ($F(2,66) = 10.77$, $p < .001$) and the six-stimulus task ($F(2,66) = 4.05$, $p < .025$), corroborating the observation that subjects attend to color and acquire a considerable amount of information about this component during this premastery stage of learning. The only other effect that proved to be significant in the analysis of color scores was a main effect of Age for the five-choice problem ($F(1,66) = 9.43$, $p < .01$); as will be discussed below, this effect is consistent with that obtained in Experiment 2 in indicating greater color recall for the 8- than the 4-year-olds.

Similar analyses performed for the shape scores indicated a main effect of Age for the five-stimulus problem ($F(1,66) = 5.38$, $p < .025$) and a main effect of Training Level for the six-choice task ($F(2,66) = 5.22$, $p < .01$). Thus, recall for the position associated with each shape was greater for the 8- than the 4-year-olds, and (for the six-choice task) greater at Criterion 2 than at Undertraining 2.

In the case of the 4-year-olds, interpretation of the present results must take into account the possibility of sample restriction for the Criterion 2 group. That is, in an effort to secure 12 subjects for the final sample in this group, 5 (of 17) subjects had to be excluded for failure to reach this criterion. Since no subjects were excluded in the Undertraining 2 group, and only one subject in Criterion 1, it is possible that the final 12 subjects in the Criterion 2 group were better learners on the average than those in either Undertraining 2 or Criterion 1. As a rough means of controlling for the effects of sample restriction, the summary data for these last two groups (at age 4) were recomputed, excluding the four subjects in each case who required the greatest number of trials to reach the appropriate criterion (these subjects also had the greatest number of errors in the first trial block of the task for each group). With the slower learners thus excluded, the reconstituted Undertraining 2 and Criterion 1 groups might be regarded as more comparable in general learning ability to the Criterion 2 group. The resultant mean shape and color scores were 63% and 23% for Undertraining 2 and 73% and 33% for Criterion 1; in contrast with the 88% and 77% scores for Criterion 2, these data again indicate a marked increase across training levels in amount of color (as well as shape) information acquired. The general conclusion remains, then, for these young children as well as the older subjects, that attention does not become more selective as learning proceeds to criterion but continues to be directed to secondary stimulus information such as color as well as toward a primary component such as shape.

Effects of overtraining. James and Greeno (1967) had also proposed that a subject should attend less selectively during a period of overtraining than during earlier stages in learning. That is, subjects should attend to a wide variety of stimulus features during post-criterion training and presumably should acquire an increasingly greater amount of information about stimulus components other than those which had served as the primary focus of attention in learning. Examination of the data beyond Criterion 2 in the present study, however, suggests that such a notion may not be valid for children of middle childhood and below. The 4- and 8-year-old subjects showed little acquisition of information about the secondary color component beyond this strong criterion; although some fluctuations occurred in the color scores, in general they were no higher at Overtraining 2 than at Criterion 2 for these younger subjects. This result is particularly noteworthy in that the scores remained markedly below the ceiling level of perfect performance, indicating that a reasonable amount of color information remained to be learned.

In accounting for this result, it is necessary first to consider a possible artifactual interpretation that might be offered--namely, that the apparent limit reached by the color scores represents an asymptote in the degree to which color can serve as an effective cue. While such a statement may seem plausible, other data from the study appear to rule it out as an explanation of the present results. First of all, a simple match-to-sample test administered to each subject following the component selection task indicated that all subjects could correctly identify all colors. That is, when a number of cards containing the colors of the experiment were placed on the table and the child was shown, one by one, cards corresponding to those on the table, all subjects correctly matched each card with its correspondent. Also, children of these ages are apparently able to learn a task with only colored cards as stimuli, as indicated in the data of Experiment 5, suggesting that the limit reached by the color scores here does not represent a limit in children's ability to learn associations involving colors. It might also be argued that the data could have been affected by the presence of color-blind subjects in the sample. The possibility of excluding color-blind children from the study was considered but rejected; since procedures do not exist that are equally adequate for identifying color-blind children at age 4 as well as at ages 8 and 12, exclusion of these subjects in the older age groups would have invalidated the developmental comparisons. However, data from the matching test described above indicate that any color-blind children that may have been contained in the sample could apparently discriminate among these colors, and the small number of such subjects could not have been enough in itself to set the low limit observed for the color scores.

It appears reasonable, therefore, to interpret the data for subjects of age 8 and below as indicating a failure of overtraining to "broaden" attention. Training past criterion apparently does not cause children of these ages to expand their focus of attention beyond the stimulus information that is functional in learning the task. Rather, continued training for these subjects may simply produce a continued demonstration of whatever knowledge was acquired during learning, with little additional acquisition of stimulus information.

While the data for children of age 8 and below thus appeared to be inconsistent with the James and Greeno analysis discussed above, the results for the 12-year-olds are somewhat less discrepant from that model. For the latter subjects, the color scores did not increase more rapidly than the shape scores between Undertraining 2 and Criterion 2 but increased by about the same magnitude. Even more importantly, the color scores for these older children showed an increase with overtraining, which was not true of the younger subjects. This apparent age difference in pattern of results is extremely provocative. It implies that the behavior of the oldest subjects in this study began to approach that specified in the James and Greeno model. Only these subjects "attended broadly" with overtraining and acquired stimulus information in addition to that which had been functional in learning the task. Since the above-mentioned model was conceived in connection with data from college-aged subjects, it is reasonable to speculate that it more nearly characterizes the behavior of adults than young children. Assuming this to be the case, the present data may be regarded as indicating a developmental transition toward an "adult-like" manner of employing selective attention in learning.

Analyses of variance involving the three levels from Criterion 2 to Overtraining 2 bear upon these interpretations. Again, the most critical analyses were those involving the color scores, and separate analyses were performed for the five- and six-stimulus tasks. The independent variables were Age and Training Level, the latter variable in this case consisting of the levels Criterion 2-Overtraining 1- Overtraining 2. These analyses indicated the main effect of Age to be significant for the five-choice task (i.e., 4- vs. 8-year-olds: $F(1,66) = 6.49$, $p < .025$), while no other effect reached significance. The failure to obtain a significant interaction between Age and Training Level indicates that the suggested age difference in effect of overtraining must be regarded as somewhat tentative at this point, and a replication is currently in preparation to determine the reliability of these effects.

Other analyses of the present data, however, lend credibility to the conclusion that overtraining may have differential effects upon 8- and 12-year-old children's attention. The frequency of subjects who had a perfect score on the color test trials (6 out of 6) was determined for each subgroup given the six-stimulus task, and the frequency observed in the two criterion groups combined was compared with that in the two overtraining groups combined at each of ages 8 and 12. According to a chi-square analysis, these numbers did not differ significantly for the 8-year-olds (4 of 24 and 5 of 24, for criterion and overtraining, respectively); however, at age 12 a significantly greater frequency of perfect color scores were observed in the overtraining groups (14 of 24) than in the criterion groups (4 of 24) ($\chi^2(1) = 8.89$, $p < .01$). (A chi-square analysis based on the frequency of subjects receiving color scores of 4,5 or 6 vs. subjects receiving scores of 0,1,2 or 3 also showed a significant difference between criterion and overtraining groups at age 12--$\chi^2(1) = 4.55$, $p < .05$.) Thus there appears to be at least a tentative basis for the hypothesis that overtraining increases learning of secondary stimulus information for children of age 12 but not for children of age 8.

Other Developmental Differences

For the shape scores, analyses of variance involving the training levels from Criterion 2 to Overtraining 2 yielded an interesting result. For the six-stimulus task, a significant main effect of Age was observed ($F(1,66) = 15.13$, $p < .001$), indicating that the 8-year-olds reached a lower asymptote in their shape scores than did the 12-year-olds (all other effects in these analyses proved nonsignificant). The lower asymptote for the 8-year-olds possibly reflects an incompleteness in these children's attention to shape, even though this component was consistently the primary target of attention, in comparison with the color component. It is also possible, however, that the younger subjects were simply affected by conditions associated with the posttest (e.g., the lack of feedback, possible anxiety over a test) such that they exhibited less recall for information about the shape component than they may have actually acquired. Research in preparation will attempt to identify the relative influence of this last factor.

An age difference involving the 4- and 8-year-olds also deserves mention. In the analyses presented above the difference between 4- and 8-year-olds in color scores proved to be significant for both the precriterion and postcriterion data. This result is consistent with that observed for the component selection task of Experiment 2 and helps to corroborate a major conclusion drawn in that experiment--namely, that 4-year-old children show a greater disposition to attend selectively to a single stimulus component (shape) than do 8-year-olds in a redundant cue situation. This evidence will be discussed further below in terms of the functional utility of redundant information for the older children (see "Conclusions").

Experiment 5: Comparison of Shape and Color as Single Learning Cues

Richardson (1971) has pointed out that the amount of attention a subject directs to each of two stimulus components may be largely a function of the relative difficulty of the two components as cues for learning. Thus, for example, the greater salience of shape than color observed in the earlier experiments of this study could be due primarily to a greater ease of learning associations involving shapes than colors. To test this possibility, subjects in the present experiment were administered one of two learning tasks, in which the stimuli were either white shapes or colored cards. The primary comparison of interest involved the number of trial blocks to criterion on each of these tasks, to determine the relative difficulty of shape and color as learning cues. A task involving both components, identical to the learning phase of the component selection problem, was also included to assess the effects of stimulus redundancy. It has been hypothesized (Bourne & Haygood, 1959; Trabasso & Bower, 1968) that learning becomes easier with an increase in number of redundant relevant components contained in the stimuli, and such an effect has been observed in 10-year-old children's learning of difficult paired-associate tasks (Baumeister & Berry, 1968; Baumeister, Berry, & Forehand, 1969). The two-component task was thus included here to determine whether this facilitative effect of cue redundancy is also characteristic of the present learning situation and whether the magnitude of this effect differs in children from preschool age to preadolescence.

Method

Subjects

A total of 192 children at three age levels were included in this study, averaging 4.5, 8.9, and 12.9 years, respectively. The subjects were drawn from the general population described in Experiment 4.

Task and Materials

The overlapping-age-levels design was used such that children of ages 4 and 8 were compared in performance on five-stimulus problems, while children of ages 8 and 12 were compared on six-stimulus problems. For the Shape Task, all stimuli were white shapes on black cards and for the Color Task they were colored cards; the Redundant Cue Task used colored shapes, as in the standard component selection problem. The particular shapes and colors selected for use in these tasks were the same as those employed in Experiment 4.

The procedure was identical to the learning phase of the component selection measure used in the other experiments, in that the subjects were required to learn the position associated with each of five (or six) stimuli resting against a Plexiglas screen. The criterion of learning in this case was the same as that used for the Criterion 2 group of Experiment 4—i.e., one perfect trial block, followed by two trial blocks in which one error was allowed—and the number of trial blocks required to reach this criterion comprised the major data of the experiment (i.e., the number of trial blocks prior to beginning a criterion run).

Experimental Design

The experiment consisted of four "subsamples": 4- and 8-year-olds given five-stimulus problems and 8- and 12-year-olds given six-choice problems. Within each of the "subsamples," 16 subjects were randomly assigned to each of the three experimental groups, Shape Task, Color Task, and Redundant Cue Task. Each group contained 10 boys and 6 girls and an equal number of subjects given each of (a) two arrays of feedback cards and (b) two orders in which the cue cards were presented. All subjects were tested by one experimenter (S. S. T.).

Results and Discussion

The data for each subgroup of the study are presented in Table 5, and a glance at the scores for the two major groups, the Shape and Color tasks, reveals no striking consistencies. Two analyses of variance were performed on the data for these tasks---one for the five-stimulus problem and one for the six-stimulus problem, with Age and Task (Shape vs. Color) as the two independent variables. These analyses yielded no significant main effects or interactions ($p > .10$), and only for the 4-year-olds, in fact, did the scores suggest the expected superiority of shape over color (this simple effect was not significant, however). It appears, therefore, that the relative difficulty of these two components as independent learning cues may not have played a large role in determining the greater attention to shape than color manifested on the component selection task in other experiments.

Comparisons involving the Redundant Cue Task did not provide general support for the hypothesis regarding the effect of stimulus redundancy, but analyses of variance involving the Shape and Redundant Cue tasks point to the possibility of an age difference in this effect. Separate analyses were conducted for the five- and six-stimulus problems, and the independent variables in each case were Age and Task (Shape vs. Redundant Cue). No effects were found to be significant for the six-stimulus problem, but for the five-choice problem, both the main effect of Age and the interaction between Age and Tasks were significant ($F(1,60) = 5.72$ in both cases; $p < .025$). The Redundant Cue Task was thus learned more slowly than the Shape Task for the 4-year-olds but more rapidly than the Shape Task for the 8-year-olds (the simple effect for the 8-year-olds proved to be significant; $F(1,60) = 4.01$, $p < .05$). Thus, only for the 8-year-old subjects did the addition of redundant stimulus information tend to facilitate learning as hypothesized, as indicated by the significant difference between the Redundant Cue and Shape tasks for the five-stimulus problem, and by a (nonsignificant) difference in the same direction for the six-choice problem.

Tentatively, it might be posited that the hypothesis regarding redundant stimulus information applies only to children of middle childhood; however, there is no obvious reason for the failure to obtain support for this hypothesis at ages both below and above this

Table 5

Mean Trial Blocks to Criterion and Standard Deviation (in Parentheses) for Each Subgroup of Experiment 5 (N=16 per Group)

	Five-stimulus problem		Six-stimulus problem	
Task	Age 4	Age 8	Age 8	Age 12
Shape	5.38 (4.08)	5.38 (4.50)	5.94 (3.87)	4.31 (4.63)
Color	7.63 (4.11)	4.31 (4.09)	4.50 (4.10)	4.88 (4.59)
Redundant Cue	7.31 (4.03)	2.56 (3.16)	4.34 (3.92)	5.63 (3.88)

level. Pending further research relevant to this point, therefore, it will simply be concluded that the facilitative effect of stimulus redundancy apparently is not universal but may depend upon characteristics of the subjects (and task) involved.

Experiment 6: Effects of Overtraining on Attention to Relevant and Irrelevant Components

It was clear from Experiment 4 that overtraining does not have the effect of "broadening" attention for children below age 8; however it remained to be determined whether postcriterion training causes children's attention simply to remain fixed upon the same stimulus features to which attention had been directed in learning or whether attention actually becomes focussed more narrowly during overtraining. Some theorists (e.g., Mackintosh, 1965) have suggested the latter to be the case, and the present experiment was specifically designed to test this notion--that postcriterion training causes children to attend more selectively to a single stimulus component. A new task was devised for this purpose, adapted from ones used in previous research (e.g., Crane & Ross, 1967; Trabasso & Bower, 1968). The task consisted of three phases, an initial learning phase, a redundancy phase, and a posttest. In the learning phase, a single component (shape) was relevant and a second component (color) was irrelevant. In the redundancy phase, the two components were redundant for a fixed number of trials, following which a posttest determined the degree of recall for color information acquired during the redundancy phase. Subjects were trained to criterion on the initial phase of the task and then either shifted immediately to the redundancy phase or given overtraining preceding the shift. It was reasoned that, if the hypothesis regarding "narrowing of attention" were correct, subjects given overtraining on the initial phase of this task should be more likely than criterion-trained subjects to attend selectively to shape and ignore the irrelevant color component at the time the redundancy phase begins. Thus the overtrained subjects should acquire less information about the color component during the redundancy phase, as reflected in lower color recall scores on the posttest, in comparison with criterion-trained subjects. In this manner, the effects of overtraining were examined in children at each of three age levels, 4, 8 and 12 years.

Method

Subjects

The subjects were drawn from third-and seventh-grade classes in a middle-class area of Bucks County, Pa., and from three nursery schools in the same vicinity. The total sample consisted of 35, 72, and 33 children in the three age groups, with mean ages of 4.6, 8.9, and 12.8 years, respectively.

Task and Materials

The shapes and colors described in Experiment 2 were used in this study and two different sets of materials were constructed, differing in the color associated with each shape in the redundancy phase of the task and (for the problem used in the comparison of 4- and 8-year-olds) differing in the specific shapes and color represented.

The basic position-learning format of the Component Selection task was employed in the present measure. To begin the initial phase, the experimenter placed a series of cards containing colored shapes in position against the Plexiglas screen and displayed them for a 5-second period. The experimenter then went through a pile of cue cards, one by one, in each case requiring the subject to indicate the position containing a card like that being shown. The cues were colored shapes as in the Component Selection task, but the two components were not redundant in this case; rather, the color associated with each shape changes from trial to trial. Shape was designated as "relevant" and color "irrelevant," in that the correct position in each instance was determined on the basis of its shape regardless of its color. To indicate this relationship, the feedback given after each response consisted of placing the cue card in the position against the screen which was correct for that shape, behind the cues from previous trials. Thus, unlike the procedure employed in other experiments, piles of cue cards were formed behind each position on the screen, increasing in size as the task progressed.

The subject was trained on this phase until reaching a criterion, defined as in Experiment 2 (two perfect trial blocks in succession, or two perfect blocks with an intervening block containg a single error). After the child had reached this criterion, he was either shifted immediately to the redundancy phase or given six trial blocks of overtraining followed by the redundancy phase. The latter phase in both cases was begun without interruption and thus appeared to the subject to be a continuation of the task. During this redundancy phase, presented for six trial blocks, colored shapes continued to be presented as cues, but the two components were redundant—that is, a given shape was the same color on all trials during this period. Following this phase, a Component Selection test similar to that of earlier experiments was administered, in which the subject was presented a number of cards each containing either a white shape or a color. For each stimulus the subject was told that, during the last few minutes, the shape (color) shown was in the same place on the screen, and he was asked to identify that place. All shapes and colors were presented in the test, intermixed across trials, and shape and color scores were derived for each subject. It was expected, however, that the scores for the relevant shape component would be _maximal_, and thus the data of primary concern were the scores for the color component.

Experimental Design

An overlapping-age-levels design was used, such that 4- and 8-year-olds were compared on a four-stimulus task (a five-choice task with an irrelevant dimension was expected to be too difficult for the 4-year-olds), and 8- and 12-year-olds were compared on a six-stimulus task. Subjects within each of these four resulting "subsamples" were randomly assigned to either of two groups, Criterion or Overtraining, with a final sample of 16 per group, except for the 4-year-old Criterion group, which contained only 15 subjects. Each experimental group (except the last) contained an equal representation of (a) the two sexes (b) two stimulus sets, differing in the color associated with each shape in the redundancy phase and, in the four-choice task, differing in the particular shapes and colors represented (c) two different assignments of shapes to positions (d) two orders in which the cue cards were presented and (e) two orders in which the test cards were presented. All subjects were tested by one experimenter (J.S.G.).

Results and Discussion

The test data for each subgroup of the experiment are presented in Table 6. In general, the differences in color scores between the Criterion and Overtraining groups appear to be relatively small, providing little support for the notion that overtraining tends to narrow one's focus of attention. This impression is confirmed by analyses of variance, which were performed on the color scores with Age and Training Level as independent variables; separate analyses were conducted for the four- and six-stimulus tasks. Neither the Age nor Training Level effect was significant in these analyses, and the interaction between Age and Training Level was also nonsignificant in each case.

Ostensibly, the lack of a training effect here fails to support the position that overtraining narrows one's focus of attention. If the latter were true, the overtraining manipulation in the present experiment would have been expected to reduce children's learning of color information during the redundancy period, as the color component had been irrelevant during the training phase of the task. Another interpretation of the present results is also possible, however. Analyses presented by Mackintosh (1965) and Eimas (1966) have suggested that overtraining should cause a person to ignore irrelevant stimulus features only when those features had initially been his primary object of attention. Under these circumstances alone, it is argued, can training beyond criterion have the effect of decreasing attention to such cues. In other words, when certain cues do not initially elicit much attention, there is little basis for expecting overtraining to cause a further decrease in attention to them. According to this analysis, then, the present experiment may not have utilized conditions most appropriate for obtaining an overtraining effect, as the irrelevant component (color) was not the feature to which these children initially directed the majority of their attention. Clarification of this issue will await research varying subjects' initial attention to relevant and irrelevant stimulus features.

One other aspect of the data in Table 6 deserves mention. While overtraining had no uniform effect on the color scores, as has been discussed, this manipulation did tend to increase the shape scores. According to analyses of variance, this effect was significant for the six-stimulus problem ($F(1,60) = 5.71$, $p < .025$) and approached significance for the five-choice task ($F(1,59) = 3.81$, $p < .10$). The effect in the latter case is primarily attributable to the 8-year-olds, as indicated by a near-significant interaction between Age and Training Level for the five-stimulus problem

Table 6

Mean Shape and Color Scores and Standard Deviations (in Parentheses) for Each Subgroup of Experiment 6

	Four-stimulus problem Age 4	Four-stimulus problem Age 8	Six-stimulus problem Age 8	Six-stimulus problem Age 12
Shape Score				
Criterion	3.80* (.41)	3.56 (.73)	5.75 (.45)	5.63 (.62)
Overtraining	3.81 (.40)	4.00 (.00)	5.88 (.34)	6.00 (.00)
Color Score				
Criterion	2.40 (1.35)	2.19 (1.17)	3.13 (1.96)	2.44 (1.83)
Overtraining	2.06 (.77)	2.31 (1.20)	2.31 (1.92)	2.56 (1.55)

*N = 15 in this group; in all other groups N = 16.

($F(1,59) = 3.28$, $p < .10$). In general, then, overtraining tended to increase the shape-position associations acquired by these children during the learning phase of the task. As discussed in connection with Experiment 4, one effect that overtraining can have is that of allowing additional practice of acquired habits, in a sense helping to "cement" associations learned. This was apparently the case here, as the major effect produced by postcriterion training was simply to improve the children's memory for the position associated with each shape, rather than to alter attention to an irrelevant stimulus component.

Conclusions

General Interpretation of the Results

From the standpoint of the theoretical analyses presented earlier, one of the most significant results of the study involves developmental changes in the degree to which the children exercised component selection. It had been hypothesized that children's tendency to discriminate among stimuli on the basis of a single dimension should increase from preschool age through middle childhood. Evidence derived from the component selection measure of the present study, however, provided little support for this hypothesis; the degree of component selection manifested on this task did not increase with age as expected and, in fact, showed a decrease from ages 4 to 8 (as indicated in Experiments 2 and 4). With stimuli differing in shape and color, then, the inclination to attend selectively to a single stimulus component appears to be actually greater among 4-year-old children than among subjects at higher age levels.

The apparent tendency of the 8-year-old children to exercise a relatively low degree of component selection—that is, to attend to color as well as shape in learning the task—can be interpreted in either of two ways. It is possible that these older subjects differentiated among the stimuli primarily on the basis of shape, as did the youngest subjects, but simultaneously acquired information about color as well. In this case, acquisition of color information could be regarded as a purely "incidental" type of learning, in that it occurred with little active attempt on the part of these children to use color information to help discriminate among the stimuli. On the other hand, these older subjects may have actively utilized information about color as well as shape in learning the task. In this way, the color of each stimulus may have served as a functional cue, in addition to shape, that aided in discriminating the stimuli.

That the latter may be the more accurate interpretation is suggested by other evidence obtained in the study; most critical in this regard are the results of comparisons (in Experiment 2) between the standard component selection task and variations in which the subjects were required to attend selectively to a single component (shape). In the former situation, color and shape were redundant, and color could serve as a functional cue that might aid in differentiating among the stimuli; in this case, as noted above, the older children showed a relatively high degree of attention to color as well as shape, in learning the task. However, under conditions in which it was clearly not to the child's advantage to attend to color—i.e., when attention to shape was required—8-year-olds showed no greater attention to color than did 4-year-olds. It would appear, then, that the older children were able to recognize those conditions under which attention to a secondary component would be useful and those under which it could not be functional for learning. These children's relatively high color scores in the component selection task, then, likely reflect an active utilization of color information in learning rather than a passive, "incidental" acquisition of such information.

Evidence from Experiment 4 provides an even more complete picture of the manner in which children employ selective attention in learning. This experiment, which examined children's component selection at varying levels of training, was partly intended to assess the validity of a recent hypothesis regarding changes in attention across stages of learning (James & Greeno, 1967). The results suggest that the James and Greeno analysis may not be accurate for children of age 8 and below in that these subjects' attention did not become more selective prior to reaching criterion, as predicted, but remained directed to the color as well as the shape component of the stimuli (although to a greater degree for the 8-year-olds than the 4-year-olds). Further, these children did not show the expected "broadening of attention" with overtraining, as they acquired little information about the secondary color component beyond the point at which criterion had been reached. These results contrast with those for the 12-year-olds, whose behavior more nearly approached that specified in the James and Greeno model. These older subjects continued to acquire information about the secondary stimulus component, color, after the task had been learned, in contrast with the younger subjects' failure to show additional stimulus learning with overtraining. These apparent age differences indicate the necessity for a comprehensive model that takes into account not only the effects of training level upon attention but developmental changes in these effects as well. The groundwork for such a model is provided in the following summary interpretation of the present results.

A major developmental change in selective attention <u>between preschool age and middle childhood</u> apparently involves an increase in the tendency to utilize redundant stimulus information. As children mature during this period, they begin to perceive the advantage of attending to redundant information to facilitate learning. Thus, they show increasingly greater attention to secondary stimulus components as well as features to which their attention is primarily directed, to aid in differentiating among stimuli. The manner in which attention is employed through the course of learning, however, does not change markedly during this age period. For children of both preschool age and middle childhood, attention to secondary stimulus components is greatest prior to the point at which learning has occurred. Training beyond criterion tends to produce no further increase in attention to a secondary stimulus component but may simply cause these children to maintain attention to whatever stimulus information was functional in learning the task. <u>By the time they reach preadolescence</u>, on the other hand, children may respond to overtraining in a somewhat different manner, in that they direct their attention to secondary as well as primary stimulus components beyond the point at which learning takes place. In contrast with the younger children, then, preadolescent subjects "attend broadly" through a period of overtraining and continue to acquire information about stimulus features other than those that were functional in learning the task.

Implications for Models of Learning and Instruction

The evidence obtained in this study has several practical implications. First of all, preschool children apparently can attend selectively to a component feature of learning materials and manifest a disposition to do so. Thus, the "effective cue" in a learning task for these children is not a global combination of components, as has been implied by some theories, but may be a single feature of the stimuli. The practical significance of this result can be viewed as positive in some respects and negative in others. On the positive side, it is encouraging to find that young children are not so bound by a tendency to perceive stimulus objects as global wholes that they are unable to attend to a single component of such objects. Acceptance of the theory that preschool children perceive objects globally would have implied the necessity for devising elaborate techniques to teach these children how to attend selectively. However, if it is true that children at 4 years of age already possess such an ability, then procedures for training selective attention may not actually be needed at this age level.

On the negative side, it is clear that these preschool subjects are less likely than older children to benefit from the inclusion of redundant information in learning materials. Young children apparently cannot be expected to acquire stimulus information other than that which is functional for them in learning a task. Rather, these children likely concentrate upon acquiring the specific habits which a task requires them to learn (such as the position associations of the present study), with attention directed only to those features of the stimuli that avail for this purpose. Thus, if it is desired that children acquire information about several different aspects of the stimuli in a learning task, for the young child it may be necessary to direct his attention specifically to each aspect, so that he may acquire information about each component in turn.

This last point bears upon an instructional device that relies on the use of redundant stimulus information as, for example, in the teaching of discriminations among letters or words (e.g., Gattegno & Hinman, 1966). An example of the technique would be to select letters whose differentiating features are difficult to detect--such as lower-case "b" and "d," which differ in orientation--and present these letters with added redundant cues, so that they differ in features such as color or size as well as orientation. The child presumably attends initially to the color and size cues, and the orientation of the letters is a "nonattended" component which it is hoped the child will gradually come to recognize. Although such a technique could conceivably be useful in some circumstances, the results of the present research suggest that it would likely be ineffective for the prereading child. This study has shown that young children do not orient to several redundant features of stimulus objects but maintain attention to a single component. Thus, these children would likely maintain attention to the irrelevant features (size, color, etc.) of the letters, rather than gradually shift their attention to the difficult-to-detect orientation difference. It is proposed that the more effective techniques for teaching discriminations to young children are ones in which the materials contain only the critical dimension(s) of difference, without other information that might divert the children's attention away from the critical features to be learned.

While redundant cue teaching techniques thus are believed ineffective for young children, the present results suggest that some method of employing redundant information in learning materials may have some merit for children of middle childhood and beyond. These older children attend to redundant information to a greater extent, as indicated by their relatively high degree of attention to the secondary stimulus component (color) as well as the more salient feature (shape) in the component selection task of the present study. Apparently, these children actively utilize redundant stimulus information when it is a useful aid for learning, yet are able to ignore it when it is not functional. Therefore, teaching techniques that rely on the child to attend to several features of the stimulus materials are likely to be more effective for the child of age 8 than for the preschool child. For the older child, it is possible to present stimulus materials differing in several redundant attributes, and a considerable amount of stimulus information will be learned, with relatively little necessity for directing the child's attention to each aspect individually. At the same time, it is possible to make use of these children's ability to attend selectively, by indicating those stimulus features that are critical and those that are incidental. In general, children of age 8 appear to be more flexible in their employment of selective attention than preschoolers and presumably more amenable to teaching techniques that rely on manipulation of attention.

The evidence obtained in this research further suggests that redundant-cue teaching techniques will not become more effective for preschool children when used in connection with overtraining. It might have seemed reasonable to expect that, with training beyond a hypothetical point of mastery, a child would "have more attention available" and thus acquire additional stimulus information, since maintenance of learned habits presumably requires less attention than does the original acquisition of these habits. Such does not appear to be the case for children below middle childhood, however; even with a considerable amount of overtraining, the 4- and 8-year-old children in the present study learned no more about the stimuli than they had already acquired during the learning phase (Experiment 4). While the study provides no evidence that overtraining actually "narrows" one's focus of attention (Experiment 6), neither is it true that overtraining can be relied upon to "broaden" young children's focus of attention. Most likely, extended training for these children simply causes them to continue practicing the specific habits acquired during learning, with attention continuing to be directed to those stimulus features that were functional in learning the task.

It is proposed that only past middle childhood are children able to benefit from overtraining as an instructional device to influence learning of stimulus information. In the present study, the 12-year-olds, but not the 4- and 8-year-olds, acquired secondary (color) information beyond the point at which they had reached a criterion of learning. Perhaps children of preadolescent age and older will actively utilize an overtraining period to learn additional information about the stimulus materials while younger children, as suggested above, simply use such a period to practice specific habits developed prior to reaching criterion.

The present study has provided some insights into the development of selective attention in children, and continued research on this topic will hopefully help to answer some of the many questions that remain. Among its activities this research will seek to establish the generality of the conclusions drawn here and to discover training techniques that are most effective in influencing children's attention.

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