The tendency to choose an optional intradimensional (ID) and extradimensional (ED) shift was investigated at five developmental levels: preschool, kindergarten, second grade, sixth grade, and college. Over this range, a significantly increasing trend to select an ID shift and a significantly decreasing trend to choose an ED shift were observed. ID Ss when compared to ED Ss exhibited higher IQ's and learned both the initial and shift discriminations more rapidly. A comparison between the present optional ID–ED study and a previous optional reversal–ED experiment revealed that the ontogenetic changes are similar. The results are interpreted to be consistent with the coordinated single-unit and mediational S–R formulation.

According to the developmental mediational theory (Kendler, 1971; Kendler & Kendler, 1962, 1968), ontogenetic changes in reversal (R) and extradimensional (ED) shift behavior reflect a transition from a single-unit mechanism in which responses are under direct control of external stimulation to a mediational mechanism in which behavior is controlled by self-generated symbolic cues that represent conceptual categories. Evidence in favor of this formulation comes from developmental studies that show that with age the relative ease of executing an R shift in comparison to an ED shift increases (Tighe & Tighe, 1967) and that the choice of an optional R increases in comparison to an optional ED shift (Kendler & Kendler, 1970; Kendler, Kendler, & Learnard, 1962).

Although Campione (1970) does not question the developmental data just cited, he suggests that other evidence denies the necessity of postulating two modes of behavior. First, Campione cites the inconsistency in experimental results concerning the relative ease with which preschoolers execute an R or an ED shift as being at odds with Kendler's formulation. Whereas Kendler, Kendler, and Wells (1960) find that preschoolers solve ED more easily than R shifts, other researchers (Dickerson, 1966; Mumbauer & Odom, 1967) report the opposite finding. But evidence about a single-age level, by itself, is irrelevant to the proposition that R shifts, with increasing age, tend to become relatively easier than ED shifts. Because variables other than age influence discrimination-shift behavior (e.g., Kendler, Kendler, & Sanders, 1967), one cannot assume that at a specific age level, such as 4 or 5 yr., an ED shift should always be executed more rapidly than an R shift. Developmental changes, not behavior at a fixed age level, are the significant data for the developmental mediational theory.

Second, Campione (1970) suggests that the comparison between intradimensional (ID) and ED shifts is as, if not more, important than the R–ED comparison in evaluating theories of discrimination-shift behavior. Thus he cites as inconsistent with the Kendlers’ two-process theory the findings from several independent experiments that ID shifts are easier to execute than ED shifts for rats (Shepp & Eimas, 1964), preschool children (Dickerson, 1966; Mumbauer & Odom, 1967), and adults (Kurtz, 1955). In order to determine whether the presumed superiority of ID over ED shifts for all ages and species extends to an optional-shift design, Cam-
pione compared the behavior of preschool with second-grade children in choosing either an optional ID or ED shift. He found no significant difference; approximately 65% of each group selected an ID shift. The conclusion drawn was that the data are "inconsistent with the notion that there exists an ontogeny of shift behavior [Campione, 1970, p. 299]."

In responding to the second point, the position can be maintained that the ID–ED comparison is not intrinsically superior to the R–ED comparison in reflecting ontogenetic changes. Each comparison, ID–ED and R–ED, emerges from a different theoretical position and thus requires different experimental controls. The ID–ED serves the needs of the mediational attention theory (Zeaman & House, 1963) because it reflects the operation of preshift attending responses presumably uninfluenced by previously learned choice responses. In contrast, the R–ED comparison, in which the discriminanda remain unchanged from preshift to postshift training, possess two advantages over the ID–ED paradigm for the Kendlers' dual-stage theory. First, complex stimulus generalization effects inherent in the ID–ED design and which cannot be simply controlled by counterbalancing, are avoided. Second, the persistence of preshift mediated representational responses to postshift training cannot be impeded by the sudden occurrence of novel discriminanda as is the case in the ID–ED comparison.

In the last analysis, however, an adequate explanation of the ontogeny of discrimination-shift behavior must account for results from both experimental paradigms. In spite of Campione's (1970) results, reservations can still be expressed about his conclusion that developmental changes in optional ID–ED choices do not occur. In addition to the logical problem of proving the null hypothesis is the more serious empirical problem of demonstrating a developmental relationship based on only two points. To evaluate the last criticism, the present experiment was designed to discover whether a sampling of five age groups, ranging from 4½ to 20 yr., would fail to reveal any developmental changes in optional ID and ED choices.

**METHOD**

**Subjects.**—A total of 163 Ss were used divided among five age levels that approximated a geometric progression: mean chronological ages (CA's) of 54.4, 70.7, 94.0, 139.9, and 229.7 mo. These age points were selected to duplicate those used in other developmental studies that employed the optional-shift paradigm (Campione, 1970; Kendler & Kendler, 1970). The lowest age group, the preschool children, were from a private nursery school in an upper-middle-class community, Montecito, California. The next three age levels, kindergartners, second, and sixth graders, were drawn from a public elementary school in a middle-class neighborhood in Goleta, California. The oldest group were college students from an introductory psychology course at University of California, Santa Barbara, who served to meet course requirements. Three Ss were eliminated from the kindergarten group, 1 because absence prevented completion of the experimental task, and 2 were randomly eliminated from the data analysis because both Es inadvertently ran 2 Ss from the same cell.

**Experimental design.**—The optional-shift procedure (Kendler & Kendler, 1970), adapted to a comparison between ID and ED shifts (Campione, 1970), was used. Table 1 illustrates the procedure. In the initial discrimination, S is confronted with a two-choice discrimination between two pairs of stimulus compounds that vary on two dimensions, form and color, with one (e.g., form) relevant and the other (e.g., color) irrelevant. After reaching criterion, S enters the second phase, the shift discrimination, where he learns to discriminate between a new pair of stimulus compounds that vary on the same two dimensions but with new values for each. Both dimensions are now relevant and redundant. After learning to select the correct compound consistently, S is shifted immediately to the test series which is designed to discover on what basis the shift discrimination was solved. In the test pair of the third phase, the previously redundant and correct cues, for example, blue and square in Fig. 1, are re-paired and the consistent choice of square indicates an ID choice because the relevant dimension in the initial discrimination was form. The consistent choice of the blue indicates an ED choice. Interspersed between the presentation of the test pair are trials with the relearning pair that continue to be reinforced as in the shift discrimination.

Two sets of stimulus compounds were used that varied in color and form: one with color values of red and green and form values of circle and triangle, and the other with color values of blue and yellow and form values of square and cross. Each S learned the initial discrimination with one set and the subsequent shift discrimination and test series with the other. A completely counterbalanced
replication required 32 Ss, eight possible (four colors and four forms) positive values in the initial discrimination and four possible positive stimulus compounds during the shift discrimination. Within each age level, each S was assigned randomly to 1 of the 32 conditions. The total design was analyzed as a $5 \times 2$ factorial; 5 age levels and 2 relevant dimensions.

**Apparatus.**—The apparatus, described in detail elsewhere (Kendler & Kendler, 1970), had a display unit containing two windows through which the stimulus compounds were presented, a start platform, and a well in which marbles could be dispensed. The S initiated all trials while response choices were recorded automatically, thus minimizing direct E-S interactions after the initial instructions.

**Procedure.**—The Peabody Picture Vocabulary Test Form A (Dunn, 1959) was first administered to all Ss except the college students, and then the following instructions were communicated:

In this game you try to win as many marbles as you can. This is how we play. Do you see these two windows? [E points to the two stimulus display windows]. When we are ready they will light up and you will see a design in each window. If you push one of the windows lightly [E demonstrates], a marble will come out here [E points to marble well]. Which window you press depends on the design. At first you have to guess which design to press but after the first guesses you should learn which design will get a marble every time. Sometimes the design you must press to get a marble will be in this window [E points to the left window]. And sometimes it will be in this one [E points to the right window]. When this platform lights up, push it [E demonstrates] and then use the same hand to choose this one or this one [E points to windows].

The preschoolers were assisted through the motion of pushing first the start platform, then one window. On all trials, S discriminated between two stimulus compounds that differed both in color and form. Each discriminandum appeared equally often in every block of 12 trials. The number of possible correct successive responses to one position (left or right) did not exceed three. A modified correction procedure was used so that a discriminandum to which an incorrect response was made was repeated on the next trial.

The criterion of learning was 10 successive correct responses. On the initial discrimination, S was run to criterion or until the first error after 100 trials, in which case training was terminated and continued on the next day that S was available. Intermittent of this sort occurred only during the initial discrimination. Immediately after the criterion was achieved on the initial discrimination, the shift discrimination began. Criterion was again 10 successive correct choices and was followed immediately by the test series. During the test series either choice on the test pair was rewarded, while responses to the relearning pair were rewarded as in the shift discrimination. The S was presented with 10 test trials with relearning trials interspersed, the number of which varied from 8 to 12 depending on what part of the program the test series began. If S made ID choices on 8 or more of the 10 test trials, he was classified as an ID S. An ED S made 8 or more ED choices, while failure to make 8 or more consistent responses produced an inconsistent classification, I S.

**RESULTS AND DISCUSSION**

The CA and IQ scores, at each developmental level, are presented in Table 1. A $4 \times 2$ (Developmental Levels X Relevant Dimensions) analysis of variance of IQ scores revealed no significant differences between ages ($F < 1$), relevant dimensions ($F < 1$), or the interaction between them ($F < 1$). One-way analyses of variance performed at each age level on CA and IQ scores failed to yield any significant
Table 1

CHRONOLOGICAL AGE AND INTELLIGENCE QUOTIENT
SCORES FOR EACH DEVELOPMENTAL GROUP

<table>
<thead>
<tr>
<th>Group</th>
<th>CA (mo.)</th>
<th>IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Preschool</td>
<td>54.5</td>
<td>3.1</td>
</tr>
<tr>
<td>Kindergarten</td>
<td>70.7</td>
<td>3.6</td>
</tr>
<tr>
<td>Second grade</td>
<td>94.0</td>
<td>4.2</td>
</tr>
<tr>
<td>Sixth grade</td>
<td>139.9</td>
<td>5.8</td>
</tr>
<tr>
<td>College</td>
<td>229.7</td>
<td>15.2</td>
</tr>
</tbody>
</table>

Table 2 presents the mean number of trials to reach the criterion on the initial discrimination for each relevant dimension at each age level. The raw scores were subjected to a square-root transformation to correct for unequal variances and then submitted to a 5 x 2 analysis of variance. Significant differences were obtained between ages, \( F(4, 150) = 37.21, p < .01 \); between dimensions, \( F(1, 150) = 16.03, p < .01 \); and from the Age x Dimension interaction, \( F(4, 150) = 2.89, p < .05 \); the last effect resulting from the decreasing difference between color and form scores as age increases.

The age component was subjected to a trend test which produced both significant linear and quadratic components: \( F(1, 150) = 134.19, p < .01 \), and \( F(1, 150) = 105.5, p < .05 \), respectively.

Table 3 reports the mean number of trials to reach the criterion on the shift discrimination for each relevant dimension at each age level. An analysis of variance of the square-root transformed scores yielded only one significant difference, the age variable, \( F(4, 150) = 8.12, p < .01 \). The age component was subjected to trend tests and again both linear and quadratic components proved significant, \( F(1, 150) = 26.54, p < .01 \), and \( F(1, 150) = 5.50, p < .05 \), respectively.

Table 4 reports the proportion of Ss at each age group, for each relevant dimension, who responded in an ID, ED, or I manner while Fig. 2 graphically represents the combined results. These data were subjected to the L test for linear ranks (Page, 1963) with color and form dimension serving as replications. A significant increasing trend of ID Ss \( (L = 109, p < .001) \) and significant decreasing trends for ED Ss \( (L = 105.0, p < .05) \) and I-Ss \( (L = 105.5, p < .05) \) were found.

Table 5 reports the learning scores of the ID, ED, and I Ss for the initial and shift...
discriminations. For both training tasks, the ID Ss learned more rapidly than did the ED Ss for all five age groups, the chance probability of either occurrence being less than .05. The performance of the I Ss during the initial discrimination was not significantly different from the ID or ED Ss. The ID Ss, however, learned the shift discrimination more rapidly than did the I Ss both at the preschool and kindergarten levels; $t (21) = 1.98, p < .05$, and $t (23) = 3.27, p < .01$, respectively. The differences between ED and I Ss at these two levels were not significant.

The mean IQs of the ID Ss at each age level from preschool to sixth grade (114, 109, 112, 110) exceeded those of the ED Ss (113, 107, 105, 101) at each age level and was also higher than the I Ss (110, 103) at the two age levels, preschool and kindergarten, at which they were represented. The mean IQ of all ID Ss (111.1) was significantly different than the mean IQ of ED Ss (107.5), $t (113) = 2.56, p < .01$.

Comparison between present results and those of Campione (1970).—A chi-square analysis of preschool and second-grade Ss classified as ID, ED, and I in this experiment produced a significant difference, $x^2 (2) = 12.5, p < .01$. An analysis of variance of the number of ID choices during the test series for these two groups also resulted in a significant age effect, $F (1, 60) = 6.21, p < .05$. Thus those comparisons between preschool and second grade which failed to produce significant differences in Campione's study were found to be significant in the present study. However, neither of the individual comparisons between the same age groups from the two studies proved to be significant below the .05 level. In Campione's study, 63% of the preschool Ss and 65% of second graders responded in an ID manner, while 45% and 84% Ss in this study behaved similarly.

One possible reason for the discrepancy between the two studies is the difference in procedure used during the initial discrimination phase. Whereas in the present study all Ss received the conventional discrimination training procedure, a special technique was used for slow learners in Campione's (1970) study. On the first error following the twentieth trial, S was shown all four stimuli, with the pair of positive stimuli separated from the pair of negative stimuli, and was told which of the two pairs of stimuli yielded a reinforcement (a marble) and which pair did not. The slow learners who received special training in Campione's study exhibited the same percentage of ID Ss as did the fast learners. In the present study, in the absence of any special training techniques, the slow learners at the preschool level, as defined by the criterion Campione used, made significantly fewer ID shifts than did the fast learners; 31% compared to 83%. A similar difference did not occur among

<table>
<thead>
<tr>
<th>Group</th>
<th>Initial discrimination</th>
<th>Shift discrimination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ID Ss</td>
<td>ED Ss</td>
</tr>
<tr>
<td>Preschool</td>
<td>193</td>
<td>194.7</td>
</tr>
<tr>
<td>Kindergarten</td>
<td>51.9</td>
<td>73.3</td>
</tr>
<tr>
<td>Second grade</td>
<td>19.7</td>
<td>35.8</td>
</tr>
<tr>
<td>Sixth grade</td>
<td>12.2</td>
<td>28.0</td>
</tr>
<tr>
<td>College</td>
<td>6.3</td>
<td>18.0</td>
</tr>
</tbody>
</table>
the second graders. Perhaps Campione's special training technique elevated the percentage of ID Ss among his preschoolers. Consistent with this possibility is the recent finding that displaying the discriminanda simultaneously facilitates reversal learning in kindergartners presumably because it encourages conceptual classification (Kendler & Ward, 1971). The elevation of the percentage of ID Ss among preschoolers combined with a chance-determined low percentage of ID Ss among 20 second graders may account for Campione's failure to find a significant difference between his two age groups.

Comparison between optional ID and R shifts.—In both the present and previous study (Kendler & Kendler, 1970) the same number of Ss and age groups (32 in each of five age groups), apparatus, procedure, and stimulus compounds from the same dimensions were used.

Of major importance is the effect of the two paradigms on the type of shift chosen by Ss during the test trials. In an analysis of variance of the number of ID or R choices, the only significant result was produced by age, $F(4, 310) = 7.97$, $p < .01$; the difference between the studies was nonsignificant, $F < 1$. Figure 3 shows the proportion of Ss in each study that chose the various kinds of optional shifts. Consistent with the apparent similarity of the graphical results are the nonsignificant results of the chi-square analyses of the differences between the frequencies of ID and R, ED, and I choices in the two studies.

The two studies also did not vary in the performance during the initial discrimination. An analysis of variance of the square-root transformation of the number of trials to reach the criterion of learning in the initial discrimination yielded a significant age effect, as expected, $F(4, 310) = 52.98$, $p < .01$, but no difference between the two studies, $F < 1$. The same analysis performed on the results of the shift discrimination, however, produced both a significant age effect, $F(4, 310) = 45.5$, $p < .01$, and a significant difference between studies, $F(1, 310) = 222.3$, $p < .01$. The interaction was also significant, $F(4, 310) = 7.9$, $p < .01$, resulting from a decreasing difference between studies as age increases. At all age levels, the shift discrimination was learned more slowly in the R-ED procedure than in the ID-ED paradigm; the differences for the lowest four age levels being significant beyond the .01 level, while the difference for the college Ss was significant beyond the .05 level. One reason for these differences is that in the R-ED procedure the stimulus compounds are unchanged when the reinforcement contingencies are switched from the initial to the shift discrimination thus producing perseverative errors. In contrast, the stimulus compounds in the ID-ED procedure are changed to new dimensional values and as a result half of the Ss by chance should make a correct response on the first trial of the shift discrimination.

The greater probability of making an error on the first trial of the shift discrimination by the R-ED Ss, or their tendency to perseverate in making the error, cannot, however, explain entirely the slower learning by these Ss when compared to the ID-ED Ss. When the performances of the
two groups are compared in the learning of the shift discrimination from the point of making the first correct response, the analysis of variance of transformed scores results in a significant study effect, $F(1, 310) = 75.35, p < .01$, age effect, $F(4, 310) = 32.80, p < .01$, and interaction effect, $F(4, 310) = 5.85, p < .05$. At each age level, except the college 5s, the R-ED 5s made significantly more errors, $p < .01$.

CONCLUSION

The present results offer strong support to the notion that ontogenetic changes occur in the tendency for humans to prefer an ID over an ED choice in an optional discrimination-shift paradigm. This empirical generalization applies to the wide age range between 4½ and 21 yr. as well as to the narrow span between 4½ and 8 yr., the two points between which Champione (1970) failed to observe any change. In addition, the results suggest that the ID-ED ontogeny is similar to the R-ED ontogeny (Kendler & Kendler, 1970).

If one assumes that ID choices reflect the operation of a mediational response, then the present data support the conclusion that mediation increases with age. Such a conclusion is at odds with Campione's (1970) assumption that the probability of a child's learning a mediational response remains constant over the age range he tested, and by implication, over the more extended span used in this study. Campione, it should be noted, conceives of mediation as a "response of attending to some dimension of the discriminanda." In contrast the Kendlers postulate the mediational mechanism to be conceptual, not perceptual; the ontogenetic changes observed in the present experiment, as was the case for the similar relationship found with R-ED shifts, reflect the transition from a single-unit continuity mechanism (Kendler, Basden, & Bruckner, 1970; Spence, 1936) to a mediational mechanism with which $S$'s capacity to classify and represent related stimuli is increased.

A mediational interpretation that emphasizes encoding processes gains support from the results of a developmental study in which pictures of conceptual instances (e.g., apple, banana; shirt, pants) were substituted for two-dimensional geometrical patterns (Kendler & Kendler, 1970; Kendler et al., 1962) and to the optional ID-ED ontogenetic relationship obtained in the present study.

The present results suggest that the introduction of the new discriminanda, which distinguishes the ID-ED procedure from the R-ED comparison, does not seem to have much influence on the ontogeny of optional-shift behavior if ID and R choices are considered to be functionally equivalent.

Although the R-ED and ID-ED procedures produce similar results on the test trials, the former generates considerably slower learning during the shift discrimination even when the number of errors during the shift discrimination is limited to those made after the first correct response. The conclusion is that the R-ED procedure produces more negative transfer effects from the initial to the shift discrimination and that these effects are distributed throughout the entire shift-discrimination trials. This finding is not surprising considering the fact that the shift-discrimination task requires $S$s in the R-ED procedure, unlike those in the ID-ED paradigm, to respond to a pair of stimuli in a manner opposite to that which was previously required during the initial discrimination.

The negative transfer effects from the initial discrimination to the shift discrimination are not distributed equally among the three choice groups in either of the two experimental paradigms. The R and ID 5s exhibit fewer errors than the ED and I 5s because the former transfer their common mediational representational response from the initial to the shift discrimination. Thus, the pattern of errors during the shift discrimination as well as developmental changes in optional choice responses in both the R-ED and ID-ED paradigms, are consistent with the coordinated single-unit and mediational theory (Kendler & Kendler, 1970).

REFERENCES


(Received November 22, 1971)