Separable and Integral Responding by Children and Adults to the Dimensions of Length and Density

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WARD, Thomas B. Separable and Integral Responding by Children and Adults to the Dimensions of Length and Density. Child Development, 1980, 51, 676–684. The classifying behavior of 5-year-old children and adults was examined in 2 studies of restricted classification using triads of stimuli composed of the dimensions of length and density. Subjects could classify on the basis of dimensional structure, overall similarity, or neither. Adults showed a majority of dimensionally based responses, while children gave a majority of similarity-based responses in experiment 1. This pattern is consistent with the notion of separable perception for adults and integral perception for children. The results of a pretask for experiment 2 in which subjects were required to make dimensional comparisons indicate that children’s integral responding is not based on an inability to access dimensional relations. The results are discussed in terms of possible strategic differences underlying separable and integral responding.

Garner (1974) has elaborated a distinction between separable and integral dimensions. Integral dimensions (e.g., value and chroma in the Munsell classification) combine in such a way that they are perceived as unitary, whereas separable dimensions (e.g., size and brightness) combine in such a way that the levels on each dimension are perceived as isolated (Garner 1974).

Operationally, these dimensions are differentiated by performance in a variety of tasks (e.g., speeded sorting and similarity scaling). Of most direct interest to the present studies are restricted classification tasks (e.g., Smith & Kemler 1977) in which subjects are presented with three or four stimuli composed from different levels on two dimensions and are instructed to put together the stimuli which “go together.” The stimulus triads or tetrads are constructed so that stimuli may be grouped together on the basis of overall similarity or dimensional structure. As an example of such a triad, stimuli A and B could share a level on dimension X and differ substantially on dimension Y. Stimulus C could differ from stimulus A by a small amount on both dimensions, with the overall similarity between A and C being greater than that between A and B. In this situation, subjects could use overall similarity and group A and C together (similarity response), they could use the dimensional structure and group A and B together (dimensional response), or they could use neither structure and group B and C together (haphazard response). One basic result from such studies is that adult subjects tend to classify separable dimensions according to a dimensional structure and integral dimensions according to overall similarity (Garner 1974).

Several investigators have made use of Garner’s separable-integral distinction in examining developmental changes in separability. Data from speeded sorting (Shepp & Swartz 1976) and restricted classification (Smith & Kemler 1977; Shepp, Burns, & McDonough, Note 1) tasks seem to indicate that young children respond in an integral fashion to dimensions which are separable for adults. The tendency of young children to treat separable dimensions as integral can have implications for many areas of developmental research. For example, since the ability to selectively attend to integral dimensions is limited (Garner 1974), children’s integral treatment of separable dimensions could put limits on their attentional abilities. Thus the well-established trend to-

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ward increased selectivity of attention with increasing age could be based, in part, on a shift toward more separable modes of perceiving, in addition to any change that results from an improvement in the attentional process itself.

Despite its potential importance for other developmental trends, and despite recent research, the basis of young children's integral responding is not well established. Two interpretations of children's "integral" responding to separable dimensions are possible. Integral responding may be based either on lack of knowledge about or access to the dimensional structure of the stimuli or on a tendency not to employ that information even though children have access to it. According to the former interpretation, young children have a basic perceptual limitation which prevents them from accessing or processing the component dimensions of a stimulus independently of one another. For example, at a young age, children may not yet have differentiated the perceptual world into its component dimensions through the process of perceptual learning (see, e.g., Gibson 1969). Only after such learning had taken place could they use the dimensions separately. According to the latter interpretation, young children have already differentiated, or can differentiate, component dimensions but do not employ that dimensional information in experimental tasks. Shepp's (1978) separability hypothesis seems more in line with the first interpretation, and Shepp et al. (Note 1) extended this position by suggesting that there is a transitional period between 6 and 8 years of age during which knowledge about dimensions develops. Kemler and Smith (1978) and Smith and Kemler (1978), on the other hand, have reported data which support the notion that, as early as kindergarten age, children do have access to the dimensional structure of at least some stimuli.

The present studies were designed to examine developmental changes in the separability-integrality of the dimensions of line length and density using a restricted classification task, and to determine whether children even younger than those tested by Smith and Kemler (1978), despite their integral-type (i.e., similarity-based) responding to such dimensions, do have access to the dimensional structure of the length-density stimuli.

Although the interest in the present study was in the dimensions of length and density, it should be noted that a third dimension, number, results from the combination of those two dimensions. In fact, much of our knowledge of children's number processing is based on studies employing length-density stimuli (e.g., Brainard 1977; Gelman 1972; Smith & Reese 1974). Because of the extensive use of the dimensions of length and density in studies of number-processing development, it is important to understand how children perceive those dimensions independently of whether they are asked to make number judgments in a given task. Consider, for example, the implications of finding that children perceive length and density as integral and are unable to access the dimensional structure of length-density stimuli. Since, as noted above, independent processing of the component dimensions of integral stimuli is difficult, such a finding would pose a problem for models of children's number processing which involve responses based on one dimension (e.g., length) to the exclusion of the other (see, e.g., Gelman 1972; Smith et al. 1974) or models directed to the independent assessment and additive integration of those two cues (Cuneo, Note 2).

The fact that length and density combine to form the number dimension also raises a methodological concern for the present study. To the degree that individuals process the present stimuli in terms of number, developmental changes in number processing could influence the results obtained. Previous data (Ward, Notes 3 and 4) indicate little tendency for subjects to use number as a basis for classification in the present task. Nevertheless, a control condition was implemented to assess the degree of number-based responding.

**Experiment 1**

In addition to providing a comparison of the responses of younger and older subjects on dimensions not previously employed (e.g., Shepp & Swartz 1976; Smith & Kemler 1977), the first experiment involved two further refinements. First, subjects' responses were analyzed on a trial-by-trial basis in order to assess any changes in responses due to experience in the task. If subjects discover anything about the dimensional structure of the stimuli during the course of the experiment, they might be expected, from Gibson's view of perceptual learning, to show an increase in dimensional responses over trials.

The second refinement involved attention to the effects of the stimulus arrangement on responding. Two arrangements were used which were expected to differ in terms of the ease of comparing items along particular dimensions.
Presumably, the more readily items can be compared along particular dimensions, the more likely those dimensions are to be used as bases for classification. For example, if the lines of varying length and density were depicted horizontally, comparisons of the items along the dimensions of length and density would be easier if the items were centered one above the other in a column than if they were placed next to one another in a horizontal row.

The separability hypothesis predicts that children will give fewer dimensional responses than adults. In addition, according to the notions of flexibility in perceived structure as discussed by Shepp (1978), it can be predicted that children will be less affected than adults by the stimulus manipulation. That is, adults should be more likely to change their patterns of classifying in response to changes in task situations. Finally, assuming that it is useful to consider a shift toward dimensional responding as a measure of some aspect of learning about dimensions, it can be predicted that children will be less likely than adults to show such a shift.

Method

Stimuli.—Triads of stimuli were chosen for the restricted classification task from a set of 20 stimuli representing the combinations of five levels of length and four levels of density. The lengths were 1, 2, 3, 4, and 8 cm. The densities in terms of interdot distance were 1, 0.5, 0.25, and 0.125 cm. The dots were “periods” typed with a Remington Automatic typewriter. Ten triads were selected from this set on the basis of data from adult similarity-scaling studies (Ward, Note 3). Triads were chosen in which two members shared a level on one dimension while differing substantially on the other (dimension pairs) and a third member differed slightly from one of the others on both dimensions (similarity pairs), with adults rating the similarity pairs as more similar than the dimension pairs. No pair of stimuli appeared in more than one chosen triad. For five of the chosen triads, the dimension on which the dimension pair shared a level was length, while for the other five, the dimension was density.

All three members of a particular triad were depicted on a single, plain white 7.6 × 12.7-cm index card or on a sheet of white paper cut to 7.6 × 27.9 cm. For the triads presented on a sheet of white paper (linear condition), the individual stimuli were depicted horizontally and arranged next to one another at the same height on the sheet to form a row. Three examples of each of the 10 triads were constructed so that each triad member appeared once in each position (left, middle, or right of the sheet), and each response type (dimensional, similarity, or haphazard) appeared once in each possible combination (left middle, left right, and middle right) of positions. For the triads presented on the index cards (columnar condition), the individual stimuli were also depicted horizontally, but they were centered one above the other on the cards. Each triad member appeared once in each position, and each response type appeared once in each possible combination of positions. It was expected that the columnar arrangement would facilitate dimensional comparisons and therefore lead to higher levels of dimensional responding.

Subjects.—The subjects were 24 undergraduates (9 males and 15 females) enrolled in introductory psychology courses at the University of Wisconsin and 16 children (nine males and seven females), between the ages of 4-1 and 6-3 (mean = 5-2), recruited from day-care centers serving middle-class areas in Madison, Wisconsin. All children were white.

Procedure.—The subjects were tested individually in a well-lighted room. They sat across a small table from the experimenter, who presented the triads one at a time by placing the card or sheet of paper containing a given triad on the table. Each of the 10 triads was presented three times (trials) for a total of 30 presentations. The order of triad presentation was randomized, with the restriction that no triad and no individual item appear on two consecutive trials. One random order was used for half of the subjects and the reverse was used for the other half.

For adults, the top, middle, and bottom (or left, middle, and right) positions on the cards (sheets) were assigned the labels a, b, and c, respectively. They were instructed to put together the two that “most go together” by writing the appropriate letter pair on a response form. Children were instructed to point to the two stimuli which most go together, and the experimenter recorded their responses. The words “similar” and “alike” were never used in the instructions. Half of the subjects from each age group were assigned to the linear and half to the columnar condition. For adults, the linear group contained four males and eight females, and the columnar group was composed of five males and seven females. The respective numbers for the children’s groups were five males and three females and four males and four fe-
males. The mean ages for the young columnar and linear groups were 5-4 and 5-1, respectively.

Results and Discussion

Table 1 presents the proportion of each type of response averaged over length-shared and density-shared triads for trials 1 to 3 for both age groups in each presentation condition. Several features of the data can be seen in examining table 1. First, overall, adults gave more dimensional responses than did children and also gave more dimensional responses for the column arrangement than for the linear arrangement condition. Adults also showed more dimensional responses than either similarity or haphazard responses in the columnar arrangement condition and more similarity than either dimensional or haphazard responses in the linear arrangement condition. Children’s responses seem less affected by the stimulus arrangement factor than were adults’, and they gave more similarity than either dimensional or haphazard responses for both the columnar and linear arrangements. Finally, adults showed a consistent increase in dimensional responses across trials, whereas children did not.

Most of the observations noted above received support from the statistical analyses performed on the data. An analysis of variance was conducted on the number of dimensional responses given using age and arrangement condition (linear vs. columnar) as between subject variables and trial type (length shared vs. density shared) and trials (1–3) as within subject variables. Consistent with the separability hypothesis, the analysis revealed a significant effect of age, $F(1,36) = 26.85, p < .001, MSe = 2.632$, indicating that adults gave more dimensional responses than did children. The analysis also revealed a significant effect of trials, $F(2,72) = 3.55, p < .05, MSe = 0.555$, with more dimensional responses occurring on later trials and a marginally significant age × trials interaction, $F(2,72) = 2.71, .10 > p > .05$. However, since children showed an increase in dimensional responses from trial 1 to trial 2, followed by a decrease from trial 2 to trial 3, the similarity of the pattern of their responses from trial 1 to trial 2 to that of adults could have reduced the magnitude of the expected interaction. Subsequent trend analyses revealed a significant linear component, $F(1,22) = 12.201, p < .001, MSe = 0.533$, and a nonsignificant quadratic component, $F(1,22) = 0.354, p > .25, MSe = 0.481$, in the change over trials for adults; and no linear component, $F = 0$, and a nonsignificant quadratic component, $F(1,14) = 1.647, p > .20, MSe = 0.809$, for children—confirming that adults, but not children, showed consistent increases in dimensional responses over trials. Adults gave more dimensional responses than children on all trials: $t(38) = 3.523, p < .005, SE = 0.514$; $t(38) = 3.455, p < .005, SE = 0.585$; and $t(38) = 4.579, p < .001, SE = 0.623$—for trials 1, 2, and 3, respectively. Therefore, the increase in dimensional responses over trials by adults contributes to but does not completely determine the observed developmental difference. Children and adults were different in their response patterns from the beginning of the task.

The main analysis also revealed a significant effect of the arrangement of the stimuli $F(1,36) = 7.54, p < .025, MSe = 2.632$, and an interaction of arrangement and age, $F(1,36) = 6.02, p < .025, MSe = 2.632$. The basis of

| TABLE 1 |
|--------------------------|-----------------|
| **PROPORTION OF SIMILARITY (S), DIMENSIONAL (D), AND HAPHAZARD (H) RESPONSES FOR ADULTS AND CHILDREN IN THE COLUMNAR AND LINEAR CONDITIONS** |
| **ARRANGEMENT CONDITION** |
| **Columnar Type of Response** | **Linear Type of Response** |
| **S** | **D** | **H** | **S** | **D** | **H** |
| **Adultr:** | | | | | | |
| 1 | .392 | .542 | .067 | .625 | .325 | .050 |
| 2 | .350 | .617 | .033 | .550 | .400 | .050 |
| 3 | .283 | .658 | .058 | .542 | .425 | .033 |
| $\bar{x}$ | .342 | .605 | .053 | .572 | .383 | .044 |
| **Children:** | | | | | | |
| 1 | .513 | .300 | .187 | .637 | .213 | .150 |
| 2 | .613 | .263 | .125 | .463 | .350 | .187 |
| 3 | .563 | .275 | .163 | .587 | .237 | .175 |
| $\bar{x}$ | .563 | .279 | .158 | .563 | .267 | .170 |
these results is that adults gave more dimensional responses in the columnar condition which was expected to facilitate dimensional comparisons than in the linear condition, \( t(22) = 3.891, p < .005, SE = 1.735 \); but children did not, \( t(14) = 0.206, p > .40, SE = 1.822 \). The adult finding questions the notion that separability as measured in the present task reflects a stable mode of perception, independent of task situations. The fact that children were less affected by the physical arrangement factor is consistent with the idea of increased flexibility in perceived structure with increasing age. That is, adults were more likely to change their response patterns under differing task conditions.

The only other significant effects in the main analysis were triad type, \( F(1,36) = 53.24, p < .001, MS_e = 4.806 \), and triad type \( \times \) age, \( F(1,36) = 21.42, p < .001, MS_e = 4.806 \). The nature of these effects is that adults gave significantly more dimensional responses for the density-shared than for the length-shared triads, \( t(23) = 11.814, p < .001, SE = 0.817 \), whereas children gave equivalent numbers of dimensional responses for the two types of triads, \( t(15) = 1.406, p > .10, SE = 1.645 \).

Since the “similarity” pairs for the length-shared triads are also the ones that are closest in density, the triad-type effect (many dimensional responses for density-shared triads; many similarity responses for length-shared triads) may reflect a preference for density as a basis of classification. By the same reasoning, the triad type \( \times \) age interaction is consistent with less preference in responding on the part of children. This result is consistent with the separability hypothesis, since preferences are supposed to apply only in the case of separable dimensions.

An analysis of variance was conducted on the number of haphazard responses, and the only significant effect in that analysis was age, \( F(1,36) = 31.49, p < .001, MS_e = 3.779 \), indicating that children gave significantly more haphazard responses than did adults. An analysis performed on similarity responses yielded significant effects of age, \( F(1,36) = 6.00, p < .025 \), arrangement, \( F(1,36) = 6.82, p < .025 \), and age \( \times \) arrangement, \( F(1,36) = 6.82, p < .025 \), with \( MS_e = 16.037 \) in all cases. Overall, children gave more similarity responses, and there were more similarity responses in the linear condition. The interaction of age and arrangement is based on the fact that children gave significantly more similarity responses than adults in the columnar, \( t(18) = 3.469, p < .005, SE = 1.887 \), but not in the linear, condition, \( t(18) = 0.573, p > .20, SE = 1.767 \).

Statistical tests did not reveal sex differences in the number of dimensional responses in either age group: \( t(22) = 0.710, p > .20, SE = 1.690 \) for adults; and \( t(14) = 1.604, p > .10, SE = 2.281 \) for children—and there was no apparent difference in responding as a function of age within the group of children tested.

**Number responding control condition.**—

There is suggestive evidence from experiment 1 that number responding was at a minimum. First, when asked to indicate the basis of their classification choices, only two adults and one child mentioned number. Second, for one of the triads, the items closest in number were the pair representing a haphazard response. If subjects used number, the proportion of haphazard responses for this triad should be much greater than for the other triads. However, the proportions were nearly identical (0.07 for adults and 0.17 for children) to the overall proportions of haphazard responding in experiment 1.

Despite these observations and the fact that previous data (Ward, Notes 3 and 4) indicated little tendency for subjects to classify length-density stimuli on the basis of number, a control condition was implemented to examine age-related changes in this tendency. Ten undergraduates (five males, five females) selected from introductory psychology classes at the University of Michigan and 10 kindergartners (five males, five females; mean age = 5-6) chosen from an elementary school in Ann Arbor, Michigan, were tested with a new set of stimuli. Six triads were constructed as described above, using the dimensions of length and density. Three had length and three had density as the dimensional response. For two of the triads (one length and one density), the two items closest in terms of the number of dots were the dimensional responses. For the other four triads, number and similarity were correlated. If subjects were responding on the basis of number, they should shift from dimensional responses for the former to similarity responses for the latter. Each triad was presented three times, and the procedure was the same as described above.

The proportion of each type of response for the triads in which the number and dimensional response were correlated (number = dimensional) and in which number and similarity were correlated (number = similarity) is presented in table 2 separately for adults and children. The data in that table provide no evidence for the shift expected on the basis of
TABLE 2
Proportion of Each Type of Response for Adults and Children with the Number = Dimensional and Number = Similarity Triads

<table>
<thead>
<tr>
<th>Type of Response</th>
<th>Type of Triad</th>
<th>Similarity</th>
<th>Dimensional</th>
<th>Hap-hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number =</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dimensional</td>
<td>.333</td>
<td>.633</td>
<td>.033</td>
<td></td>
</tr>
<tr>
<td>Number =</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>similarity</td>
<td>.350</td>
<td>.600</td>
<td>.050</td>
<td></td>
</tr>
<tr>
<td>Children:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number =</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dimensional</td>
<td>.683</td>
<td>.250</td>
<td>.067</td>
<td></td>
</tr>
<tr>
<td>Number =</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>similarity</td>
<td>.592</td>
<td>.267</td>
<td>.142</td>
<td></td>
</tr>
</tbody>
</table>

number responding. In fact, for children, the trend is in the direction opposite that predicted. Statistical analyses conducted on the proportion of similarity and dimensional responses revealed effects of age, $F(1,18) = 9.52$, $p < .01$, $MS_e = 0.092$, for similarity responses, and $F(1,18) = 15.42$, $p < .001$, $MS_e = 0.083$, for dimensional responses, but not type of triad (i.e., number = dimensional vs. number = similarity), $F < 1$ for both similarity and dimensional responses. Thus, there is little evidence that subjects of the ages tested spontaneously employ number when asked to classify length-density stimuli in the present task.

Experiment 2

The results of experiment 1 indicate that preschoolers use overall similarity as a basis for classifying stimuli which adults classify predominantly on the basis of dimensional structure. Young children’s use of similarity could indicate that they perceive length and density as integral in the same way that adults perceive, say, saturation and brightness as integral. That is, the children may not have knowledge about the dimensional structure of such stimuli or not be able to access and use the dimensions independently. Alternatively, children’s use of similarity could reflect a tendency not to employ such dimensional information even though they have access to it.

The question of whether children can access the dimensional structure of the length-density stimuli is relevant to notions of number processing. If children perceive the dimensions as integral to the degree that they are incapable of accessing and using them separately, then this basic perceptual limitation would put severe limits on their abilities to make number judgments on the basis of a single dimension or by independent assessment of both dimensions. If, on the other hand, children are perfectly capable of accessing and using the dimensions separately, and their “integral” responding reflects a tendency to not employ that dimensional information in the present task, the implications of that responding for notions of dimension usage during number judgments may be less extreme.

If young children’s response patterns are based on a lack of knowledge about or access to the dimensional structure of the stimuli, training them with respect to that structure should result in an increase in dimensional responding. With this notion in mind, an initial training task was designed which was patterned after a pilot study described by Kemler and Smith (1979) in which adults were trained to determine whether pairs of stimuli were the same or different along the integral dimensions of chroma and value. Adults required extensive training in order to make such comparisons accurately. If children were able to make accurate dimensional comparisons without such training, then it would be erroneous to conclude that a lack of access to dimensional relations determines their similarity responding in the classification task. In this case, if the initial comparison task resulted in increased dimensional responding in a later classification task, the result could be attributed to subjects’ adopting the mode of classification (dimensional sameness) suggested by that comparison task. That is, the comparison task would be viewed as inducing subjects to employ the dimensional information which they were already capable of accessing.

Method

Stimuli.—The stimuli for the main classification task were the 10 triads arranged in a columnar format as described in experiment 1.

A new set of stimuli was constructed for the subjects’ initial task of comparing the same-ness or difference of the length and density of items. This set was composed of new combinations of levels of length (1.5, 3, and 6 cm) and density (1.5-, 0.75-, and 0.37-cm interdot distance). Pairs of stimuli from this set were typed onto 7.6 × 12.7-cm white index cards. In addition, the initial comparison set included pairs that represented the “dimensional” classification response for one of the length-shared and one of the density-shared triads used in the main classification task. These pairs were included to provide a check on whether any transfer to the
main classification task was general or specific to the levels of the dimensions employed.

Subjects.—The subjects were 12 undergraduates (10 females and 2 males) enrolled in introductory psychology courses at the University of Wisconsin—Madison and 12 children ranging in age from 4-0 to 6-1 (mean = 5-2) recruited from day-care centers serving middle-class neighborhoods in the Madison area. All children were white.

Procedure.—Subjects were tested individually in a well-lighted room. Half of the subjects in each group received standard instructions and performed only the main classification task, as in experiment 1. The other half performed an initial comparison task prior to the main classification task. For children, the former group contained four females and two males and the latter contained three males and three females. The mean ages of these groups were 5-4 and 5-1, respectively. The two adult groups were each composed of five females and one male. For the initial comparison task, subjects were told that they would be shown pairs of items differing in length and density (“spacing”). Subjects were first shown six pairs of items all of the same density and were asked to make a same-different judgment regarding length. They were then shown six pairs all of the same length and asked to make density comparisons. In each case, three pairs from the set were the same and three were different on the relevant dimension. Finally, the subjects were shown sets of 12 pairs each in which the items could vary in both length and density and were asked to compare the items on both dimensions simultaneously. Each such set included three examples of each of the possible types of pairs (same length–different density, different length–same density, both same, and both different). Feedback was given and subjects were required to respond correctly to 11 of the 12 pairs in a given set, comparing the items on length and density simultaneously before proceeding to the main classification task.

The sequencing of the triads in the main task and the subjects’ modes of indicating their choices were the same as in experiment 1.

Results and Discussion

Initial comparison task.—Nearly every subject in both age groups performed perfectly on the initial comparison task. Only one child, a 4-year-old, made errors on the portion of the task requiring comparison of the items on length and density simultaneously. This child performed perfectly on the second set of 12 comparison items for that portion of the task. The children’s performance contrasts sharply with that of the adults in Kemler and Smith’s (1979) pilot study who required extensive training with the integral dimensions of chroma and value before they could accurately make dimensional comparisons. Assuming that these children are representative of others their age, it is reasonable to conclude that the young children’s tendency toward similarity classifications observed in experiment 1 is not based on a lack of ready access to the dimensional structure of the stimuli. Rather, it may be related to the tendency to use that information.

Main classification task.—The proportion of similarity, dimensional, and haphazard responses is presented separately in table 3 for children and adults in the control and experimental (initial comparison task) conditions. Inspection of that table indicates that adults gave more dimensional responses than did children and that both age groups gave more dimensional responses in the experimental condition than in the control condition. These observations were confirmed by the results of an analysis of variance on the number of dimensional responses with age and condition (experimental vs. control) as between subject variables and triad type and trials as within subject variables. Consistent with experiment 1, there was a significant effect of age, $F(1,20) = 29.55, p < .001, MS_e = 4.157$, with adults giving more dimensional responses than children. There was also a significant effect of condition, $F(1,20) = 17.04, p < .001, MS_e = 4.157$, with experimental subjects giving more dimensional responses than those in the control condition. The interaction of age and condition was not significant, $F(1,20) = 0.60, p > .25, MS_e = 4.157$, indicating that children and adults were affected in the same way by the manipulation. These results could not be due to “training” subjects with regard to the di-

### Table 3

<table>
<thead>
<tr>
<th>Type of Response</th>
<th>Group</th>
<th>Similarity</th>
<th>Dimensional</th>
<th>Haphazard</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Adult control</td>
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<td>.578</td>
<td>.083</td>
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<tr>
<td></td>
<td>Adult experimental</td>
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<td>.028</td>
</tr>
<tr>
<td></td>
<td>Child control</td>
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<td>.261</td>
<td>.211</td>
</tr>
<tr>
<td></td>
<td>Child experimental</td>
<td>.405</td>
<td>.489</td>
<td>.106</td>
</tr>
</tbody>
</table>
dimensional structure of the stimuli, since all subjects were able to use dimensional relations in the initial comparison task. It is possible that the initial task resulted in an expectancy that dimensional classifications were the "correct" responses in the classification task. To the degree that the effect represents an experimenter-suggested mode of classification, the increase in dimensional responses for those in the experimental condition should be rulelike rather than specific to the levels of the dimensions used in the initial task. In support of this, adults in the experimental condition gave 89% dimensional responses for triads whose dimensional pair had been shown in the initial task and 92% dimensional responses for triads whose dimension levels had not appeared in that task. The respective percentages for children in the experimental condition were 36 and 52, with the difference being nonsignificant, $t(5) = 2.07, p > .05, SE = 0.077$. Thus, there is no evidence that the greater number of dimensional responses shown by subjects in the experimental condition was specific to the levels of the dimensions used in the initial task.

**General Discussion**

The major findings of the present studies can be summarized and interpreted as follows. Adults' responding to the dimensions of length and density was dominated by dimensional classifications, whereas that of children was dominated by similarity classifications. This result supports the notion that children will treat as integral those dimensions which adults treat as separable and is consistent with previous developmental findings (Shepp & Swartz 1976; Smith & Kemler 1977).

A second finding of interest is that adults showed increases in dimensional responses across trials, while children did not show such systematic increases. This result supports an extension of the separability hypothesis to include the notion that adults are more likely than children to discover something about the usefulness of dimensional structure in classifying stimuli during the course of experience with them. It should be noted that the increase in dimensional responding shown by adults contributed to, but did not completely determine, the developmental difference. That is, adults gave more dimensional responses than did children both at the beginning and at the end of the task.

Adults gave more dimensional responses when presented with the stimuli in an arrangement which was predicted to facilitate dimensional comparisons and when required to perform a prior task involving dimensional comparisons. Children were less influenced by the physical arrangement factor. This finding is consistent with Shepp's (1978) suggestion that there may be increased flexibility in perceived structure with increasing age. It is also possible, however, that flexibility in perceived structure is related to the degree of separability of the dimensions which is, in turn, based both on age and on the specific dimensions employed. That is, subjects may be less flexible with dimensional combinations which, for them, are highly separable or highly integral. So, for example, adults are relatively inflexible with size and brightness, which are highly separable dimensions for them (Kemler & Smith 1979; Smith & Kemler 1978), and flexible with the present dimensions, which, based on the relative proportions of the various responses, are only moderately separable. Conversely, young children are more flexible with size and brightness (Kemler & Smith 1979; Smith & Kemler 1978), which may be moderately separable for them, in contrast to the present dimensions, which are more highly integral for them.

Regardless of whether flexible use of perceived structures is based solely on age or on separability as a product of age and the specific dimensions employed, the findings with regard to flexibility raise an important issue. If subjects' responding varies from one task or situation to the next, questions regarding absolute differences in separability with age may be inappropriate. The present results imply that questions could be framed more productively in terms of under what circumstances and in what conditions adults and children respond differently to the dimensions presented.

It is unlikely that children's similarity responding is based on a lack of knowledge about or access to the dimensional structure of the stimuli. Unlike the adults in the pilot study reported by Kemler and Smith (1979) who required extensive training to use the dimensional structure of integral stimuli, children were perfectly capable of accessing dimensional relations, as evidenced by their performance in the initial task of experiment 2. It is of interest, too, that the children spontaneously adopted higher levels of dimensional responding following performance of that task. These findings are consistent with the views expressed by Kemler and Smith (1979) that children can access the dimensional structure of what, for adults, are separable dimensions.
Since children's "integral" responding to the dimensions of length and density is not identical to adults' processing of integral dimensions, it can be argued that the processing consequences of integral perception (e.g., limited selective processing) may not be directly applicable to understanding the development of number-processing abilities. On the other hand, it can be argued that the initial comparison task of experiment 2 induced children to process length and density in a way that is much different from the way they spontaneously do in the present task (or in number-processing tasks). That is, the present studies show that children can use length and density independently in making judgments when asked to do so, but the question still remains whether they do so under the standard conditions of number judgment tasks without special instructions.

If not related to a basic perceptual limitation, such as the inability to access dimensional structure, then the developmental trend toward separability responding may be based on developmental changes in the subjects' strategies of processing information. The processing factors related to cognitive tempo (see, e.g., Kagan 1965; White 1965) have received attention as a possible starting point in identifying the relevant process (Smith & Kemler 1977; Ward, Notes 3 and 4). Ward (Notes 3 and 4) did find more dimensional responding by adults in conditions leading to slower tempos of responding but found no such effect with children. Thus, the exact relation between cognitive tempo (i.e., the tendency to respond impulsively or reflectively) and developmental changes in separable-integral responding is unclear but appears to be a potentially informative topic for further study.

References


Reference Notes


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