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Ward, Thomas Bernard

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Function of Stimulus and Response Variables

A thesis submitted to the Graduate School of the

University of Wisconsin-Madison in partial fulfillment of

the requirements for the degree of Doctor of Philosophy

BY

Thomas Bernard Ward

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# DIMENSIONAL RESPONDING IN CHILDREN AND ADULTS AS A FUNCTION OF STIMULUS AND RESPONSE VARIABLES

By

Thomas Bernard Ward

A thesis submitted in partial fulfillment of the
requirements for the degree of
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1978

Dimensional Responding in Children and Adults As A Function of Stimulus and Response Variables

Thomas Bernard Ward

Under the supervision of Professor Leonard E. Ross

## Abstract

Restricted classification and similarity rating tasks employing the dimensions of line length and density were used to investigate several issues. One of these was developmental differences in the overall separability of those dimensions. The contribution of perceptual limitation and strategic factors to levels of dimensional responding and to developmental changes in that responding were also investigated. Finally, changes in levels of dimensional responding across trials with stimuli and the contribution of those changes to observed developmental differences were studied. Adults (college students) gave more dimensional responses than did children (4- to 6-year-olds) and tended to give more dimensional classifications than any other type of response. They also gave more dimensional responses when stimuli were arranged in a columnar format, when they were instructed to be slow and careful in making their choices, when required to delay responding 5 seconds as compared to a 2 second time limit, and when performing a dimensional comparison task prior to the restricted classification task. Finally, adults showed increases in dimensional responding across trials with the stimuli. Children gave a majority of similarity responses, and were less affected than adults by the stimulus and response manipulations. They did show increased dimensional responding following performance of a dimensional comparison task in which they gave evidence of having access to the dimensional structure of the length and density stimuli. Children did not show systematic increases in dimensional responding across trials. The results were interpreted as being supportive of an organismic or processing emphasis in separability and as being consistent with a general notion of an increase in separable-type responding with increasing age. They were also interpreted as implying that children's similarity responding to dimensions which are separable for adults is not based on a lack of access to dimensional relations or structure. It was suggested that questions regarding the conditions under which children and adults treat dimensions differently may be more fruitful than questions of absolute differences in separability. Finally, the results were interpreted as indicating that adults more so than children, are likely to discover the dimensional relations that exist within particular sets of stimuli which they experience.

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According to one conception of perceptual development, children are seen to progress from diffuse, global, undifferentiated perception to a more articulate, specific, or differentiated manner of perceiving (see Gibson, 1969). Children have also been characterized as developing toward greater proficiency in selective attention or selective processing (Hagen and Hale, 1973; Maccoby, 1969). Shepp (1977) has introduced an hypothesis about perceptual development which bears on the relationship between these trends. In Shepp's conception, termed the separability hypothesis, the shift from undifferentiated to differentiated perception is seen to involve specific age changes in the perceived structure of stimuli or in the mode in which perceptual information is represented, with increasing extraction of dimensional structure occurring with increasing age. Selective attention changes, on the other hand, are seen as changes in the processing of the represented information. An implication of the hypothesis is that the perceived structure which characterizes young children's perceptions may limit their ability to selectively attend.

The plan of the present paper is to discuss certain concepts related to the perceived structure of stimuli, and present a description of the separability hypothesis including a consideration of a similar hypothesis offered by Smith and Kemler (1977). The evidence for and against the hypothesis will be discussed. This will be followed by a consideration of the factors which control the emergence of dimensional structure, the relationship of the separability hypothesis to certain processing concepts, e.g. selective attention, and the possibility of developmental trends in perceived structure which would be inconsistent with the separability hypothesis. Finally, studies addressed to some of these issues will be described.

# Perceived Structure

Garner (1974, 1976) has pointed out that when stimuli are composed of two or more dimensions, the dimensions can interact or combine in a variety of ways. The two types of dimensional combination that are of most interest in the present context are integral and separable. 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). Other theorists have made essentially similar distinctions between "unitary" and "analyzable" (Shepard, 1964) and integral and nonintegral (Lockhead, 1972) dimensions, but the terms integral and separable will be used throughout this paper. Garner (1974) has summarized data from a variety of experiments which provide operational distinctions between integral and separable dimensions. Those data as well as more recent findings will be discussed in the following sections.

## Similarity Scaling Studies

One source of evidence regarding the distinction between integral and separable dimensions is the data from studies of similarity scaling. Of most direct interest to the separable-integral distinction are studies concerned with the relationship of the perceived similarity of stimuli differing on two dimensions simultaneously to the perceived similarity of stimuli differing on each of the dimensions separately. For example, in the two-dimensional space defined by the dimensions X and Y, if stimulus B differs from stimulus A only on dimension X (by an amount $d_x$) and stimulus C differs from the same stimulus A only on dimension Y (by an amount $d_y$), the concern is with the perceived dissimilarity of B and C (symbolized by $d_{xy}$), which differ on both X and Y. (As Garner (1974) has noted, the concept of dissimilarity is more appropriate to measurement even though most experiments are concerned with similarity.) Considering similarity as distance, concepts of geometry might reasonably apply and the distance $d_{xy}$ could be represented as the hypotenuse of a right triangle with sides $d_x$ and $d_y$ and vertexes A, B, and C. In this case $d_{xy} = \sqrt[2]{d_x^2 + d_y^2}$, and data giving such a result would be said to conform to a Euclidean metric. Alternatively, the perceived dissimilarity $d_{xy}$ could simply be the sum of the perceived dissimilarities $d_x$ and $d_y$. In this case the data are said to conform to a city-block metric.

In studies of similarity scaling, integral dimensions produce data conforming to a Euclidean metric, whereas separable dimensions yield a city-block metric (Garner, 1974; Handel and Imai, 1972; Hyman and Well, 1967, 1968; Shepard, 1964). Garner's interpretation of these findings is that a true similarity structure in which distance relationships are meaningful characterizes integral dimensions, whereas a dimensional structure in which similarity, in the sense of distance, is unimportant characterizes separable dimensions.

An alternative use of similarity data in identifying integral dimensions has been reported by Somers and Pachella (1977) who had subjects rate the similarity of items (faces) on the relevant dimension of shape with the irrelevant dimension (emotional expression) either varying or held constant. The degree to which changes in the irrelevant dimension influenced similarity ratings on the relevant dimension was taken as a measure of the degree of integrality of the dimensions. Some subjects ignored the irrelevant dimension, whereas others did not as evidenced by the effect of that dimension on their similarity judgments. Presumably, the dimensions were separable for the former group and integral for the latter.

Restricted Classification Studies

Dimensions classed as integral or separable according to similarity scaling data have also been differentiated on the basis of data from restricted classification tasks (see Garner, 1974). In such studies (e.g., Handel and Imai, 1972) subjects typically are presented with three or four stimuli composed from different levels on two dimensions. They are instructed to put together in a group the stimuli which "go together." The stimulus triads or tetrads are constructed so that the stimuli may be grouped together either 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 can use overall similarity and group A and C together, or dimensional structure and group A and B together. One basic result from such studies is that when potential classifications on the basis of similarity and dimensional structure are put into conflict, subjects tend to classify separable dimensions according to a dimensional structure and integral dimensions according to overall similarity (Garner, 1974; Handel and Imai, 1972).

Triads can also be constructed so that dimensional preference and similarity classifications are put into conflict. In this case, dimensional preferences, in which one dimension is used as a basis for classification despite the fact that similarity relationships favor classification according to the other dimension, can exist for separable stimuli (Garner, 1974). Integral dimensions on the other hand, are grouped in terms of similarity and therefore the grouping chosen depends to a great extent on the similarity relationships among the triad members.

Both of the patterns of results reported in this section are consistent with Garner's interpretation that separable dimensions are perceived according to a dimensional structure, whereas integral dimensions are related by a similarity structure.

Smith and Kemler (1977) have argued that classification tasks as described above represent the most direct operation for distinguishing between separable and integral dimensions. The series of experiments reported in the present paper is relevant to the question of whether this paradigm does yield direct observations of subjects' modes of perceptual representation.

### Concept Learning Tasks

Smith and Kemler (in press) have reported data from concept learning tasks which converge on the notion that integral dimensions are perceived as related by a similarity structure and separable dimensions are perceived as related by a dimensional structure. Their data indicate that dimensional relations are more readily accessed from separable stimuli and that similarity relations are more readily accessed from integral stimuli.

Across three experiments, adult subjects were presented with variations on a concept learning task in which they had to discover the experimenter's rule for classifying pairs of stimuli. The rules to be learned involved similarity relations or dimensional relations. Generally, similarity relations were more readily learned for the integral dimensions of saturation and brightness, and dimensional relations were more readily learned for the separable dimensions of size and brightness.

Smith and Kemler's data were somewhat more complex, however, in the sense that dimensional relations were, overall, more readily learned than were similarity relations. Some subjects learned both similarity and dimensional rules for classifying the presumably integral dimensions of saturation and brightness whereas the learning of dimensional rules alone characterized subject's performance with size and brightness. Smith and Kemler (in press) suggest that the dimensional relations which subjects sometimes extract from integral dimensions are not the same as those which characterize separable dimensions. The axes of saturation and brightness, for example, which define a particular stimulus space are conceived as being arbitrary. The dimensional relations which characterize separable dimensions, on the other hand, are seen as being nonarbitrary.

Speeded Classification Studies

The same dimensions which are termed integral or separable based on the methods mentioned above are also discriminated on the basis of data from speeded classification studies. Subjects in these tasks typically are presented with decks of cards with the task of sorting the cards on the basis of one of two dimensions. For integral dimensions, sorting is faster when the irrelevant dimension varies in a correlated fashion with the relevant one, and slower when the dimensions vary orthogonally relative to a condition in which the value on the irrelevant dimension is held constant (Garner and Felfoldy, 1970). For separable dimensions, these three sorting conditions typically yield equivalent sorting times.

Presumably, when integral dimensions are redundant, they combine to yield stimuli of greater perceived dissimilarity or discriminability, and thus facilitate sorting (see Lockhead and King, 1977; Monahan and Lockhead, 1977). With separable dimensions, presumably the irrelevant dimension is filtered and thus correlated changes in that dimension do not add to the dissimilarity of the items to be sorted.

A variety of processes have been postulated to account for the interference produced by orthogonal variation in the irrelevant member of an integral dimension pair. These include stimulus and response repetition effects in reaction time (Felfoldy, 1974) and a process of "normalization" (Dixon and Just, 1978) in which items must be equated on the irrelevant dimension or differences on the irrelevant dimension must be normalized before a decision can be made on the basis of the relevant dimension.

It should be noted that both facilitation and interference in sorting are possible with separable dimensions under certain conditions, but that the effects are assumed to be mediated by mechanisms other than those underlying the effects observed with integral dimensions. According to Garner (1974), facilitation in sorting with separable dimensions is based on selective serial processing of the easier of two dimensions when they vary in a correlated way. In this case, sorting is faster than sorting on the slower of the two dimensions alone, but not faster than sorting with the easier dimension alone. Interference in sorting with separable dimensions has also been observed when a condensation task, which requires that the dimensional structure be ignored, has been employed (Garner, 1974; Gottwald and Garner, 1972).

Other Types of Dimensional Interaction

Garner (1974, 1976) has identified two other types of dimensional interaction. One of these is called configural and the other has been called asymmetric integral (Garner, 1974) and asymmetric separable (Garner, 1976). According to Garner (1976, see also Pomeranz and Garner, 1973), configural dimensions produce interference in sorting when the relevant and irrelevant dimensions vary orthogonally, but do not result in facilitation when the dimensions vary in a correlated fashion. Garner (1976) also conjectured that similarity ratings and classifications with configural dimensions would depend upon "the configural properties of the stimuli, such as stimulus equivalences based on rotations and reflections (p. 104)." Finally, dimensional preferences are assumed not to exist for configural dimensions.

Asymmetric separable dimensions produce both facilitation and interference in sorting, but only one of the dimensions will interfere with the other, not vice versa (Garner, 1976). Similarity scaling for these dimensions should result in a city-block metric and classification should be based on dimensional structure (Garner, 1976). Finally, Garner has also suggested that dimensional preferences can exist with stimuli composed of asymmetric separable dimensions, but that the preference will always be for the dimension which can be selectively processed.

### Stimulus vs Organismic Construct

Garner (1974) chooses to emphasize the stimulus rather than the organismic nature of the separable-integral distinction. In Garner's approach, the separability of dimensions is assumed to inhere in the stimulus and to be relatively independent of the processes which subjects bring to bear on the stimuli. He does suggest that there are important interactions between the structure of stimuli and subjects' processing, but his primary emphasis is on the stimulus side of the interaction. For example, certain kinds of processes are seen to be possible with separable dimensions (e.g., selective attention, selective serial processing), but not with integral dimensions.

It is also possible to emphasize the processing side of the interaction. Somers and Pachella (1977) seem to favor this latter approach and suggest a refocussing of research energies away from questions about which dimensions are integral and which are separable, and toward questions about how the perceiver characterizes multidimensional stimuli. Monahan and Lockhead (1977) also seem to favor an emphasis on the processor. In discussing possible definitions of integrality, they suggest that stimuli are integral if, when a physical aspect (one of the dimensions) is removed a relational aspect is also removed. They argue further that "relations may be the psychological attributes... rather than physically measured attributes themselves (p. 109)." In discussing the possibility of stimuli being integral for some subjects but not for others, Monahan and Lockhead (1977) contend that the relational requirement in their definition of integrality is entirely dependent upon the observer.

To the degree that individual differences in responsiveness to dimensions exist, the emphasis on the processing side of the interaction is favored. As noted, some of Somers and Pachella's subjects treated the dimensions of facial shape and emotional expression as integral whereas others treated them as separable. The developmental data discussed below also favor an emphasis on processing notions since children and adults are seen to perceive different types of structure in the same stimulus.

An emphasis on processing factors is also favored to the degree that subjects' responding can be affected by changing task conditions. The experiments reported later in this paper examine the possibility that manipulating factors such as the subjects' approach to the task will affect their responding in an interpretable manner.

## The Separability Hypothesis

Shepp (1977) has offered an hypothesis regarding perceptual development which makes use of the distinction between separable and integral dimensions. The hypothesis holds that "...dimensions that are perceived by the older child and adult as separable, are perceived by the younger child as integral, and it is through perceptual learning that dimensional structure is extracted from the stimulus (Shepp, 1977, p. 4)." A similar hypothesis has been advanced by Smith and Kemler (1977). Shepp notes that in postulating developmental differences, his view differs from that of Garner (1974) who views separability to be a pure stimulus concept. However, the views of the two theorists are similar in the sense that Shepp (1977) contends that young children have not yet extracted the dimensional structure inherent in the stimuli.

For both Shepp (1977) and Smith and Kemler (1977) the separability hypothesis deals with the mode in which perceptual information is represented. In Shepp's view, the separability hypothesis is compatible with Gibson's (1969) notion of differentiation in perceptual development, but provides a more precise account of the perceived structure which characterizes young children's perception. Similarly, Smith and Kemler (1977) note the utility of considering young children's perception to be "integral" rather than "undifferentiated." In their view, the notion of undifferentiated perception fails to capture the regularities which appear to exist in the modes of perception which characterize young children. Specifically, Smith and Kemler (1977) suggest that perception organized around a similarity structure, i.e., integral perception, is a more useful characterization. Kemler and Smith (unpublished, cited by Smith and Kemler, in press) have recently modified their views and the modification is considered later in this paper. The discussion below is concerned with the empirical evidence for and against the separability hypothesis; a consideration of factors controlling the emergence of perceived dimensional structure; a discussion of the relation of the hypothesis to processing concepts; and a consideration of trends other than those predicted from the separability hypothesis.

## Empirical Evidence

Direct support for the separability hypothesis comes from experiments reported by Shepp and Swartz (1976) and Smith and Kemler (1977). Shepp and Swartz had first- and fourth-graders perform a speeded-sorting task with pictures of houses. Sorting was done on the basis of features of the doors of the houses. The doors were composed of dimensions thought to be integral, hue and brightness, or separable, shape of door-window and hue or brightness of the door. When the dimensions of interest were hue and brightness, both age groups produced results which Shepp and Swartz (1976) interpreted as being consistent with those dimensions being integral. That is, sorting was faster when hue was relevant and both dimensions varied in a correlated fashion (correlated dimensions) and slower when the dimensions varied orthogonally (orthogonal dimensions) relative to the condition in which the value on the irrelevant dimension was constant (one dimension). However, since hue was the more difficult of the two dimensions and facilitation occurred in the correlated dimensions condition only when hue was relevant, the result is also consistent with selective serial processing of brightness in the correlated dimensions condition.

When the dimensions used were window shape and hue or brightness of the door, the data were consistent with those dimensions being separable for the older children and integral for the younger subjects. Sorting by the first-graders was facilitated in the correlated dimensions condition and slowed in the orthogonal dimensions condition relative to the one dimension condition. The sorting of the fourth-graders varied little across the three sorting conditions with these same dimensions.

Smith and Kemler (1977) observed the performance of kindergarten, second- and fifth-graders in a free classification experiment. On each trial subjects were presented with triads of stimuli varying in size and brightness and were to group together the two out of the three stimuli which "go together." The proportion of dimensional classifications increased with age, with the kindergarteners producing significantly greater than chance similarity groupings and fifth-graders producing significantly greater than chance dimensional groupings. Similar results were obtained in a second experiment having children from the same age groups classify stimulus tetrads.

In addition to the data reported above, there are findings from a number of experiments, not designed to directly test the separability hypothesis which are nevertheless consistent with that hypothesis.

First, Arabie, Kosslyn, and Nelson (1975) used multidimensional scaling techniques to analyze data from children's and adults' simultaneous and successive comparisons of complex stimuli. The stimuli, composed of LEGO blocks, varied in the number of colors and the number of block-crossings contained in each stimulus. The adult data for simultaneous comparisons were interpretable according to a city-block metric whereas those for five-year-olds were more interpretable in terms of a Euclidean metric.

Secondly, Shepp (1977) has suggested that the results of subproblem analyses of discrimination learning (see Tighe, 1973) are consistent with the separability hypothesis. In these analyses, younger children tend to show post-shift errors consistent with independent subproblem learning, whereas older children's errors are consistent with dimensional learning (Tighe, Glick, and Cole, 1971). According to Shepp's (1977) analysis, this pattern of results is consistent with younger children perceiving the dimensions as integral and older children perceiving them as separable. Presumably, separable dimensions would be required for dimensional learning.

Finally, the separability hypothesis is consistent with the results of many studies which have examined the development of selective attention through the use of sorting tasks. Nearly all of these studies show a decrease with age in the amount of interference produced by changes in the irrelevant dimension. The results could reflect integral perception of the dimensions by younger children, with increasing separability allowing more filtering of the irrelevant dimensions with increasing age. The results are, of course, consistent with a developmental trend toward more efficient or more widely used selective attention processes per se without reference to changes in perceived structure.

There are data which are inconsistent with the notion that young children's perception of dimensions which are separable for adults is like older children's and adults' perception of integral dimensions. First, according to Garner's (1974) analysis, dimensional preferences should exist only for separable dimensions. Yet Smith and Kemler (1977) reported that some of the subjects at all ages showed preferences for one dimension over the other. Similarly, there is a considerable literature concerning age related changes in preference for color or form, dimensions similar to those which Shepp and Swartz suggested to be integral for younger children and separable for older children (e.g., Suchman and Trabasso, 1966). In the Smith and Kemler (1977) study, the youngest subjects were also capable of generating dimensional classifications although they preferred similarity classifications, and their justifications of their similarity classifications made reference to the dimensional structure of the stimuli.

In addition to the above findings, Kemler and Smith (submitted, cited by Smith and Kemler, in press) reported data from condensation and selective filtering tasks which are inconsistent with the idea that size and brightness are integral dimensions for young children. The data revealed that even five-year-olds were sensitive to the dimensional structure of the stimuli but made less use of that information to aid them in performing the task.

Finally, Smith and Kemler (in press) used a concept learning task employing the dimensions of size and brightness with 5- and 10-year-olds. Subjects could learn to classify stimuli on the basis of an identity rule or a dimensional rule. A majority of children at both ages gave evidence of learning a dimensional rule, and their explanations of what they had learned included mention of the dimensional structure of the stimuli. Thus even 5-year-olds were sensitive to the dimensional structure of the size-and-brightness stimuli.

Smith and Kemler (in press) discuss a modified version of the separability hypothesis which takes into account these discrepant observations. The new view differs from their earlier notion and the ideas expressed by Shepp in the sense that young children's perception of what for adults are separable dimensions is no longer seen as completely like adult's perception of integral stimuli. It differs in the sense that for children perceiving what for adults are separable dimensions, the dimensional structure is given and can be readily accessed. On the other hand, children's perception of what for adults are separable dimensions differs from adults' perception of separable stimuli in the sense that the individual dimensions are not available independently to young children as evidenced by their performance in speeded-sorting tasks (Shepp, 1977; Shepp and Swartz, 1976).

It is useful to consider the nature of the tasks in which children show evidence of being sensitive to the dimensional structure of separable stimuli. As Smith and Kemler (in press) note, it is the more difficult or complex tasks such as condensation and concept learning which reveal children's knowledge of dimensional structure. The authors suggest that such tasks may lead to a more analytic approach and increased use of "higher-level perceptual skills." Given that this notion is correct, it is important to consider factors such as instructions and task requirements which can influence the degree to which subjects give "integral" or "separable" responses.

Extraction vs Use of Dimensional Structure

As noted in introducing the separability hypothesis, Shepp's (1977) view is that dimensional structure is achieved through a process of perceptual learning. At another point in his paper, Shepp notes that one feature of such perceptual learning may be learning to attend to a dimensional structure rather than a similarity structure. Although the factors which would control perceptual learning are not specified, one interpretation is that experience with the dimensions can result in the extraction of their dimensional structure.

If experience with particular dimensions is important in extracting their dimensional structure, then it might be possible to observe extraction of dimensional structure during the course of a single experiment as well as across age. Smith and Kemler (in press) have reported that some children "discover" the dimensional structure of size and brightness stimuli during experiments, although the authors do not report any resultant changes in responding across trials. The degree to which both young children and adults show such changes, and the effect of those changes on observed developmental differences should be examined systematically.

As an alternative to the notion of perceptual learning of the specific dimensions experienced, the developmental trend toward greater separability could be accounted for by assuming a more general trend toward the development of or the use of different strategies for processing dimensional information, independent of experience with specific dimensions. By this account, young children would be seen as having access to dimensional structure but not employing strategies that would lead to separable-type responses. Although Smith and Kemler are less specific than Shepp in considering factors responsible for the separability trend, their views seem more in line with the development of strategies for the processing of dimensional information. An example of this tendency toward a more strategic interpretation is seen in their suggestion that more difficult tasks may result in subjects adopting more analytic modes and thereby being more sensitive to dimensional structure (Smith and Kemler, in press).

It should be noted that strategic and experiential factors are not necessarily mutually exclusive. It may be, for example, that the tendency to employ particular strategies could lead to more rapid perceptual learning of the dimensional structure of the particular stimuli, or that learning about structures could lead to the use of different strategies.

Fisher (1977) has reported data which point to the importance of strategic factors. She found that hyperactive children as old as nine years of age showed a pattern of responses in speeded-sorting that was similar to a pattern found in non-hyperactive first-graders by Shepp (1977). Thus it appears that factors other than experience may affect responding in situations used to assess the separability or integrality of dimensions. One of these factors may be something akin to conceptual tempo (Kagan, 1965; Messer, 1976) or temporal stacking (White, 1965). That is, it may take more time to analyze a stimulus into its component dimensions in order to generate separable-type responses and less time to give a more global analysis which might result in integral-type responses (cf. Lockhead, 1972). In this way, the pattern shown by hyperactive boys might be related to impulsivity or difficulty in inhibiting responses. Similarly, since children become more reflective with increasing age (Kagan, 1965) the processing differences between impulsive and reflective responders may be related to the developmental increase in separability. Consistent with this notion, Zelniker and Jeffrey (1976) presented data from a variety of task situations which converge on the notion of impulsive responders being global processors and reflective responders being analytic processors. Of particular interest is performance on a concept attainment task indicating that impulsives considered several dimensions simultaneously whereas reflectives considered a single dimension at a time. The different kinds of processing strategies are what would be expected with integral and separable perception respectively. Thus with increasing age and a concomitant increase in reflectiveness, or use of reflective strategies, an increase in separable responding would be expected.

Relation to Selective Attention

The separability hypothesis, as stated by Shepp (1977), emphasizes the results of processes (e.g., dimensional structures) rather than the processes themselves. This emphasis can be illustrated by considering the way in which Shepp (1977) deals with the concept of selective attention. Shepp contends as does Garner (1974) that selective attention is not possible with integral dimensions. Therefore, "...If the young child perceives dimensional combinations as integral, the suggestion that such children show an inability to attend selectively may often be erroneous (Shepp, 1977, p. 5)." The idea here is that the mode in which young children perceive dimensions may limit their ability to selectively process that information. The point is well taken in that it emphasizes that conclusions about age-related changes in selective attention as a higher level process (see e.g., Hagen and Hale, 1973) are unwarranted without knowledge about the underlying perceived structure. However, it fails to give appropriate emphasis to the processes by which the perceived structure is achieved. It may be reasonable to suppose that young children perceive dimensions as integral because they fail to selectively attend to or to selectively process the dimensions concerned. The tautological nature of this statement without further defining operations is obvious, but it serves to emphasize the potential relevance of processing notions to the separability hypothesis. The argument here is not with the separability notion per se. It is that the separability hypothesis, rather than treating the separability of perceptions as given, should incorporate notions regarding the processes which subjects employ when their overall performance indicates particular types of perceived structures.

## Relation to Piagetian Notions

The notion of a limitation on selective attention either as the cause or result of integral perception of stimuli suggests an important way in which the issue of integrality-separability has implications for Piagetian notions of conservation development. Specifically, one interpretation of young children's failure to conserve is that they centrate or fixate on one of the dimensions of the array and thus treat changes in that dimension as changes in volume, number, etc. (Ginsburg and Opper, 1969). For example, in discussing the young child's failure to conserve number, Ginsburg and Opper state that the child "sometimes centers on the lengths (ignoring densities) and sometimes centers on the densities (ignoring lengths), p. 148." With increasing age, children are supposed to become better at coordinating the information from the dimensions and no longer fixate or focus on one to the exclusion of the other. If young children perceive the dimensions employed as integral, then it is less reasonable to assume that they would selectively process one of the dimensions and ignore the other in a conservation task. Since the integrality of length and density is examined in the present studies, they may provide information on the reasonableness of a centration interpretation.

A qualification on the above statement is necessary, however, since Lockhead (1972) has suggested that integral stimuli can be analyzed into their components. Thus even if young children do perceive dimensions as integral, it is possible that they could decompose the stimuli into their component dimensions and fixate on only one of those components in order to answer a conservation problem.

It has also been suggested that young children can form accurate, number-based representations of small numbers of items, i.e. < 5, (Gelman, 1972; 1977), but that they tend to base numerosity judgments for larger numbers of items only on the length of the array (Gelman, 1972; Smither, Smiley, and Rees, 1974). However, other studies of direct numerosity comparisons (Brainerd, 1977) and numerosity judgments considered within a functional measurement framework (Cuneo and Anderson, 1977; Pringle and Andrews, 1977) suggest that young children's numerosity judgments are based on both the length or size and density of the arrays. Finding that length and density are integral for young children would be consistent with this latter group of studies and would suggest not only that children do use both length and density but also that they would have difficulty using one independently of the other. The qualification regarding the analyzability of integral stimuli is also applicable here.

The concern of the present studies is with the processing of the dimensions of length and density themselves rather than with the combination of those dimensions into the third dimension of numerosity. Therefore, it will be useful to examine the degree to which numerosity responses affect the data obtained in these studies.

## Other Developmental Trends

Shepp (1977) has allowed that other developmental trends in perceived structure are possible. He reported, for example, a study done in collaboration with Eimas in which the dimensions of letter type (A or E) and letter size were varied. The data were consistent with those dimensions being integral for young children and configural for older subjects. Shepp has also noted that the development of other perceived structures (e.g., asymmetric separable) is possible. Finally, he has acknowledged that some concepts and dimensions seem to be represented for adults according to a similarity structure (cf. Rosch and Mervis, 1975). However, in characterizing developmental changes, Shepp has consistently emphasized development from a single, particular structure, perceived similarity (integral perception), to some other perceived structure (e.g., separable). Implicit in this notion is the idea that integral dimensions are perceived in a similar manner by children and adults.

The possibility of trends other than from integrality to some other structure cannot be ignored. First, according to Gibson (1969), in addition to a developmental trend toward greater differentiation, there is also a trend toward integration of perceptions into higher-order units or structures. This trend in perceptual development might be expected to be manifested in a shift from separable to integral perception, exactly the opposite of the trend predicted by the separability hypothesis. Secondly, data reported by Shepp himself that children showed facilitation in a correlated sorting condition only with the more difficult of two integral dimensions (hue and brightness), could be interpreted to mean that children and adults do not treat integral dimensions alike.

There is also evidence that younger and older children treat certain other integral dimensions differently. For example, for the integral dimensions of height and width of geometric forms (see Felfoldy, 1974), young children's area judgments seem to follow a height + width rule while older children's judgments follow a height x width rule (Anderson and Cuneo, 1977). Since in these cases it is reasonable to expect an adding rule to apply for separable dimensions and a multiplying rule to apply for integral ones, the pattern of results is exactly the opposite of the patterns predicted by Shepp's hypothesis.

Young children's numerosity judgments also obey a size + density (Pringle and Andrews, 1977) or a length + density (Cuneo and Anderson, 1977) rule while those of adults obey a multiplicative rule for those dimensions. This highlights another value in using the dimensions of length and density in the present studies, i.e. the possibility of finding a trend inconsistent with the separability hypothesis as originally stated.

One final feature of Shepp's hypothesis is appropriately considered in this section. Shepp (1977) contends that "attention to alternative structures may become more labile during the course of perceptual development (p. 43)." If this notion is correct, in the present studies it may be expected that adult responses will be more affected by manipulations such as changes in the physical arrangement of the stimuli, the instructions, and the response requirements. Thus the studies described below provide a means of testing this aspect of the separability hypothesis.

## Experiments

A focal point in the preceding discussion has been a concern with the factors which underlie separable and integral responding and developmental changes in that responding. This concern was evident in considering both a stimulus and an organismic emphasis in separability, and both a perceptual learning and a strategic account of the increase in separability with increasing age. It was further evident in considering the possibility that certain tasks may affect the subject's mode of processing and thereby influence his or her tendency to give separable- or integral-type responses. In discussing the relation of the separability hypothesis to developmental trends in selective attention the importance of considering the processes by which separable and integral structures are achieved was also discussed. In addition, the importance of considering changes in response tendencies during an experiment, and the effect of those changes on developmental comparisons were discussed. Finally, the possibility that certain dimensions or tasks might lead to developmental trends other than that predicted by the separability hypothesis was discussed.

An important implication of the possibility that different tasks can lead subjects to give more or fewer separable responses is that separable and integral responding may reflect the use of different rules or strategies on the part of the subject rather than fixed, stable modes of perceiving the dimensions concerned. In view of this, one purpose of the studies to be reported was to investigate the degree to which strategic factors and perceptual limitation factors are involved in subjects' response tendencies and in the developmental difference in separable responding. The approach in investigating these issues was to examine the factors which might be expected to influence responding in tasks typically employed to investigate separable and integral dimensions. Most of the studies described employed a restricted classification paradigm in which subjects could classify stimuli according to a similarity (integral) or a dimensional (separable) structure or neither. Presumably, if strategic factors are involved, then manipulations designed to facilitate or inhibit the use of those strategies should influence subjects' tendencies to give the various types of responses. On the other hand if responding in these tasks represents stable perceptual modes of representing information about the dimensions, then subjects of the same age should show approximately the same level of the different types of responding regardless of those manipulations.

After preliminary studies (Experiments I, II, and III) to assess adult responding to the dimensions of line length and density, and to generate triads for later classification studies, the responding of 4- to 6-year-old children and adults was observed in a variety of task situations. Children of this age range were used since they have been shown to respond to what for adults are separable dimensions in an integral fashion (Shepp, 1977; Shepp and Swartz, 1976; Smith and Kemler, 1977).

In addition to examining the factors that underlie separable and integral responding and developmental changes in that responding, a second major purpose of the present studies was to assess the degree to which a tendency to show an increase in dimensional responses over trials contributes to observed developmental differences. If both age groups do show some shifting in response tendencies, then it becomes necessary to compare both their initial and asymptotic levels of responding to get a clearer picture of the developmental differences.

Different patterns of changes in responding across presentations could lead to differing interpretations of the observed developmental differences. For example, it might be the case that adults show considerably more dimensional responses than children both at the beginning and the end of an experiment. In this case it could be concluded that the two age groups came to the task with different modes of perceiving the stimuli and maintained those different modes throughout the task. On the other hand, adults and children might give approximately the same number of dimensional responses at the beginning of a task, but only the older subjects show an increase in dimensional responses over trials. In this case it would be inappropriate to conclude that the two age groups came to the task with different modes of perceiving the stimuli. Without analyzing the responses on a trial-by-trial basis, it may be impossible to distinguish between the two patterns described above since both could yield more dimensional responding overall for adults. Under these circumstances, changes which occur during the course of an experiment may be ascribed incorrectly to differences in some abstract mode of representing the dimensions used in an experiment which subjects bring to the task with them. Smith and Kemler (1977) did present each triad in their experiment more than once but did not report any systematic changes in responding across presentations. The present studies do allow a comparison of such changes.

To summarize, the purposes of the present studies were as follows. The first was to examine the classifying behavior of children and adults under a variety of task conditions in order to assess the relative contribution of strategic and perceptual limitation factors in separable and integral responding and the developmental trend toward separability. Another major focus of the present studies was to examine the tendency of adults and young children to show an increase in dimensional responding over trials, and the contribution of such increases to observed developmental differences. The final purpose was to provide data on any developmental changes in the overall separability of the dimensions of length and density.

## Experiment Ia

The first experiment had two main purposes. One was to gain information regarding the metric which would most accurately describe adult's similarity judgments for the dimensions of line length and line density. Density here refers to the separation between the dots composing the lines. Presumably, if the dimensions are integral, then the metric would most closely approximate a Euclidean one, whereas a city-block metric would apply if the dimensions are separable. The second purpose of this experiment was to provide relative similarity ratings to be used in selecting stimulus sets for later classification studies.

### Method

Stimuli and materials. The stimulus set consisted of the 16 possible combinations of four levels on each of the dimensions of line length and density. The lengths were 1, 2, 3, and 4 cm. The densities, in terms of inter-dot distance, were 1, .5, .25, and .125 cm. These values were expected to represent roughly comparable levels of discriminability along the two dimensions. The stimuli were typed onto 7.6 x 12.7 cm plain white index cards using the "period" key of a Remington Automatic typewriter. There was one stimulus per card. Response forms consisted of a 20-page booklet each page of which contained 6 equally spaced 10 cm horizontal lines. The lines had the words "very similar" typed at the left end and "very dissimilar" typed at the right end.

Subjects. The subjects, six undergraduates enrolled in introductory psychology courses at the University of Wisconsin, received "experimental points" for their participation. Two subjects were male and four were female.

Procedure. Subjects were tested individually in a well-lighted room. They were shown pairs of cards from the stimulus set described above and were asked to judge the similarity between the members of each pair. Subjects indicated each of their similarity judgments by making a mark at some point along one of the 10 cm lines in the response booklet. Prior to each subject's first judgment, he or she was required to examine the 16 individual items of the stimulus set to become familiar with the range of similarities and differences among the members of the set. This was done to minimize instability in the subjects' first few similarity judgments.

One-hundred and twenty pairs can be constructed from the set of 16 stimuli. Each subject judged all 120 pairs. A random sequence for presenting the pairs was generated with the restriction that no individual item appear in two consecutive pairs. Half of the subjects received the pairs according to that sequence while the reverse of the sequence was used for the other half of the subjects.

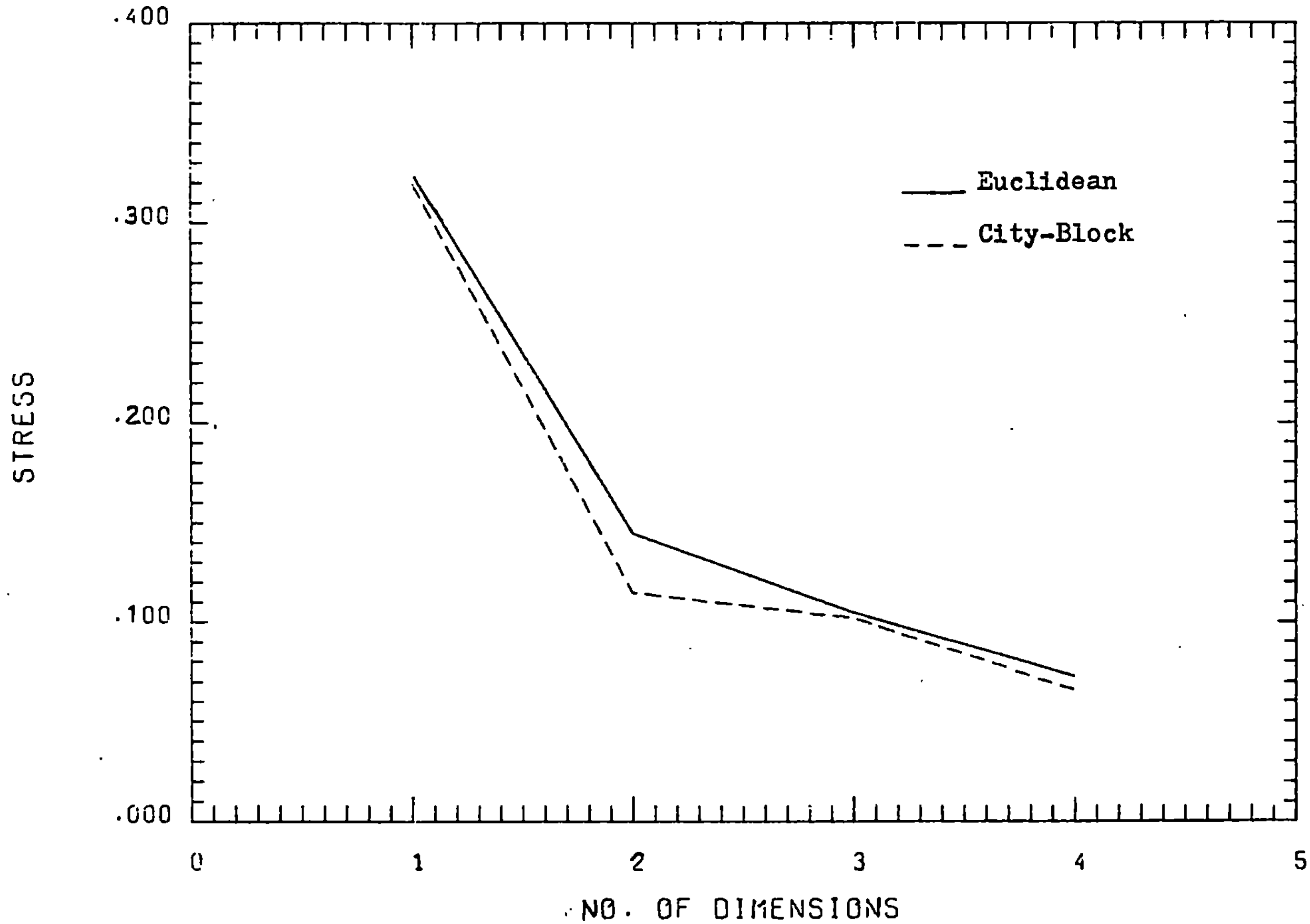
### Results and Discussion

Scoring. The position of each subject's mark on each line was measured with a ruler to the nearest ½ cm in assigning an integer value between 0 and 20 to the subject's ratings. The nearer the subject's response was to "very similar" the lower the score was for that particular pair. The closer to "very dissimilar" the response was, the higher the score for that pair. These values were taken to represent distances in some n-dimensional space, in which the most dissimilar items are the most distant.

Analysis. The similarity ratings were analyzed via a program called KIST. The program uses the similarities as distances to generate the "best possible" configuration for the stimuli in a set in an n-dimensional space, assuming a particular metric. The program provides a nometric (monotone) fit to the data. Configurations or solutions in one, two, three, and four dimensions were generated using both city-block and Euclidean metrics. The program also provides a measure of stress or badness-of-fit of the final configuration in each case. This measure is based on deviations of the distances of items from one another in the final configuration from those distances as given by subjects' similarity ratings.

There are three primary features of this analysis to be considered. The first can be seen in Figure 1. In that figure, the stress for each final configuration is plotted against the number of dimensions used in that configuration, separately for city-block and Euclidean metrics. As can be seen, stress decreased as the number of dimensions considered increased. The greatest improvement occurred in going from one to two dimensions (.3225 to .1300) with somewhat less improvement when using three (.1035) or four (.0695) dimensions. Given that fitting a model to any set of data is easier with more degrees of freedom (dimensions) this latter small amount of improvement is to be expected. The pattern of results, considerable improvement with a two- over a one-dimensional solution and somewhat less change thereafter, suggests that subjects

Figure 1. Stress for the final configuration in 1 through 4 dimensions assuming a city-block and Euclidean metric.



.400
.300
.200
.100
.000
STRESS
Euclidean
City-Block
0
1
2
3
4
5
NO. OF DIMENSIONS

may have been using primarily two dimensions in rating the stimuli.

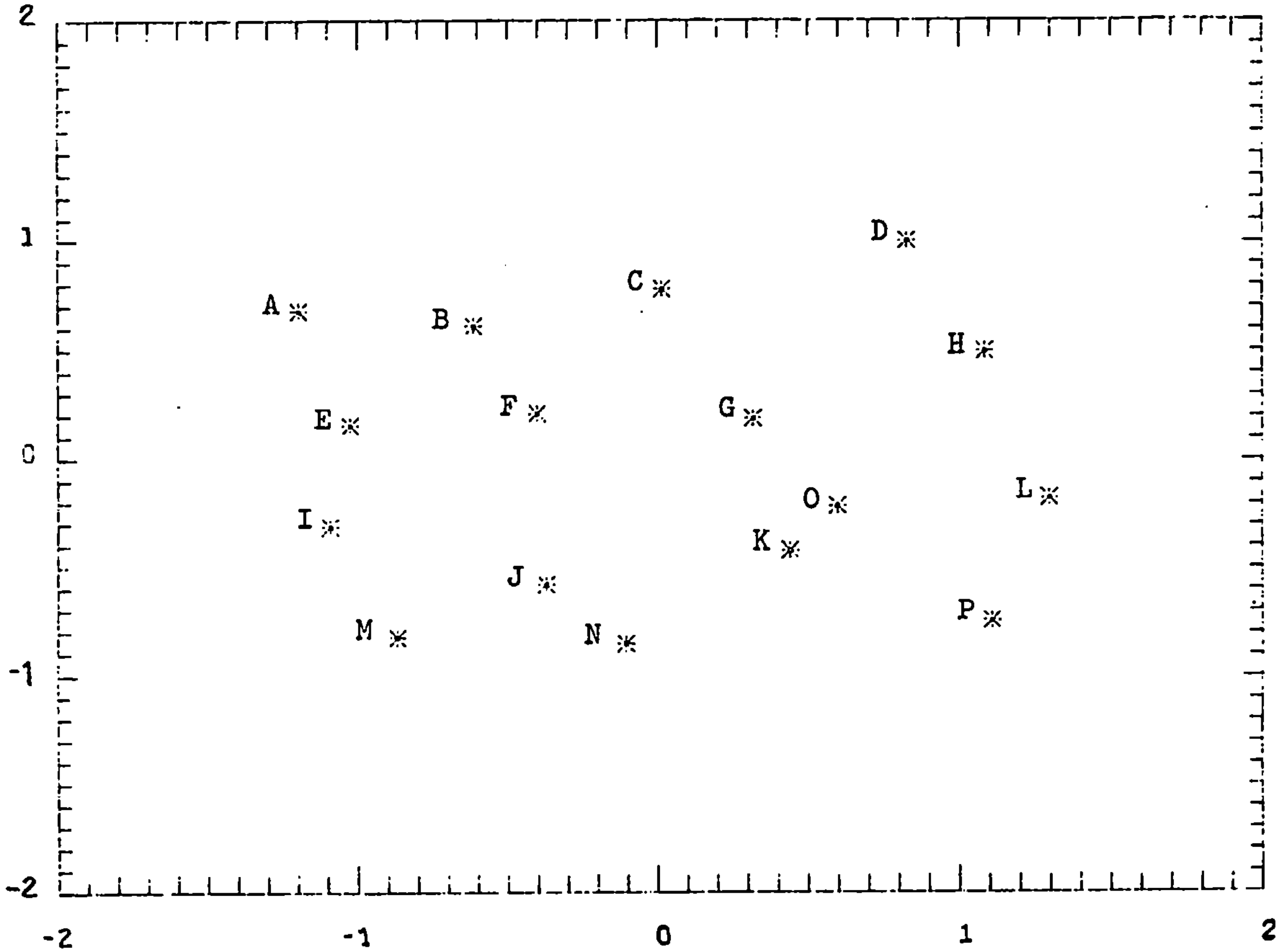
A second important feature of the data is also presented in Figure 1. As shown, the stress for each n-dimensional solution was virtually the same for the city-block and Euclidean cases except for the two dimensional solution. In that case, the stress was slightly lower for the city-block than for the Euclidean solution (.115 vs .145).

The third feature of interest in the data is that the final configuration in two dimensions indicates that length and density are likely candidates for the two dimensions used by subjects. Using the labels assigned to the stimuli by the KIST program, a two-dimensional space defined by the dimensions of length on the Y axis and density on the X axis would appear as the four rows of four letters each, A B C D, E F G H, I J K L, and M N O P. As shown in Figure 2, the final configuration in two dimensions using the city-block metric is very similar to the length-density configuration. The functions relating subjects' given similarity ratings to the distances as recovered by the program were not excessively step-like. Thus there is no evidence of "degeneracy" (see Shepard, 1974) or failure to preserve the structure contained in subjects' ratings and the configuration shown in Figure 2 can reasonably be interpreted as reflecting that structure.

To summarize, the results indicate that subjects used primarily two dimensions, length and density, in their similarity comparisons, and a city-block metric did a slightly better job than a Euclidean metric in describing the data.

Selection of triads. Since one way to distinguish between separable and integral dimensions is that the former are classified on the

Figure 2. Final configuration in two dimensions assuming a city-block metric.


2
1
0
-1
-2
-2
-1
0
1
2
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P

basis of dimensional structure while the latter are classified on the basis of similarity, an attempt was made to generate triads for a restricted classification study in which similarity and dimensional classifications would be in conflict. Triads of stimuli were examined in which two members shared a level on one dimension while differing substantially on the other dimension (dimension pairs) and the third member differed slightly from one of the others on both dimensions (similarity pairs). Only those triads for which at least five of the six subjects rated the similarity pair as more similar than the dimension pair were considered further. From that group, triads were chosen to maximize the mean similarity-rating difference between the dimension pair and similarity pair, and to minimize the overlap among triad members. No pair of stimuli appeared in more than one chosen triad. These selection criteria resulted in five triads in which the shared dimension was length and only one triad in which the shared dimension was density. These triads are included in Appendix C. Apparently, even the maximum length difference for items sharing a level of density was not great enough to yield reliably (according to the present criteria) lower similarity ratings than those for items with single-level differences on both dimensions. In order to provide more triads in which the shared dimension was density, a second similarity-rating study was carried out in which the range of length differences was extended.

## Experiment Ib

### Method

Stimuli and materials. The stimuli and materials were the same as in Experiment Ia except that the four lengths employed in Experiment Ib were 1, 2, 4, and 8 cm.

Subjects. The subjects were six undergraduates, four males and two females, drawn from the same subject pool as described in Experiment Ia.

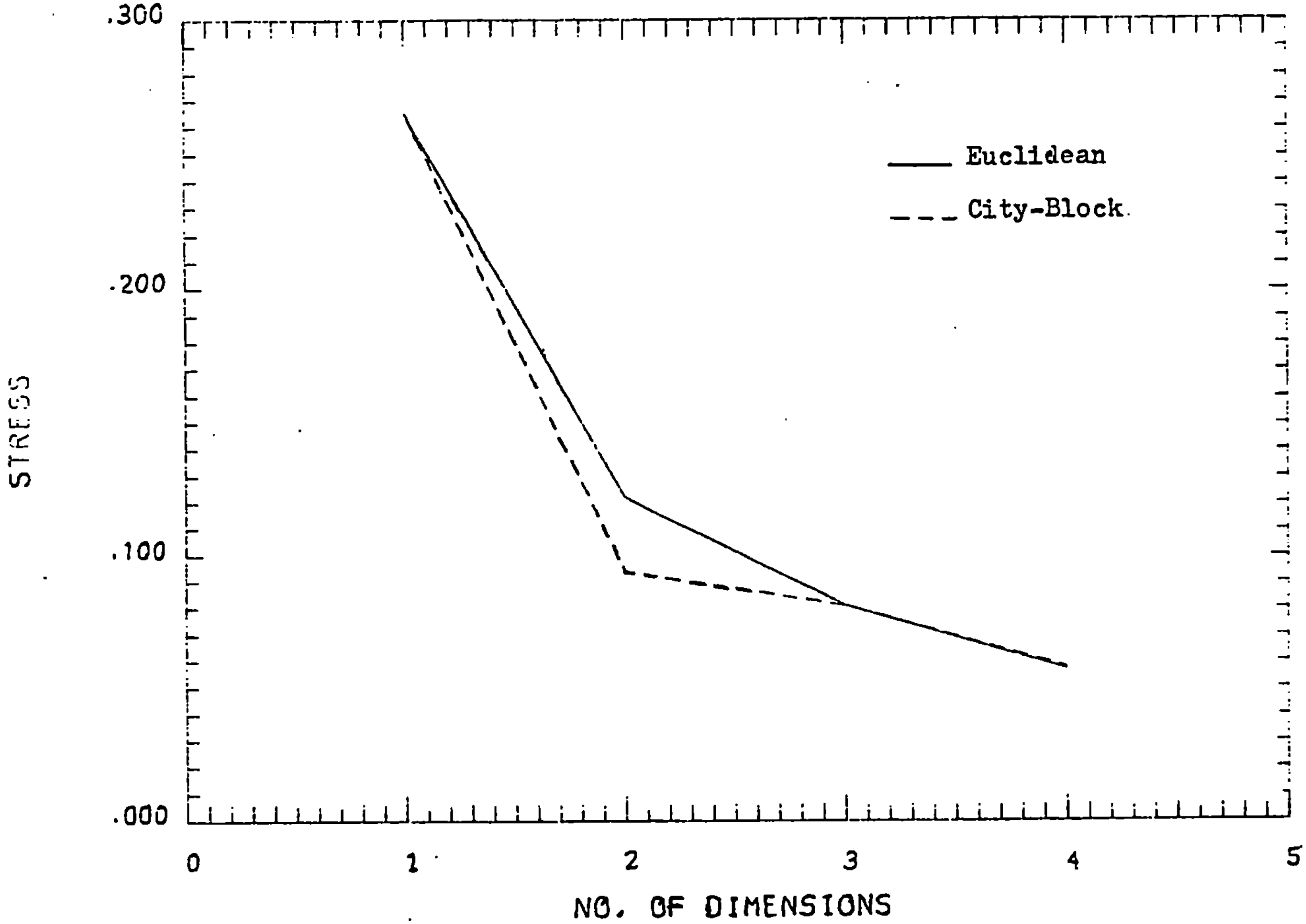
Procedure. The procedure was identical to that of Experiment Ia.

### Results and Discussion

The results of this study provide essentially a replication of Experiment Ia, and are shown in Figures 3 and 4. As can be seen by examining Figure 3, the greatest improvement in terms of stress occurred in going from one to two dimensions (.266 to .108), and there was less stress for the city-block than for the Euclidean two-dimensional solutions (.094 vs .122). An examination of Figure 4 reveals that the configuration in two dimensions is very similar to the length-density configuration. As in Experiment Ia, there was no evidence of degeneracy in the functions relating similarity ratings to recovered distances.

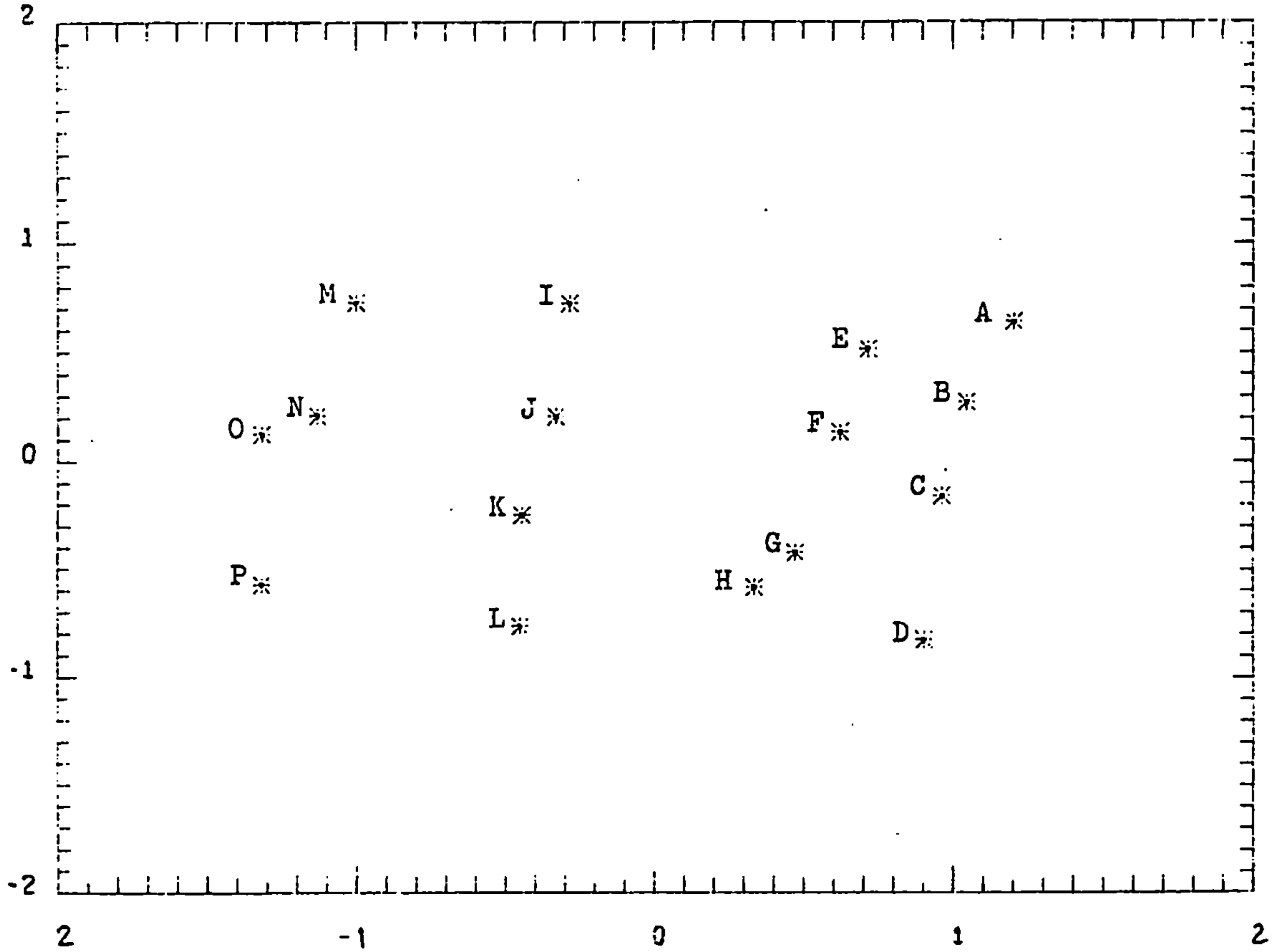
Taken together the results of Experiments Ia and Ib indicate that subjects were basing their similarity ratings on the two dimensions of concern in the present studies, i.e. length and density. Further the results are consistent with those dimensions being either separable or asymmetric separable for adults since a city-block metric resulted in

Figure 3. Stress for the final configuration in 1 through 4 dimensions assuming a city-block and a Euclidean metric.



.300
.200
.100
.000
STRESS
Euclidean
City-Block
0
1
2
3
4
5
NO. OF DIMENSIONS

Figure 4. Final configuration in two dimensions assuming a city-block metric. (Note that the configuration is rotated 90$^{\circ}$ from that in Figure 2.)



2
1
0
-1
-2
2
-1
0
1
2
M
I
A
E
B
N
J
O
F
C
K
G
P
H
L
D

less stress than a Euclidean metric for the two dimensional solution.

Selection of triads. The increase in the range of length differences was effective and four additional triads in which density was the shared dimension were selected according to the criteria described in Experiment Ia. These triads are also included in Appendix C.

Numerosity. The data do not provide any evidence for subjects making similarity ratings on the basis of numerosity. Presumably, a tendency toward numerosity comparisons would be reflected in a one dimensional solution. As can be seen in Figures 1 and 3 the stress associated with one-dimensional solutions was quite high for both sets of data. In addition, the proximities of the items in the one dimensional solution were not directly related to the number of dots composing each item.

## Experiment II

This study employed a constrained classification paradigm with the triads selected on the basis of Experiment I similarity data. If the dimensions of length and density are separable, their dimensional structure should dominate and subjects should show a tendency to group together items sharing a level on one of the dimensions. If the dimensions are integral, overall similarity rather than dimensional structure would be important, and subjects should tend to group together the most similar pair which differ slightly on both dimensions. Haphazard responses, favoring neither dimensionality nor similarity, should be at a minimum. It can also be predicted that if adults discover anything about the dimensional structure of the stimuli during the course of the experiment, they will show an increase in dimensionally based responses over trials. Thus, the purposes of the present study were to gain more information regarding the separability/integrality of the dimensions of length and density for adults, and to assess any changes in responding over trials to those dimensions.

Method

Stimuli. The stimuli were the 10 triads selected on the basis of data from Experiments Ia and Ib. Five had two members sharing a level of density and five had two members sharing a level of length. These members differed substantially on the length and density dimensions respectively. Each triad also contained two members differing slightly on both dimensions and being rated as more similar than those sharing a level on a single dimension. Each member of each triad was typed on a separate 7.6 x 12.7 cm index card.

Subjects. The subjects were eight undergraduates (five females, three males) enrolled in introductory psychology courses and received experimental points for their participation in the experiment.

Procedure. The subjects were tested individually in a well-lighted room. They sat across a small table from the experimenter who arranged the members of the triad for each trial in a row on the table. Subjects were instructed to "put together in a group the two which most go together." Subjects indicated their choices by picking up the chosen two and handing them to the experimenter. The experimenter then recorded the subject's response and presented the next triad in the sequence. Each triad was presented 4 times (trials) for a total of 40 presentations for each subject. 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.

Results and Discussion

Dimensional vs Similarity Classifications. The overall proportions of similarity, dimensional, and haphazard classifications were .41, .57, and .02 respectively. This pattern of results is consistent with the dimensions being either separable or asymmetric separable in agreement with the results of Experiment I. However, the apparent dominance in the number of dimensional over similarity classifications did not reach statistical significance, $t(7) = 1.25$, $p > .10$, $SE = 5.48$, with 4 of the subjects giving more dimensional than similarity responses, 3 showing the opposite pattern, and 1 showing no difference. Furthermore, the overall results obscure two important trends in the data. First, the dimensional responses occurred primarily for triads in which the shared dimension was density, with the proportion of similarity, dimensional, and haphazard responses for these triads being .07, .92, and .01 respectively. All 8 subjects gave more dimensional responses than any other type. Similarity responses dominated for the length-shared triads, with the proportion of similarity, dimensional, and haphazard responses being .74, .23, and .03 respectively. Six of eight subjects gave more similarity responses than any other type. This pattern of results is consistent with a strong preference for density since the "similarity" pairs for the length-shared triads are also the members of those triads that are closest in density.

The second important trend in the data involves changes in the relative proportions of responses across the four presentations of each triad. Table 1 shows the proportion of each type of response for the first through fourth presentation of each triad. The data for triads in which length and density were the shared dimensions are presented separately. As can be seen from the table, dimensional responses increased across trials.

In order to examine both of these factors further, an analysis of variance was conducted with the number of dimensional responses as a dependent variable and triad type (length-shared or density-shared) and trials (1-4) as within subject factors. Consistent with the above observations there were significantly more dimensional responses given for density-shared than for length-shared triads, $\underline{F}(1,7) = 37.80$, $\underline{p} < .01$, $\underline{MSe} = 4.821$. The effect of trials, however, was only marginally significant, $\underline{F}(3,21) = 2.98$, $.10 > \underline{p} > .05$, $\underline{MSe} = .518$. The interaction of triad type and trials did not approach statistical significance, $\underline{F}(3,21) = .38$, $\underline{p} > .25$, $\underline{MSe} = .542$, indicating that whatever shifting toward dimensional responses did occur, it occurred to a roughly comparable degree for both types of triads. Since the greatest amount of change in dimensional responding occurred between trials 1 and 2, a $\underline{t}$-test was used to examine further that change by comparing the number of dimensional responses given by each subject on trial 1 to the average number of dimensional responses given on trials 2-4. That test revealed

Table 1

Proportion of similarity, dimensional, and haphazard classifications across trials for each type of triad

| | Type of Triad | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Length-Shared Trials | | | | Density-Shared Trials | | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Similarity | .875 | .750 | .650 | .675 | .125 | .050 | .075 | .050 |
| Dimensional | .125 | .225 | .300 | .275 | .850 | .925 | .925 | .950 |
| Haphazard | .000 | .025 | .050 | .050 | .025 | .025 | .000 | .000 |

a significant increase in dimensional responses from trial 1 to later trials, $t(7) = 1.925$, $p < .05$, $SE = .606$. Separate t-tests for individual trial comparisons yielded a significant t only for the comparison of dimensional responses on trial 1 to those on trial 4, $t(7) = 2.023$, $p < .05$, $SE = .679$.

The results of the present study are suggestive rather than conclusive. They suggest that the dimensions used are separable (i.e., adults gave mostly dimensional responses), but the dominance of dimensional responses was not statistically significant. They suggest further that subjects have a strong bias toward density classifications and that adults may show increases in dimensional responses across trials for both length-shared and density-shared triads. The shift to dimensional responses could indicate that subjects are discovering the dimensional structure of the stimuli during the course of the experiment. Furthermore, if the shift toward dimensional classifications is found to be reliable in later experiments, the result would imply that separability as measured in the present context reflects something other than a stable mode of perceiving the stimuli. In any case, a change in the number of dimensional responses given over trials will be particularly important to consider in developmental studies of classification with the present stimuli since adults and children may shift to dimensional responses at different rates.

Numerosity. There is no evidence that subjects were basing their classifications on numerosity. If subjects adopted a rule to put together those stimuli which were closest in the number of dots, a particular pattern of results would be predicted. For all of the length-shared and for four of the density-shared triads such a response rule would lead subjects to put together those stimuli which would also be put together on the basis of a similarity rule. Thus if a numerosity rule were being used, all of these triads should be dominated by similarity responses. Although there were many similarity responses for the length-shared triads, there were very few for the density-shared triads which were clearly dominated by dimensional responses. For one of the triads, the items which are closest in number are the ones which would be put together as a haphazard response. Two haphazard responses were given to that triad, but two were also given for each of two other triads, and that triad was clearly dominated by dimensional responses (87.5%).

## Experiment III

The results of Experiment II suggest, among other things, that subjects may have a strong preference for density over length as a dimension for classification. In fact the possibility exists that when two members of a triad share a value of density, length is not considered at all. In order to examine this possibility and adult preferences for one or the other of the dimensions in general, triads were selected such that one member shared a level of length with a second member of the triad and a level of density with the remaining member. Three examples of each of five types of triads were chosen on the basis of the similarity data from Experiment I. The five types of triads were: one in which the similarity responses highly favored and one in which they moderately favored classification according to length (Types I and II, respectively), one in which they highly favored and one in which they moderately favored density classifications (Types V and IV, respectively), and one in which the similarities were approximately equal for each type of classification (Type III). The triads are shown in Appendix C.

Method

Stimuli. The stimuli were as described in the introduction to this experiment. The average ratio of the similarity rating for the density pair to that for the length pair was 3.59, 1.71, .99, .63, and .31 for the Type I, II, III, IV, and V triads respectively. It should be noted that higher numbers on the similarity scale reflect greater dissimilarity. Thus, for example, the 3.59 ratio of the ratings for the density pairs to those for the length pairs in the Type I triads reflects more dissimilarity for the density pairs than for the length pairs. The triads for each triad type were selected to yield roughly equivalent steps in the ratio described above.

Subjects. The subjects were eight undergraduates (six males, two females) enrolled in introductory psychology classes who received experimental points for their participation.

Procedure. Each triad was presented three times for a total of 45 trials for each subject. The presentation and sequencing of triads, the instructions, and the subjects' response mode were as described in Experiment II.

Results and Discussion

The results are shown in Table 2 as the proportion of "density" classifications for each triad type. There was clearly a strong preference for density classifications with 72% of the classifications being based on density and 7 of 8 subjects giving more density responses than either length or haphazard classifications. Even when similarities highly favored length classifications, 48% of the triads were grouped according to density. The same observation, however, indicates that a shared value of density does not completely determine responding. When the similarity-rating advantage for length was great (Type I), 51% of the classifications given were according to length. Examination of Table 2 also reveals that the number of density responses was systematically related to the similarity relationships in the triads. The more similarity favored classification according to density, the more density responses were given. In order to examine this trend further, the number of density responses was used as a dependent measure in an analysis of variance with triad type and trials as within subject variables. The only significant effect in that analysis, triad type, $F(4,28) = 6.01$, $p < .005$, $MSe = 1.310$, is consistent with the observed trend. The results of a trend analysis on the effect of triad type are also consistent with the observation of a systematic increase in density responses across triads in which similarity relationships increasingly favor density classifications. Only the linear component of that effect was found to be significant, $F(1,7) = 11.308$, $p < .025$, $MSe = 2.6$.

Table 2

Proportion of "density" classifications for each type of triad

| Type of Triad | | | | |
|---|---|---|---|---|
| I | II | III | IV | V |
| .48 | .61 | .75 | .77 | .99 |

The strong preference for density over length as a basis of classification is consistent with those dimensions being either separable or asymmetric separable, and lends support to the suggestive evidence for such a preference in Experiment II. Further, the present results indicate that density does not completely determine responding in the sense that many length classifications were given even though all triads had two members sharing a level of density.

Numerosity. For 7 of the 15 triads used, the response which would put together the items closest in number would be classified as a haphazard response. The proportion of haphazard responses for these triads was .059. The triads were clearly dominated by length and density responses. Thus there is little evidence from this experiment to support the view that adults classify the stimuli on the basis of numerosity.

## Experiment IVa

One factor which favors classifications according to density over those according to length may be the physical arrangement of the stimuli in Experiments II and III. The cards were arranged in a row, and that arrangement could make length comparisons difficult. One purpose of the present experiment was to present the stimuli in a columnar arrangement which would facilitate length comparisons and to examine the effect of that arrangement on the salience of length as a dimension, and on subject's overall tendency to give dimensional vs similarity responses. Presumably, the more readily the items can be compared along particular dimensions, the more likely those dimensions are to be used as bases for classification.

Another purpose of the present experiment was to provide essentially a replication of Experiment II in order to assess the reliability of the increase in dimensional classifications, and to examine the effects of the stimulus arrangement on that shift.

The final purpose was to examine young children's perception of the length and density stimuli. This involved an examination of their overall tendency to give similarity or dimensional responses, their tendency to shift to dimensional classifications across trials, and the degree to which their responses were affected by the physical arrangement of the stimuli. The separability hypothesis predicts that, overall, children will give fewer dimensional responses than adults, and that their responses will be dominated by similarity choices. In addition, according to the notions of flexibility in perceived structure as discussed by Shepp (1977), it can be predicted that children will be less affected than adults by the stimulus manipulation. Finally, assuming that it is useful to consider a shift toward dimensional responding as a measure of some aspect of dimensional learning, it can be predicted that children will be less likely than adults to show such a shift. This is so since children can be expected to show slower or less complete dimensional learning than adults (see e.g., Gibson, 1969).

## Method

Stimuli. The stimuli were the 10 triads used in Experiment II. Rather than having a single stimulus per card as in that experiment, all three stimuli of a particular triad were depicted on a single index card or on a sheet of white paper cut to 7.6 by 27.9 cm. For the triads presented on the sheets of paper (linear condition) the stimuli were arranged linearly as they had been in Experiment II. 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 stimuli were depicted 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.

Subjects. The subjects were 24 undergraduates (9 males and 15 females) enrolled in introductory psychology courses and 16 children (9 males and 7 females), between the ages of 4 years, 1 month and 6 years, 3 months recruited from day-care centers in the Madison area.

Procedure. Due to the arrangement of the stimuli on the cards as described above, each triad was presented three times rather than four times as in Experiment II. The sequencing of the triads was randomized as described in Experiment II. 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 on score sheets. 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 4 males and 8 females, and the columnar group was composed of 5 males and 7 females. The respective numbers for the children's groups were 5 males and 3 females and 4 males and 4 females. The mean ages for the young columnar and linear groups were 5 years 4 months and 5 years 1 month, respectively.

Results and Discussion

Table 3 presents the proportion of each type of response for the length-shared and density-shared triads separately across trials 1 to 3 for both age groups in each presentation condition. Several features of the data can be seen in examining Table 3. First, overall, adults gave more dimensional responses than did children and also gave more dimensional responses for the columnar 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 (consistent with Experiment II) 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 subjects'

Table 3

Proportion of similarity (S), dimensional (D), and haphazard (H) responses broken down for each factor

| | | Type of Triad | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Length-Shared Trial | | | | Density-Shared Trial | | | | Combined Trial | | | |
| Group | Re-sponse | 1 | 2 | 3 | $\bar{X}$ | 1 | 2 | 3 | $\bar{X}$ | 1 | 2 | 3 | $\bar{X}$ |
| Adult Columnar | S | .717 | .700 | .567 | .661 | .067 | .000 | .000 | .022 | .392 | .350 | .283 | .342 |
| | D | .200 | .250 | .333 | .261 | .883 | .983 | .983 | .950 | .542 | .617 | .658 | .605 |
| | H | .083 | .050 | .100 | .078 | .050 | .017 | .017 | .028 | .067 | .033 | .058 | .053 |
| Adult Linear | S | .933 | .900 | .883 | .906 | .317 | .200 | .200 | .239 | .625 | .550 | .542 | .572 |
| | D | .033 | .050 | .050 | .044 | .617 | .750 | .800 | .722 | .325 | .400 | .425 | .383 |
| | H | .033 | .050 | .067 | .050 | .067 | .050 | .000 | .039 | .050 | .050 | .033 | .044 |
| Adult Combined | S | .825 | .800 | .725 | .783 | .192 | .100 | .100 | .131 | .508 | .450 | .413 | .457 |
| | D | .167 | .150 | .192 | .153 | .750 | .867 | .892 | .836 | .433 | .508 | .542 | .494 |
| | H | .058 | .050 | .083 | .064 | .058 | .033 | .008 | .033 | .058 | .042 | .046 | .049 |
| Child Columnar | S | .650 | .700 | .700 | .683 | .375 | .525 | .425 | .412 | .513 | .613 | .563 | .563 |
| | D | .175 | .200 | .125 | .167 | .425 | .325 | .425 | .392 | .300 | .263 | .275 | .279 |
| | H | .175 | .100 | .175 | .150 | .200 | .150 | .150 | .167 | .187 | .125 | .163 | .158 |
| Child Linear | S | .750 | .500 | .625 | .625 | .525 | .425 | .550 | .500 | .637 | .463 | .587 | .563 |
| | D | .150 | .325 | .200 | .225 | .275 | .375 | .275 | .308 | .213 | .350 | .237 | .267 |
| | H | .100 | .175 | .175 | .150 | .200 | .200 | .175 | .192 | .150 | .187 | .175 | .170 |
| Child Combined | S | .700 | .600 | .663 | .654 | .450 | .475 | .488 | .471 | .575 | .538 | .575 | .563 |
| | D | .163 | .263 | .163 | .196 | .350 | .225 | .350 | .350 | .256 | .306 | .256 | .273 |
| | H | .137 | .137 | .175 | .150 | .200 | .175 | .163 | .179 | .169 | .156 | .169 | .164 |

variables and triad type (length-shared vs density-shared) and trials (1-3) as within subject variables. 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. This result is consistent with the prediction from the separability hypothesis of greater separability of dimensions with increasing age. Also consistent with the separability hypothesis, individual t-tests revealed that children's responding was dominated by similarity classifications. Children gave significantly more similarity than dimensional responses in both the linear and columnar conditions, $t(7) = 3.185$, $p < .01$, $SE = 2.875$, and $t(7) = 4.14$, $p < .005$, $SE = 2.053$, respectively. Adults, on the other hand, gave more dimensional than similarity responses in the columnar condition, $t(11) = 3.011$, $p < .01$, $SE = 2.6$, and more similarity responses in the linear condition, $t(11) = 2.722$, $p < .01$, $SE = 2.083$. The analysis of variance also revealed a significant effect of trials, $F(2,72) = 3.55$, $p < .05$, $MSe = .555$, with more dimensional responses occurring on later trials. Subsequent t-tests revealed significantly more dimensional responses on trials 2 and 3 than on trial 1, $t(39) = 2.736$, $p < .005$, $SE = .228$, and $t(39) = 2.36$, $p < .025$, $SE = .265$ respectively. In addition, there was a marginally significant age x trials interaction, $F(2,72) = 2.71$, $.10 > p > .05$. Since this particular interaction was of major interest in the present study, it was investigated further. A comparison of the data for children and adults in Table 3 reveals that only the adults showed consistent increases in dimensional responses across trials. Children showed an increase 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. Given this possible reduction in the age x trials interaction, an analysis which compares the shape of the curves relating trials to number of dimensional responses for children and adults may be better to test the developmental effect of interest. Trend analyses revealed a significant linear component, $F(1,22) = 12.201$, $p < .001$, $MSe = .5336$, and a nonsignificant quadratic component, $F(1,22) = .354$, $p > .25$, $MSe = .481$, in the change over trials for adults, and no linear component, $F=0$, and a nonsignificant quadratic component, $F(1,14) = 1.647$, $p > .20$, $MSe = .809$ for children. Thus although the expected interaction of age and trials was only marginally significant, the subsequent trend analyses confirmed that adults but not children showed consistent increases in dimensional responses over trials. As noted, this result is to be expected if the increase in dimensional responses reflects a discovery of the dimensional structure of the stimuli. A final comparison relevant to the interaction of age and trials is that adults gave more dimensional responses than children on all trials, $t(38) = 3.523$, $p < .005$, $SE = .514$, $t(38) = 3.455$, $p < .005$, $SE = .585$, and $t(38) = 4.579$, $p < .001$, $SE = .623$, 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 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 the interaction is that adults gave more dimensional responses in the columnar than in the linear condition, $t(22) = 3.891$, $p < .005$, SE = 1.735, but children did not, $t(14) = .206$, $p > .40$, SE = 1.822. The physical arrangement factor affected adults' responding in the expected direction. That is, the columnar condition which was expected to facilitate comparison along the dimensions resulted in more dimensional responses. The 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.

The only other significant effects in the main analysis were triad type, $F(1,36) = 53.24$, $p < .001$, MSe = 4.806, and triad type x age, $F(1,36) = 21.42$, $p < .001$, MSe = 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 = .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 as noted in Experiment II the triad type effect may reflect a preference for density as a basis of classification, the triad type x age interaction is consistent with less preference in responding on the part of children. This too is consistent with the separability hypothesis since preferences are only supposed to apply in the case of separable dimensions.

Adults gave so few haphazard responses that a trial-by-trial analysis of these responses was not feasible. The overall number of haphazard responses was used in an analysis of variance with the between subjects factors of age and arrangement. The only significant effect in that analysis was age, $F(1,36) = 31.49$, $p < .001$, $MSe = 3.779$, indicating that children gave significantly more haphazard responses than did adults. The same type of 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 x arrangement, $F(1,36) = 6.82$, $p < .025$, with $MSe = 16.037$ 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, $t(18) = .573$, $p > .20$, $SE = 1.767$.

Since there was an imbalance in the relative proportions of males and females in the two age groups, it was conceivable that sex differences contributed to the observed age differences. Statistical tests did not bear this out, however. Males and females did not give significantly different numbers of dimensional responses in either age group, $t(22) = .710$, $p > .20$, $SE = 1.690$ for adults, and $t(14) = 1.604$,

$\underline{p} > .10$, $\underline{SE} = 2.281$ for children.

Finally, there was no apparent difference in responding as a function of age within the group of children tested.

To summarize, the results of Experiment IVa revealed that, overall, children treat length and density as integral dimensions, show no consistent tendency to shift to dimensional responding over trials, and are relatively unaffected by a change in the physical arrangement of the stimuli. Thus even with a physical aid (i.e., a columnar arrangement) in discovering the dimensional structure and experience with the dimensions, children do not adopt dimensional modes of responding. Adults on the other hand treat the dimensions more separably, show even more dimensional responses on later trials, and are affected by the physical arrangement of the stimuli.

## Experiment IVb

There was no evidence in Experiment IVa to support the contention that subjects were classifying items on the basis of numerosity. As a final check on this possibility, however, a group of 16 undergraduates who received experimental points for their participation was instructed to classify the items on the basis of number, and the results were compared to those from Experiment IVa. Half of the subjects (4 males, 4 females) received the linearly arranged stimuli and half (2 males, 6 females) received the columnar arrangement. The proportion of similarity, dimensional, and haphazard responses for the "numerosity" subjects are presented in Table 4 separately for the linear and columnar arrangements. As can be seen by comparing Tables 3 and 4, the results

Table 4

Proportion of each type of response for subjects instructed to classify on the basis of numerosity

| | Type of Response | | |
|---|---|---|---|
| Group | Similarity | Dimensional | Haphazard |
| Columnar | .758 | .071 | .171 |
| Linear | .713 | .104 | .183 |

were quite different from those of Experiment IVa with subjects in the "numerosity" conditions giving more responses classed as similarity responses for both of the stimulus arrangements than did the subjects in Experiment IVa. This general observation was confirmed by the results of an analysis of variance conducted with the total number of similarity responses for each subject as a dependent measure, and arrangement (linear vs columnar) and instructions (Experiment IVa vs numerosity) as between subjects variables. The effects of arrangement, instructions, and arrangement x instructions were all significant, $F(1,36) = 5.157$, $p < .025$, $F(1,36) = 29.002$, $p < .001$, and $F(1,36) = 7.510$, $p < .025$, respectively with $MSe = 22.416$ in each case. Subsequent $t$-tests revealed that "numerosity" subjects gave significantly more similarity responses than did subjects from Experiment IVa in both the linear, $t(18) = 1.827$, $p < .05$, $SE = 2.212$, and columnar, $t(18) = 5.89$, $p < .005$, $SE = 2.109$, conditions. The shift toward similarity responding with "numerosity" instructions is to be expected since for 9 of the 10 triads the items classified together by such a response are the ones closest to one another in number. Thus it is reasonable to conclude that numerosity responding is not a major factor in the present studies. The interaction of arrangement and instructions is based on the fact that subjects in Experiment IVa gave more similarity responses in the linear than in the columnar condition, $t(22) = 4.012$, $p < .005$, $SE = 1.682$, while the "numerosity" subjects did not show a significant difference between the conditions, $t(14) = .584$, $p > .25$, $SE = 2.782$. Thus the Experiment IVb subjects differed from those in

Experiment IVa not only in terms of overall number of similarity responses, but also in the fact that the latter but not the former were influenced by the stimulus arrangement.

## Experiment V

Since the manipulation of the stimulus arrangement had a large impact on adults responding in Experiment IVa, the present experiment was conducted to examine the effects of that factor on subjects' preference for length vs density. Presumably if the columnar arrangement facilitates length comparisons, that arrangement could reduce the preference for density classifications which was demonstrated in Experiment III. Reducing the preference for density could result in an overall pattern of responses more in line with the similarity ratings among the triad members. Such a result would be particularly interesting since it would mean that the same manipulation which shifted subjects' responses toward greater separability in Experiment IVa would shift them toward greater integrality (similarity based classifications) in the present experiment. In addition, the present experiment provides another measure of the overall separability of length and density for children, and the degree to which children's responding can be influenced by the physical arrangement of the stimuli. According to the separability hypothesis, children should not show a preference for one or the other of the dimensions since such a preference would be consistent with separable rather than integral perception.

Method

Stimuli. The stimuli were the 15 triads described in Experiment III. All three stimuli of a particular triad were depicted on a single index card or sheet of paper as discussed in Experiment IVa. Each triad member appeared once in each position (top, middle, or bottom of the card, or left, middle, or right side of the sheet) and each response type (density, length, or haphazard) appeared one in each possible combination of the three positions.

Subjects. The subjects were 16 undergraduates enrolled in introductory psychology courses and 16 4-6 year-olds (range = 4 years, 1 month to 6 years, 3 months) recruited from day-care centers in the Madison area. There were 14 female and 2 male undergraduates and 13 female and 3 male children.

Procedure. Subjects were tested individually, with half in each age group receiving the stimuli in the linear arrangement and half receiving the columnar arrangement. One male and seven female adults were in each of the arrangement conditions. For children, there were seven females and one male in the linear condition and six females and two males in the columnar condition, and both groups had mean ages of 5 years, 2 months. Each triad was presented 3 times for a total of 45 presentations, and the order of presentation was randomized as described in Experiment II. Adults were instructed to put together the two which "most go together" by writing the letters for that pair on an answer sheet, and children were instructed to do so by pointing as discussed in Experiment IVa.

Results and Discussion

The results are shown in Table 5 as the proportion of density classifications for each type of triad separately for adults and children in the linear and columnar conditions. Inspection of the table indicates that adults gave more density responses than did children and that the proportion of density responses was systematically related to triad type for each of the four age x arrangement groups.

The number of density responses was used as a dependent measure in an analysis of variance with age and arrangement (linear vs columnar) as between subjects variables and triad type as a within subject variable. The analysis revealed a significant effect of age, $F(1,28) = 9.07$, $p < .01$, $MSe = 33.662$, with adults giving more density responses than did children. This effect is consistent with the observation from Experiment IVa of a greater preference for density on the part of adults. The analysis also revealed a significant effect of triad type, $F(4,112) = 14.76$, $p < .001$, $MSe = 2.20$, confirming the observation of systematic increases in density responses with increases in the similarity ratio favoring such classifications. Surprisingly, the effect of arrangement was not significant, $F(1,28) = 2.37$, $p > .10$, $MSe = 33.662$, even though inspection of Table 5 indicates consistently higher proportions of density responses in the linear than in the columnar condition. There were no other significant effects in the main analysis.

Since children were expected to show less preference than adults for either dimension, several statistical tests were employed in

Table 5

Proportion of density responses for adults and children in each condition

| Group | Triad Type | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | V |
| Adult Linear | .750 | .722 | .805 | .847 | .986 |
| Adult Columnar | .347 | .444 | .625 | .638 | .819 |
| Child Linear | .361 | .305 | .417 | .444 | .597 |
| Child Columnar | .292 | .305 | .347 | .417 | .430 |

examining this possibility. Initially, subjects were divided into those showing a preference for one of the dimensions and those not showing such a preference, with preference defined as at least 75% of one type of response. Ten adults and six children were classified into the former category and six adults and ten children were classified into the latter. A chi-square test was used to determine whether, collapsing across arrangement condition, classification into the above categories was independent of the age of the subjects. The test did not yield a significant value, $\chi^2_{(1)} = 2.0$, $p > .10$. Separate chi-squares were also computed for the linear and columnar conditions. The test yielded a significant value for the linear condition, $\chi^2_{(1)} = 4.0$, $p < .05$, consistent with the more preference on the part of adults, but did not reach significance for the comparison in the columnar condition, $\chi^2_{(1)} = 0$.

In addition to the difference between children and adults in the linear condition in terms of overall preference, the type of preference shown differentiated the age groups. Of the six children who showed a preference, four had a preference for length. Of the 10 adults showing a preference, 9 preferred density. A chi-square computed on the age x type of responder (length-preference, density-preference, no-preference) contingency table yielded a significant value, $\chi^2_{(2)} = 7.25$, $p < .05$.

There are regularities in the data consistent with expectations. First, subjects in all conditions showed regular increases in density responses across triad types which increasingly favored such classifications. Secondly, adults were somewhat more likely than children to show preferences, although the difference was only significant in the linear condition. The type of preference differed as a function of age, with children showing more length preference and adults showing more density preference. The children's greater reliance on length is consistent with studies of children's numerosity comparisons (e.g., Brainerd, 1977).

The fact that children did show some dimensional preference in this experiment is inconsistent with the separability hypothesis as discussed by Shepp (1977). If children do not have access to a dimensional structure, they should not show dimensional preferences. The result is not inconsistent with a modified version of the separability hypothesis (Smith and Kemler, in press) in which children are seen to have ready access to the dimensional structure.

## Experiment VI

Just as separability might reflect a mode of responding based on particular physical arrangements of the stimuli (Experiment IV), it could also reflect responding based on the individual subject's approach to the particular task. The present study was directed at manipulating a particular aspect of the subjects' approach to the task to determine whether such a factor does affect responding.

The discussion presented by Smith and Kemler (in press) suggests that a more analytic approach would lead to more dimensional (separable) responding. In addition, Zelniker and Jeffrey's (1976) characterization of impulsive responders as "global" and reflective responders as "analytic" suggests the importance of response tempo to separable and integral responding. Perhaps, as implied by the preferences which they showed in Experiment V, children do have access to dimensional structure but they use "impulsive" strategies which lead to integral-type responding. Smith and Kemler (1977) were concerned about the issue of response tempo, and used a more difficult four item classification task in an effort to slow the subjects' pace in performing the task. The manipulation was ineffective in the sense that children still treated the size-and-brightness stimuli as integral as measured by the number of similarity classifications which they produced. The present study represented a more direct attempt to affect subjects' response tempo. If the response tempo factor is important in the developmental trend toward separability, it might be possible to make adults classify more like children by having them perform a faster, more cursory examination of the items, and to make children respond more like adults by having them perform a slower, more careful, analytic examination of the items. The present study examined this possibility. In addition, the effects of a "more careful" approach on the tendency to shift to dimensional responding across trials was assessed both for adults and children. Presumably, a more careful examination of the items would lead to a greater tendency to discover the dimensional structure and thus the slow-careful group would be expected to show a more pronounced shift to dimensional responding.

## Method

Stimuli. The stimuli were the linearly arranged triads that had been used in Experiment IV.

Subjects. The subjects were 16 adults (12 females, 4 males) and 16 children (5 females, 11 males) sampled from the same populations as in previous experiments in this series.

Procedure. Each subject was tested individually and received three presentations of each of the ten triads. The order of presentation and the subjects' response modes were as described in Experiment IVa. All subjects were asked to pick the two members of each triad which "most go together." Half of the subjects were instructed to go slowly in making their choices and to examine each triad member very carefully before choosing. The other half of the subjects were instructed to examine all items before making a choice but to do so rapidly, not spending a great deal of time examining each one. For adults, there were six females and two males in each group. The mean ages of the children in the slow and fast groups were 5 years, 0 months and 4 years, 11 months respectively, and there were five males and three females in the slow group and six males and two females in the fast group.

## Results and Discussion

The proportion of similarity, dimensional, and haphazard responses are presented in Table 6 separately for adults and children in each of the instructional conditions. Inspection of that table reveals that adults had generally higher levels of dimensional responding than did children, and that only adults' levels of dimensional responding were

Table 6

Proportion of similarity (S), dimensional (D), and haphazard (H) responses for adults and children in the slow and fast conditions

| | | Trial Type | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Length-Shared Trials | | | | Density-Shared Trials | | | | Combined Trials | | | |
| Group | Response | 1 | 2 | 3 | $\bar{X}$ | 1 | 2 | 3 | $\bar{X}$ | 1 | 2 | 3 | $\bar{X}$ |
| Adult Slow | S | .700 | .550 | .525 | .592 | .125 | .025 | .000 | .050 | .413 | .287 | .263 | .320 |
| | D | .150 | .375 | .375 | .300 | .850 | .975 | .950 | .925 | .500 | .675 | .663 | .613 |
| | H | .150 | .075 | .100 | .108 | .025 | .000 | .050 | .025 | .087 | .037 | .075 | .067 |
| Adult Fast | S | .775 | .750 | .775 | .767 | .250 | .225 | .275 | .250 | .512 | .487 | .525 | .508 |
| | D | .125 | .100 | .075 | .100 | .675 | .750 | .725 | .717 | .400 | .425 | .400 | .408 |
| | H | .100 | .150 | .150 | .133 | .075 | .025 | .000 | .033 | .088 | .088 | .075 | .083 |
| Child Slow | S | .425 | .550 | .650 | .542 | .575 | .650 | .525 | .583 | .500 | .600 | .587 | .563 |
| | D | .225 | .225 | .150 | .200 | .350 | .200 | .275 | .275 | .287 | .213 | .213 | .237 |
| | H | .350 | .225 | .200 | .258 | .075 | .150 | .200 | .142 | .213 | .187 | .200 | .200 |
| Child Fast | S | .575 | .550 | .475 | .533 | .350 | .600 | .475 | .475 | .463 | .575 | .475 | .504 |
| | D | .200 | .225 | .200 | .208 | .425 | .300 | .275 | .333 | .313 | .263 | .237 | .271 |
| | H | .225 | .225 | .325 | .258 | .225 | .100 | .250 | .192 | .225 | .163 | .287 | .225 |

affected in the expected direction by the manipulation. The number of dimensional responses given was used in an analysis of variance with age and instructional condition (slow-careful vs fast) as between subjects variables and triad type and trials as within subject variables. The analysis provided support for the observations described above. The effect of age was significant, $F(1,28) = 20.84$, $p < .001$, $MSe = 3.781$, with adults giving more dimensional responses. While there was no significant overall effect of the instructional manipulation, $F(1,28) = 2.32$, $p > .10$, $MSe = 3.781$, the manipulation interacted significantly with age, $F(1,28) = 4.48$, $p < .05$, $MSe = 3.781$. The basis of this interaction is that adults gave more dimensional responses in the slow-careful condition than in the fast condition, $t(14) = 2.12$, $p < .05$, $SE = 2.89$, whereas children gave roughly the same number of dimensional responses in the two conditions, $t(14) = .581$, $p > .25$, $SE = 1.720$. Adults gave significantly more dimensional responses than children in both the slow, $t(14) = 4.629$, $p < .005$, $SE = 2.430$, and fast, $t(14) = 1.769$, $p < .05$, $SE = 2.331$, instructional conditions. As an additional comparison consistent with these observations, children gave more similarity than dimensional responses in both the slow and fast conditions, $t(7) = 3.675$, $p < .005$, $SE = 2.619$, and $t(7) = 3.407$, $p < .01$, $SE = 2.091$, respectively, while adults gave significantly more dimensional than similarity responses in the slow condition, $t(7) = 2.253$, $p < .05$, $SE = 3.828$, but not in the fast condition, $t(7) = .676$, $p > .20$, $SE = 4.437$. This pattern of results provides support for notions of increased separability and flexibility in perceived structure with increasing age.

As in previous experiments the overall analysis revealed a significant effect of triad type, $F(1,28) = 37.78$, $p < .001$, $MSe = 4.126$, and a significant age x triad type interaction, $F(1,28) = 19.72$, $p < .001$, $MSe = 4.126$. Adults gave more dimensional responses than children to density-shared, $t(30) = 5.30$, $p < .001$, $SE = 1.356$, but not length-shared triads, $t(30) = .416$, $p > .30$, $SE = 1.202$.

The only other significant effect in this analysis was an age x trials interaction, $F(2,56) = 5.39$, $p < .01$, $MSe = .629$. The basis of the interaction is that adults showed increases in dimensional responses over trials whereas children did not. Separate *t*-tests revealed that the only significant trial-by-trial changes were increases in dimensional responses for adults from trial 1 to trial 2, $t(15) = 2.406$, $p < .025$, $SE = .364$, and trial 1 to trial 3, $t(15) = 2.145$, $p < .025$, $SE = .379$. Although the difference between children and adults increased over trials, adults gave more dimensional responses than did children at the beginning and end of the task with the *t* values for trials 1, 2, and 3 being $t(30) = 2.479$, $p < .01$, $SE = .605$, $t(30) = 4.217$, $p < .001$, $SE = .741$, and $t(30) = 4.326$, $p < .001$, $SE = .708$, respectively. This pattern of results is also consistent with previous findings in this series of experiments.

In addition to the above findings, a separate analysis on the adult dimensional responses revealed significant effects of trials, $F(2,28) = 7.71$, $p < .005$, $MSe = .293$, and the trials x instructional condition interaction, $F(2,28) = 5.58$, $p < .01$, $MSe = .293$. The interaction may be viewed in two ways. First, adults showed more dimensional responses in the slow than the fast condition on trials 2 and 3, $t(14) = 2.395$, $p < .025$, $SE = 1.044$, and $t(14) = 2.225$, $p < .025$, $SE = 1.164$ respectively, but not on trial 1, $t(14) = 1.24$, $p > .10$, $SE = .802$. Secondly, the only significant trials effects were increases in dimensional responses for adults in the slow condition from trial 1 to 2, $t(7) = 2.291$, $p < .05$, $SE = .655$, and trial 1 to 3, $t(7) = 2.728$, $p < .025$, $SE = .596$. As in Experiment IVa, an analysis of haphazard responses yielded a significant effect only for age, $F(1,28) = 17.92$, $p < .001$, $MSe = 7.598$, with children giving more haphazard responses than adults.

The results of the present study indicate that adults' patterns of responding in this situation are affected by their approach to the task. Adults instructed to go slowly and carefully gave more dimensional responses than those who were instructed to be less careful. The effect is consistent with the suggestion that more analytic reflective processing may be associated with more separable responding. The fact that the discrepancy between the slow and fast groups (adults) increased over trials is also consistent with the notion that the increase in dimensional responding represents a discovery of the dimensional structure of the stimuli. That is, subjects taking a more careful approach to the task would be more likely to discover something about the dimensional structure of the triads employed.

Although it can be concluded that the approach to the task can influence the pattern of responding, it cannot be concluded that children give more similarity responses because of an "impulsive," less analytic approach. This is so because the attempt to slow their responding did not increase their levels of dimensional classification. It is not clear whether the lack of influence is due to the lack of importance of the tempo factor in the developmental trend toward separability or to children's failure to slow their responding as instructed. Finally, as in Experiment IVa, the shift toward dimensional responding by adults contributes to but does not completely determine the developmental difference.

## Experiment VII

In Experiment VI it was demonstrated that manipulating the adult subjects' approach to the task through instructions can affect their tendency to give the various types of responses. The present study was conducted to determine whether placing time constraints on subjects' responses can also influence their responding in the absence of instructions to be very careful or less careful.

In addition the present study represented a more direct attempt to influence the response tempo of children than was the manipulation of Experiment VI. Rather than assuming that children will take more or less time when instructed to go slowly or quickly, the present study directly controlled the amount of time that children could take in generating responses.

### Method

All but the instructional aspects of the method were the same as in

Experiment VI including the subject populations sampled, the stimuli, and the sequence of presentation. Of the 16 undergraduates tested, 14 were females and 2 were males. Of the 16 children there were 9 females and 7 males.

Half of the subjects were required to make their choices within 5 seconds and the other half had to wait at least 5 seconds before responding. For both groups, the experimenter, using a stopwatch for timing, held the items in view for 5 seconds. For the fast group, the item was placed out of view after 5 seconds had passed. These subjects were instructed to make their choices before, or at the latest at the same time as, the item was placed out of view. For the slow group, the item was placed on the table in view of the subject after the 5 seconds had passed, and this served as a cue that they could make their choice whenever they were ready. There were seven females and one male in each of the adult groups. The mean ages of the children in the slow and fast conditions were 5 years, 9 months and 5 years, 8 months, respectively. There were four male and four female children in the slow group, and three males and five females in the fast group.

<u>Results and Discussion</u>

The proportion of similarity, dimensional, and haphazard responses is presented separately in Table 7 for adults and children in the slow and fast groups. Inspection of the table indicates that the time constraints used had little effect on subjects' overall patterns of responding, and that as in previous studies adults gave more dimensional responses than did children. An analysis of variance was conducted on

Table 7

Proportion of each type of response for adults and children in the slow and fast temporal conditions

| | Type of Response | | |
|---|---|---|---|
| Group | Similarity | Dimensional | Haphazard |
| Adult > 5-seconds | .487 | .450 | .063 |
| Adult < 5-seconds | .450 | .508 | .042 |
| Child > 5-seconds | .496 | .296 | .208 |
| Child < 5-seconds | .571 | .267 | .162 |

the number of dimensional responses with age and temporal condition as between subjects factors and triad type and trials as within subject factors. Consistent with previous studies there was a significant effect of age, $F(1,28) = 11.16$, $p < .005$, $MSe = 4.035$, with adults giving more dimensional responses than children. The only other significant effects, triad type, $F(1,28) = 41.54$, $p < .001$, $MSe = 4.017$, and age by triad type, $F(1,28) = 37.03$, $p < .001$, $MSe = 4.017$, are also consistent with previous studies in this series. The nature of these effects is that adults gave significantly more dimensional responses for density-shared than for length-shared triads, $t(15) = 9.897$, $p < .001$, $SE = 1.099$, whereas children did not, $t(15) = .224$, $p > .25$, $SE = 1.393$.

Aside from replicating previous findings, the results of the present study are inconclusive. There are several possible reasons for the failure of the temporal manipulation employed to affect subject's responding. Some of these are explored in the next experiment.

## Experiment VIII

The failure to find an effect of time constraints in Experiment VII could be due to a variety of factors. First, it may simply be the case that integral and separable responding is unrelated to response deadlines. Secondly, however, it is possible that the particular time constraints employed were not extreme enough to affect responding. Finally, subjects in the slow condition may have made their choices as rapidly as those in the fast group and simply postponed writing them down until the deadline passed. The present study was conducted with these latter possibilities in mind. The time limit for the fast conditions (2 seconds) was chosen to maximize the probability of affecting subjects' responding. This more extreme time constraint precluded the use of children in the present study. The present experiment also included a control group receiving no time constraints in order to be able to assess whether any effects observed reflect shifts toward integrality with less time, separability with more time, or both factors.

## Method

All aspects except those related to the specific time constraints and subjects tested were the same as in Experiment VII. The subjects were 24 undergraduates (11 males and 13 females) enrolled in introductory psychology courses who received experimental points for their participation. In the present study, the fast group of 8 subjects (5 females, 3 males) was instructed to respond within 2 seconds and was given no more than 2 seconds to examine the items. The slow group of 8 subjects (4 males, 4 females) was instructed to delay their decision for at least 5 seconds as was true in Experiment VII. The slow group in the present study was instructed further not to simply make their choices quickly and postpone writing them down, but rather to try to delay the decision itself. A control group of 8 subjects (4 males, 4 females) was given standard instructions and allowed to respond at their own pace.

## Results and Discussion

The proportion of similarity, dimensional, and haphazard responses for subjects in the three time conditions are presented separately in Table 8. Inspection of this table indicates that the proportion of dimensional responses was systematically related to the time constraints employed, with the least occurring in the 2-second condition and the most occurring in the 5-second condition. An analysis of variance was performed on the number of dimensional responses given with temporal condition (2-seconds, 5-seconds, and control) as a between subjects variable, and triad type and trials as within subject variables. The effect of the temporal manipulation was marginally significant, $F(2,21) = 2.84$, $.10 > p > .05$, $MSe = 4.235$. However, since the difference between the 2-second and 5-second groups was of major interest in this study, separate $t$-tests were conducted to examine possible group differences. These tests revealed that subjects in the 5-second condition gave significantly more dimensional responses than those in the 2-second condition, $t(14) = 2.276$, $p < .025$, $SE = 2.69$, but that the 5-second and control, and 2-second and control conditions did not differ significantly, $t(14) = 1.04$, $p > .20$, $SE = 2.69$, and $t(14) = 1.15$, $p > .20$, $SE = 2.93$, respectively. The fact that temporal constraints did influence the number of dimensional responses given is consistent with the notion that responding in the restricted classification task is related to factors controlling subject's approaches to the task rather than stable perceptual modes. Apparently, slower responding is associated with greater separability. This result is consistent with the findings of Experiment VI.

Table 8

Proportion of each type of response for subjects in each of the conditions of Experiment X

| | Type of Response | | |
|---|---|---|---|
| Group | Similarity | Dimensional | Haphazard |
| 5-seconds | .379 | .579 | .042 |
| 2-seconds | .575 | .379 | .046 |
| Control | .450 | .487 | .063 |

The analysis also yielded a significant effect of triad type, $F(1,21) = 31.83$, $p < .001$, $MSe = 8.814$, with more dimensional responses for density-shared than for length-shared triads, and a significant effect of trials, $F(2,42) = 5.11$, $p < .025$, $MSe = .426$, with more dimensional responses occurring on later trials. There were no other significant effects. The fact that temporal conditions did not interact with trials indicates that the effect of the temporal constraints was primarily on overall levels of dimensional responding rather than changes in responding over trials. As can be seen in Table 8, there were low and roughly equivalent proportions of haphazard responses in all conditions, and similarity response effects mirrored those for dimensional responses.

## Experiments IX and X

The results of previous experiments indicate that children's responding is dominated by similarity choices across a number of different task situations. This tendency cannot be attributed unambiguously to an impulsive response tempo on their part (Experiments VI and VII). Even though adults' responding was affected by manipulations controlling their tempo in performing the task, this may not be the most effective way in which to affect children's responding. In their analysis of the attempts to modify the performance of impulsive responders, Zelniker and Jeffrey (1976) note that the most successful attempts have been those directed at the subjects' strategies rather than those directed at slowing the children's responding. If children do not possess the relevant skills or the tendency to employ those skills then slowing their responding will be ineffective. In the present case, children may not have access to dimensional structure or may tend not to use that information in generating responses. The results of Experiment V indicating dimensional preferences for young children are more consistent with the latter possibility, but either of these factors could have limited the effectiveness of the manipulations in Experiments VI and VII.

If young children's response patterns are based on a lack of knowledge regarding the dimensional structure of the stimuli or a lack of access to dimensional structure, pointing out the dimensions to them or training them with respect to the dimensional structure should result in an increase in dimensional responding. On the other hand, if young children already have access to the dimensional structure of the stimuli, their similarity responding would be based on some other factor, such as the tendency to employ that information, and training them to identify when items are the same or different along the dimensions of interest would neither be necessary nor expected to shift them toward dimensional responding. The one sense in which such training would be expected to be effective is in suggesting dimensional sameness as a classification rule. The following two studies were directed at determining the impact of instructions regarding the dimensional structure of the length and density stimuli on subjects' patterns of classification. The purpose was to assess the importance of this factor to separable and integral responding in the present task. In addition to the developmental question discussed above, the studies were an attempt to observe the classifying behavior of adults under conditions which should reduce their preference for density as a basis for classification.

## Experiment IX

This experiment was conducted to assess whether or not simply mentioning the dimensions of length and density in the instructions would affect subjects' tendencies to use those dimensions as bases for classification or to use dimensional classifications in general. It was expected that this manipulation would lead subjects to adopt higher levels of dimensional responding and reduce the preference for density as a basis for classification.

### Method

Stimuli. The stimuli employed were the 10 triads arranged in a columnar format as described in Experiment IVa.

Subjects. The subjects were 20 undergraduates (15 females, 5 males) enrolled in introductory psychology courses who received experimental points for their participation. Initially, it had been planned to include a group of 5-year-olds in this study. However, the adult portion of the data was collected first and the unexpected results prompted a decision to conduct a more extensive study (Experiment X) and examine children's performance in that task rather than in the present situation.

Procedure. Subjects were tested individually and each received three presentations of each triad in a random order as described in Experiment IV. A control group was run in which 10 subjects (8 females, 2 males) received standard instructions. The experimental group of 10 subjects (7 females, 3 males) differed from the control group only in that the sentence "As you can see, some of the items are longer than others and some have the dots spaced farther apart than others" was inserted in the instructions for the experimental subjects.

## Results and Discussion

The proportion of similarity, dimensional, and haphazard responses is presented separately for the control and experimental subjects in Table 9. Inspection of Table 9 indicates little impact of the manipulation on adults' overall patterns of responding. As in previous experiments, the number of dimensional responses was used in an analysis of variance with instructions (control vs experimental) as a between subjects variable and triad type and trials as within subject variables. Consistent with the above observation, there was no significant effect

Table 9

Proportion of each type of response for subjects in each condition

| | Type of Response | | |
|---|---|---|---|
| Group | Similarity | Dimensional | Haphazard |
| Instructed | .347 | .583 | .070 |
| Control | .370 | .557 | .073 |

of the instructional manipulation on the number of dimensional responses given, $\underline{F}(1,18) = .18$, $\underline{p} > .25$, $\underline{MSe} = 6.611$. In fact, the only significant effect in the overall analysis was triad type, $\underline{F}(1,18) = 66.27$, $\underline{p} < .001$, $\underline{MSe} = 3.807$, with subjects giving more dimensional responses to density-shared than to length-shared triads.

Inspection of single-subject data indicates that the instructional manipulation may have had an effect that was more subtle than was anticipated. Although the groups did not differ in overall levels of dimensional responding, the distributions of dimensional responses among the groups were not the same. In particular, subjects in the experimental group showed either very high or very low levels of dimensional responding as opposed to more moderate levels of dimensional responding among the control group subjects. In order to assess the reliability of this tendency, a Moses test of extreme reactions was performed on the data. The test revealed that the experimental subjects were significantly more extreme in their responding than were control subjects, $\underline{p} = .035$. This effect should be viewed with caution since it is based solely on a post hoc rather than a planned analysis. However, the finding can be interpreted to mean that subjects who are told what the relevant dimensions are show less bias to respond on the basis of density alone, and that in doing so treat the dimensions as primarily integral or separable (i.e., very few or very many dimensional responses). The finding that, when told the dimensions, some subjects treat them as integral and some treat them as separable is consistent with similar findings of Somers and Pachella (1977) who used the shape and emotional expression of faces as dimensions.

Control Group Replication. The control group in this study represents essentially a replication of earlier experiments. The data for the control group were analyzed separately using the number of dimensional responses as a dependent measure and triad type and trials as within subject variables. Consistent with previous analyses there was an effect of triad type, $F(1,9) = 51.00$, $p < .001$, $MSe = 3.40$, with subjects giving more dimensional responses for density-shared than for length-shared triads. The effect of trials was marginally significant, $F(2,18) = 2.916$, $.10 > p > .05$, $MSe = 1.189$. Subsequent $t$-tests revealed a significant increase in dimensional responses only from trial 1 to trial 3, $t(9) = 2.228$, $p < .05$, $SE = .718$. Triad type and trials did not interact significantly, $F(2,18) = 1.075$, $p > .20$, $MSe = .744$, indicating that whatever increase in dimensional responding occurred, the increase was roughly comparable for the length-shared and density-shared triads. These results are largely consistent with previous findings.

## Experiment X

Since the instructional manipulation of Experiment IX did not have the expected effect, a more complete study was carried out with both children and adults in an effort to maximize the probability of affecting their performance. In the present experiment not only were the dimensions of length and density mentioned to the subjects, but also subjects were required to determine whether items were the same or different on those dimensions in an initial comparison task prior to the main classification task. In contrast to Experiment IX, this procedure allows a determination of whether subjects (particularly children) are able to perceive and compare items along the dimensions of interest. Without this prior task, had the manipulation of Experiment IX been entirely ineffective with children, it would not have been clear whether the failure was due to the ineffectiveness of pointing out the dimensions per se, or to children's inability to access those dimensions.

If children (or adults) were not able to make the dimensional comparisons in the initial task accurately, they could be trained to do so, and when they reached criterion on training they could be put into the main classification task. If such training resulted in increased dimensional responding, then it would be reasonable to conclude that at least part of their similarity responding is based on a lack of knowledge regarding dimensional relations or structure. If children were able to make the comparisons without training, then it would be erroneous to conclude that a lack of access to dimensional relations determines their similarity responding in this task. In this latter case, if the initial comparison task resulted in increased dimensional responding, the result could be attributed to subjects adopting the mode of classification (dimensional sameness) suggested by that task.

<u>Method</u>

<u>Stimuli</u>. The stimuli for the main classification task were the

same as those used in Experiment IX. To this group of triads, two unique members were added, one length-shared and one density-shared. Each of these new triads was presented once at the end of the original 30 triad presentations as a check on whether the shift toward dimensional responding across trials that was observed in previous experiments is specific to individual triads that are presented in that task or generalizes to new examples of the dimensions, which subjects have not previously encountered.

A new set of stimuli was constructed for the subjects' initial task of comparing the sameness 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, .75, and .37 cm interdot distance). Pairs of stimuli from this set were typed onto 7.6 x 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 in the initial comparison set to provide a check on whether any transfer from that set 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, and 12 5-year-olds (7 females and 5 males) recruited from day-care centers in the Madison area.

*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 previous experiments. 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 years, 4 months and 5 years, 1 month, 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 6 pairs of items all of the same density and were asked to make a same-different judgment regarding length. They were then shown 6 pairs all of the same length and asked to make density comparisons. In each case, 3 pairs from the set were the same and 3 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 3 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 previous experiments except that the two new triads described above were each presented once at the end of the normal 30 presentations.

## Results and Discussion

Initial Comparison Task. Nearly every subject in both age groups performed perfectly on the initial comparison task. Only one child, a four-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. Given that these children are representative of others their age, it is reasonable to conclude that young children's tendency toward similarity classifications observed in previous studies in this series is not based on a lack of access to dimensional relations or 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 10 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 subjects variables and triad type and trials as within subject variables. Consistent with previous experiments, there was a significant effect of age, $F(1,20) = 29.55$, $p < .001$, $MSe = 4.157$, with adults giving more

Table 10

Proportion of each type of response for adults and children in the experimental and control conditions

| Group | Type of Response | | |
| --- | --- | --- | --- |
| | Similarity | Dimensional | Haphazard |
| Adult Control | .339 | .578 | .083 |
| Adult Experimental | .061 | .911 | .028 |
| Child Control | .528 | .261 | .211 |
| Child Experimental | .405 | .489 | .106 |

dimensional responses than children. There was also a significant effect of condition, $\underline{F}(1,20) = 17.04$, $\underline{p} < .001$, $\underline{MSe} = 4.157$, with subjects who received the initial comparison task giving more dimensional responses than those in the control condition. The interaction of age and condition was not significant, $\underline{F}(1,20) = .60$, $\underline{p} > .25$, $\underline{MSe} = 4.157$, indicating that children and adults were affected in the same way by the manipulation. Subsequent $\underline{t}$-tests confirmed that both adults and children gave more dimensional responses in the experimental than in the control condition, $\underline{t}(10) = 3.03$, $\underline{p} < .005$, $\underline{SE} = 3.299$, and $\underline{t}(10) = 2.854$, $\underline{p} < .01$, $\underline{SE} = 2.395$ respectively. These results could not be due to "training" subjects with regard to the 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 a suggested mode of classification, the increase in dimensional responses for those in the experimental condition should be rule-like 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, $\underline{t}(5) = 2.07$, $\underline{p} > .05$, $\underline{SE} = .077$. 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 comparison task.

Increased Dimensional Responding Over Trials. Just as the overall effect of the manipulation in this experiment could have been specific or general, the increase in dimensional responding across trials that has been observed could be rule-like or specific to the triads presented. The comparisons reported in this section were performed to examine which of these possibilities is supported better by the data. In order to increase the power of these comparisons, eight additional adults were tested. Of the total of 32 subjects tested in the present experiment, 18 showed an increase in dimensional responding for length-shared or density-shared triads or both. The proportion of dimensional responses given on trials 1 and 3 by these subjects were used to predict the frequency of dimensional responses to the two new triads which were presented at the end of the standard 30 presentations. The proportion of dimensional responses to length-shared triads was .45 on trial 1 and .80 on trial 3. Of the 11 subjects who showed an increase in dimensional responses to length-shared triads, 7 gave dimensional responses for the new length-shared triad. Using the proportions for the first (.45) and third (.80) occurrence of each triad as $p$ values in a binomial test, this frequency was not significantly different from what would be expected either at the beginning or end of the task, $p = .1128$ and $p = .1107$ respectively. Thus for length-shared triads, the test was indeterminate with respect to the specificity of the increase in dimensional responses. For the density-shared triads, the proportions of dimensional responses on trials 1 and 3 were .33 and .60 respectively. Of the 11 subjects who showed increases in dimensional responding to density-shared triads, 3 gave dimensional responses to the new density-shared triad. Using a binomial test, this frequency does not differ significantly from that predicted on the basis of trial 1 dimensional responding (using .35 as the predictor), $p = .2254$, but is significantly less than expected on the basis of trial 3 dimensional responding, $p = .0234$. Thus unless there is something unusual about the new density-shared triad, it appears that the increase in dimensional responding over trials was specific to the triads presented rather than general, at least for density-shared triads. This result might have been expected in the sense that adults clearly have access to the dimensional structure of the length and density stimuli, and therefore would not have to "discover" that structure. What they may have discovered during the course of the experiment is the specific relations which exist in the particular triads presented.

Replication. An analysis of variance conducted on the number of dimensional responses given by the adults who were tested in the control condition revealed results consistent with previous findings. There was a significant effect of trials, $F(2,22) = 3.70$, $p < .05$, $MSe = .521$, with more dimensional responses on later trials, and a significant effect of triad type, $F(1,11) = 18.60$, $p < .001$, $MSe = 7.923$ with more dimensional responses for density-shared than for length-shared triads. The fact that the interaction of triad type and trials was not significant, $F < 1$, $MSe = .726$, indicates that the increase in dimensional responding was comparable for both length-shared and density-shared triads.

# General Discussion

The major findings of the present studies can be summarized 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. Adults generally showed more dimensional preference in classification than did children, and had a strong bias toward density as a basis of classification. When children did show a preference in classifying, it was generally for length. The pattern of responding was not constant across different experimental situations or within a given experimental session. Adults showed increases in dimensional responses across presentations of the triads and the increase seemed to be specific to the triads employed. Adults gave more dimensional responses when presented with the stimuli in an arrangement which was predicted to facilitate dimensional comparisons, when required to perform a prior task involving dimensional comparisons, and when instructed or required to take more time in generating responses. Children were generally less influenced by these same factors, but did show increased dimensional responding when they performed an initial task involving dimensional comparisons. Their performance in that initial task was nearly perfect.

## Separability as a Construct

As noted, Garner (1974) views separability as primarily a stimulus construct. He emphasizes the impact of the perceived structure of stimuli on subjects' processing of those stimuli. The results of the present studies, in conjunction with other findings in the literature, suggest the usefulness of considering the organismic aspects of separability to be relatively important, and examining the impact of particular kinds of processing on the patterns of responding thought to reflect separable or integral perception.

Consistent with previous studies (Shepp, 1977; Smith and Kemler, 1977), the results indicate that the dimensions employed were primarily separable for adults and integral for children. If the perceived structure was determined entirely or even primarily by the properties of the stimuli, then it would be expected that individuals in both age groups would treat those dimensions as either integral or separable. In support of a stimulus-construct emphasis, it might be argued that young children have not yet extracted the dimensional structure inherent in the stimuli. However, children's performance in the initial comparison task of Experiment X indicated that they were perfectly capable of accessing the dimensional structure of the stimuli.

In addition to the developmental findings, the results of Experiment IX indicate that even within the same age group (adults) some subjects treated the dimensions as separable and some treated them more integrally. This finding is consistent with the report by Somers and Pachella (1977) that some adult subjects treated the dimensions of facial shape and emotional expression as integral and others treated them as separable. As with the developmental findings, this sort of variability in response patterns would not be expected if the perceived structure was based entirely on properties inherent in the stimulus.

In addition to these individual difference findings, the results of the present studies also indicate the importance of considering how the subject's approach to the task influences the pattern of responding observed. Adults gave more dimensional responses when instructed to be slow and careful than when instructed to respond more quickly and examine the items less carefully. Adults also gave more dimensional responses when required to delay responding for 5 seconds than when required to respond within 2 seconds. These findings, combined with the suggestions of Zelniker and Jeffrey (1976) concerning the global and analytic processing of impulsive and reflective responders, and the finding of a "less mature" pattern of responding by hyperactive children (Fisher, 1977), indicate that a useful direction in which to proceed is to consider the relation of responding in separability tasks to conceptual tempo.

Finally, the pattern of responding observed was not even constant within a given subject in an experimental session. Adults showed increases in dimensional responses across trials with the triads. These increases seem to reflect changes that are specific to the triads presented rather than the adoption of rules for classifying on the basis of dimensional structure. In any case, it is clear that the pattern of responding in the classification task employed reflects something other than a stable mode of perceiving the stimuli.

If Smith and Kemler's (1977) contention that the restricted classification task represents the most direct means of assessing the perceived structure of stimuli is correct, then the results of the present studies take on greater significance. The pattern of responding in this task is clearly affected by factors other than properties of the stimuli. These include factors controlling the subject's approach to the task, amount of experience in the task, and age, as well as interactions among these factors.

If the restricted classification task is simply viewed as one of many means of determining the separability of stimuli, rather than the most direct one, then it is possible to consider a strong and a weak interpretation of the present results. The strong interpretation is that separability itself is determined by factors other than, or in addition to, properties inherent in the stimuli. The weak interpretation is that separability as measured by performance in this particular task is related to those other factors. The strong interpretation is favored by the fact that the individual differences in responding that have been observed are independent of one particular task. Developmental differences have been observed in speeded sorting (Shepp, 1977) and restricted classification (Smith and Kemler, 1977), and Somers and Pachella's (1977) individual difference findings among adults were obtained in a similarity rating task. In discussing the concept of separability, Garner (1974) states that "...converging operations help to establish that the concept is indeed independent of any single experimental outcome and thus has a status of its own (p. 138)." By the same token, the individual differences in separability are independent of any single experimental outcome and have a status of their own.

It is not argued that properties inherent in the dimensions are unimportant in determining responding in these tasks. Clearly, some dimensions are more "integral" than others (e.g., hue and brightness) and most subjects would treat them as such. It is argued that in accounting for the separability-integrality of dimensions, an emphasis on stimulus factors to the relative exclusion of subject factors is inconsistent with the present data and with that from the studies discussed above.

## The Separability Hypothesis

In general, the results of the present studies support the notion that children will treat as integral those dimensions which adults treat as separable. The most consistent finding of these studies is that adults, across a variety of task conditions, gave more dimensional responses than did children. Adults tended to give a majority of dimensional responses and children tended to give a majority of similarity responses. These results are consistent with the separability hypothesis (Shepp, 1977) and with previous developmental findings (Shepp, 1977; Shepp and Swartz, 1976; Smith and Kemler, 1977). The fact that adults were more affected by the stimulus and task manipulations than were children is also consistent with Shepp's (1977) suggestion of increased flexibility in perceived structure with increasing age. At the same time, the findings with regard to flexibility raise an important issue. If adults' responding varies from one task or situation to the next, then it becomes important to consider what, if any, are the appropriate situations in which to compare the separability of dimensions for children and adults. Since responding in the present task does not reflect stable modes of perceiving the stimuli, 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.

The present results also support an extension of the separability hypothesis. It was observed that adults showed increases in dimensional responding over trials but that children did not. It was observed further that the increase in dimensional responding 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. The extension of the separability hypothesis is that not only are adults more likely than children to treat dimensions as separable across a variety of task situations, but also they are more likely to discover something about the usefulness of dimensional structure in classifying stimuli during the course of experience with them.

The present results are also relevant to an understanding of the factors which underlie the developmental trend toward greater separability. It is unlikely that children's similarity responding is based on a lack of knowledge about or a lack of access to the dimensional structure of the stimuli. Children were perfectly capable of accessing dimensional relations as evidenced by their performance in the initial task of Experiment X and the preferences they showed in Experiment V.

These findings are consistent with the views expressed by Smith and Kemler (in press) that children can readily access the dimensional structure of what for adults are separable dimensions. They are inconsistent with the notion, implicit in Shepp's position, that children's integral treatment of separable stimuli is the result of some basic perceptual limitation which must be overcome through perceptual learning.

If not related to a basic perceptual limitation, then the developmental trend toward separability may be based on developmental changes in the subjects' strategies of processing information. The concept of individual differences in cognitive tempo was mentioned earlier in this discussion as a potentially informative direction in which to proceed in asking questions regarding the importance of processing factors in separability. It is useful to expand this suggestion in relation to the developmental findings discussed above. That is, since children become more reflective with increasing age (Kagan, 1965) and older impulsive children have been found to perform similarly to younger reflectives (Ault, 1973), there may be a relationship between impulsive and reflective responding and the developmental increase in separability. Zelniker and Jeffrey's (1976) data which converge on the notion of impulsive responders being global processors and reflective responders being analytic processors are consistent with this possibility.

There are two alternative views of the relationship. With increasing age there may be a concomitant increase in reflectiveness, or use of reflective strategies, leading to an increase in separable responding.

Alternatively, with increasing age there may be a shift to perceived dimensional structure which could lead to more reflective responding. That is, perceiving dimensions as separable may lead to separate (analytic) and therefore slower consideration of each of them. Three aspects of the present data favor the former interpretation. First, tempo was found to play a causal role at least in adults' patterns of responding (Experiments VI and VIII). Secondly, children did give evidence of having access to dimensional structure (Experiment X) even though they typically gave the similarity responses that would be expected with impulsive responding. Finally, as noted in discussing separability as a construct, the present data as well as other findings in the literature favor an emphasis on strategies determining structure rather than vice versa.

The exact relation between response tempo and the developmental trend in separability is not clear from the present data. The difference cannot be attributed unambiguously to developmental differences in response tempo since children's classifying behavior was unaffected by manipulations intended to slow their responding. Children did not show more dimensional responses when instructed to perform the task more slowly and carefully or when required to delay responding for 5 seconds. The response tempo factor cannot be ruled out however, since there could be many reasons for the ineffectiveness of the procedures. For example, Barstis and Ford (1977) reported that by early school years some children are able to modify their conceptual tempo in the MFF task but that the ability increases with age. Since the subjects employed in the present studies were younger than those studied by Barstis and Ford, it is possible that they were unable to modify their tempo in response to the task requirements.

It is also possible that response tempo is unrelated to the developmental difference in separability. However, adults' responding was greatly affected by instructions and time constraints, indicating that performance in the task is sensitive to tempo factors. Thus developmental differences in response tempo could be related to the trend toward separability.

It may not be surprising that slowing children's responding had little effect on their classifying behavior. It is not time per se that would be expected to be important, but rather the processes that occur in time. If children show no tendency to make dimensional comparisons unless they are suggested (Experiment X), then no matter how long they are required to delay their responding, they will not show increased dimensional classifications.

The situation may be viewed usefully in relation to a distinction between mediational and production deficiency made by Flavell (1970). In Flavell's view, production deficiency refers to the failure to generate mediators which could facilitate performance in a particular task, whereas mediation deficiency refers to a failure of mediators, when produced, to facilitate performance. According to Flavell (1970), if performance is facilitated when mediators are provided to the subject, a mediation deficiency is ruled out allowing the inference that the original poorer performance is the result of a production deficiency. If, on the other hand, the providing of mediators does not improve performance, then the original difficulty is labeled mediation deficiency.

Since children's dimensional responding increased following the performance of a dimensional comparison task, the impact of that task may have been due to providing, or at least suggesting, the needed mediator (i.e., dimensional comparisons). In that case, children's low levels of dimensional responding would not represent mediational deficiencies. Therefore using Flavell's (1970) chain of inference, young children would be viewed as "production deficient" with respect to the mediator of dimensional comparisons. This production deficiency would be expected to limit the effectiveness of the tempo manipulations (instructions and requirements to slow responding) designed to increase their dimensional responding.

It should be noted that the term "deficiency" may not be the best one to use in the present context. This is so since both similarity and dimensional classifications are reasonable given the nature of the triads presented.

<u>Numerosity Processing and Conservation of Number</u>

The present studies were concerned primarily with the processing of length and density as dimensions rather than with the combination of those dimensions into the third dimension of numerosity. In fact, the data indicate that numerosity was of little importance in subject's classifications. In addition, since variations in the present task produced different levels of dimensional responding, and different tasks can be expected to result in differential use of dimensional relations

(Smith and Kemler, in press), the results of the present studies may not be directly applicable to studies concerned with number processing. However, with these limitations in mind, it is useful to consider the implications of the present findings for interpretations of number processing abilities since many of the developmental studies of such abilities employed stimuli composed of the dimensions of length and density.

In contrast to earlier views (e.g., Gelman, 1972) that children's concepts of number are based on length or density, Cuneo and Anderson (1977) argued that children's number judgments are based on both length and density and that the dimensions are combined in an additive way by young children. The present results are consistent with the views expressed by Cuneo and Anderson. That is, since independent processing of the component dimensions of integral stimuli is difficult (Garner, 1974; Shepp, 1977) children's integral perception of length and density as demonstrated in the present studies suggests that they would have difficulty in basing number judgments on one of the dimensions and ignoring the other dimension.

Similarly, young children's failure to conserve number has been attributed to their tendency to "centrate" on one of the dimensions and ignore the other (Ginsburg and Opper, 1969). The integrality of the dimensions would be expected to limit the tendency or ability to centrate on one dimension to the exclusion of the other.

Another way in which the present results might relate to conservation of number studies is as follows. It is possible to consider number as a dimension itself. Since length and density are integral for children (as measured by a dominance of similarity classifications) it might be the case that number, length, and density would all be integral for them as well. In that case, changes in the length of an array would not be viewed independently of changes in number for that array. Consequently, simply changing the length of an array could result in a response by the young child that the number has changed. This interpretation is directly opposed to a centration interpretation. Rather than saying that young children have difficulty because of a tendency to fixate one dimension to the exclusion of others, this interpretation says that young children have difficulty because of an inability to treat dimensions independently. The results of a training study by Gelman (1969) are consistent with this notion. Gelman used an oddity learning paradigm to train nonconservers to attend to the dimension of number and ignore irrelevant changes in length and density. This training resulted in an increase in the number of conservation responses given. Particularly when combined with the observation that young children can discover the dimensional structure of some stimuli (Smith and Kemler, in press), i.e. learn to separate the dimensions, the results of the Gelman study are consistent with the "integrality" notion of nonconservation of number. The added benefit of such an interpretation is that it is more consistent with the well established trend away from distributed attention and toward selective attention with increasing age than is the centration notion.

One final way in which the results of the present studies relate to the numerosity processing literature is with respect to the integration rule which characterizes children's numerosity judgments. Cuneo and Anderson (1977) have reported that young children's judgments are consistent with an additive rule for combining the dimensions of length and density, whereas those of older children are consistent with the use of a multiplicative rule. In the introduction to the present studies the possibility was considered that the additive rule represented separable perception and that the multiplicative rule reflected integral perception in that task. Since the dimensions were found to be basically integral for young children and separable for adults using the present classification task, the results of the present studies do not provide support for the expected relation between separability and the combining rules identified through functional measurement procedures. It may be that the different tasks lead subjects to process the dimensions differently. This illustrates another way in which responding to dimensions may be task-dependent, and serves to re-emphasize the previously stated caveat regarding the search for absolute differences in separability with age.

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## APPENDIX A

## INSTRUCTIONS

### Instructions for Experiments Ia and Ib

In this experiment, I am going to be showing you these index cards. Each card has one item shown on it. Each time, I will show you two cards, and I would like you to rate the similarity of items shown on those cards. You should indicate how similar the pair of items is by placing a mark along one of these lines in this booklet (pointing). The more similar you think the items are, the closer you would put your mark to this end (pointing to end labelled very similar). The more dissimilar the items are, the closer you would put your mark to this end (pointing to end labelled very dissimilar). Do you understand what I am asking you to do? . . . Before we begin, I would like you to look through these cards (handing deck of 16 cards which contains one of each stimulus in the set) to get some idea of the range of similarities and differences among the items that you will be rating so that your first few judgments will make sense in terms of that range. . . OK, let's begin.

### Instructions for Experiments II and III

In this experiment, I am going to be showing you these index cards. Each card has one item shown on it. Each time, I will place three cards on the table in front of you. What I would like you to do each time I do that is pick out the two out of the three items which most go together; the ones that go together best. The way to indicate which two go together is by picking up those two cards and handing them to me. Do you understand what I am asking you to do? . . . OK, let's begin. Remember each time just hand me the ones that most go together.

Instructions for Experiments IVa, V, and Control Conditions of VIII, IX, and X for Children and (Adults)

In this game (experiment) I am going to show you these cards. Each card has three pictures (items) shown on it. (For simplicity we will always call the one on the top (left) "A", the one in the middle "B", and the one on the bottom (right) "C".) Each time I show you one of these cards I would like you to pick out the two out of the three pictures (items) which most go together; the ones that go together best. The way you can do that is by pointing to those two (writing down the letters for that pair on this sheet). Do you understand what I am asking you to do? . . . OK, let's begin. Remember, each time pick the two out of the three that most go together.

Instructions for Experiment IVb

Standard instructions with the following additions prior to "Do you understand....":

> The way I would like you to make your decisions is on the basis of the number of dots making up each item. The ones that most go together are the ones that are closest to one another in number.

Instructions for Experiment VI

Standard instructions with the following additions prior to "Do you understand....":

Slow Group. I would like you to be very slow and very careful in making your choices. Take your time and examine each item on each card very carefully before making your choice.

Fast Group. I would like you to make your choices as quickly as possible. You should look at each item on each card before making your choice but don't spend a great deal of time looking at each one.

Instructions for Experiment VII and (VIII)

Standard instructions with the following additions:

Slow Group. I am going to put a time constraint on the way that you make your choices. I am going to hold up each card for you to look at for 5 seconds. After 5 seconds has passed, I will put the card on the table in front of you and you can make your choice at that time. Do not make your choice until after I have set the card down. (Please try to hold off the decision itself. Don't simply make your choice quickly and hold off writing it down, but try to hold off the decision itself.)

Fast Group. I am going to put a time constraint on the way that you make your choices. I am going to hold each card up for 5 (2) seconds for you to look at. After 5 (2) seconds has passed I will place the card out of view, so you must make your choice before the 5 (2) seconds are up.

Instructions for Experiment IX

Standard instructions with the following addition:

As you can see, some of the items are longer than others and some have the dots spaced farther apart than others.

Instructions for Experiment X, Initial Comparison Task for Children and (Adults)

In this game (experiment) I am going to show you these cards. Each card has two pictures (items) on it. Some of the pictures (items) will be longer than others and some will have the dots spaced farther apart than others. First I am going to show you some where the spacing between the dots is the same and I would like you to tell me whether the length is the same or different. . . . Now I am going to show you some where the lengths will all be the same and I would like you to tell me whether the spacing between the dots is the same or different. . . Now I am going to show you some where the length or the spacing might be the same or different. I would like you to tell me whether the pictures (items) are the same or different in both length and spacing.

# APPENDIX B

## ANALYSIS OF VARIANCE SUMMARY TABLES

Analysis of variance summary tables are presented in this appendix for each analysis discussed in the main body of the paper. The tables are numbered to correspond to the experiment for which the analysis was done and the order in which analyses were reported within a given experiment. For example, Table 2.1 is for the first analysis reported in Experiment II.

Table 2.1 Analysis of variance with the number of dimensional responses as the dependent variable

| Source | df | Mean Square | F |
|---|---|---|---|
| S | 7 | 4.821 | |
| A (Triad type) | 1 | 182.250 | 37.80 |
| SA | 7 | 4.821 | |
| B (Trials) | 3 | 1.542 | 2.98 |
| SB | 21 | .518 | |
| AB | 3 | .208 | .38 |
| SAB | 21 | .542 | |

* $p < .001$

Table 3.1 Analysis of variance with the number of density responses as the dependent variable

| Source | | df | Mean Square | F |
|---|---|---|---|---|
| S | | 28 | 1.310 | |
| A | (Triad type) | 4 | 7.867 | 6.01 |
| SA | | 28 | 1.310 | |
| B | (Trials) | 2 | .558 | .82 |
| SB | | 14 | .682 | |
| AB | | 8 | .235 | 1.03 |
| SAB | | 56 | .228 | |

* $p < .005$

Table 4.1 Analysis of variance with the number of dimensional responses as the dependent variable

| Source | df | Mean Square | F |
|---|---|---|---|
| A (Age) | 1 | 70.667 | 26.85*** |
| B (Arrangement) | 1 | 19.834 | 7.54** |
| AB | 1 | 15.834 | 6.02** |
| S(AB) | 36 | 2.632 | |
| C (Triad type) | 1 | 255.867 | 53.24*** |
| AC | 1 | 102.934 | 21.42*** |
| BC | 1 | 2.417 | .50 |
| ABC | 1 | 1.284 | .27 |
| S(AB)C | 36 | 4.806 | |
| D (Trials) | 2 | 1.969 | 3.55* |
| AD | 2 | 1.503 | 2.71 |
| BD | 2 | 1.219 | 2.20 |
| ABD | 2 | .769 | 1.39 |
| S(AB)D | 72 | .555 | |
| CD | 2 | .186 | .43 |
| ACD | 2 | 1.053 | 2.43 |
| BCD | 2 | .136 | .31 |
| ABCD | 2 | .953 | 2.20 |
| S(AB)CD | 72 | .432 | |

* $p < .05$ ** $p < .025$ *** $p < .001$

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TITLE OF THESIS Dimensional Responding in Children and Adults as a Function of Stimulus and Response Variables

Major Professor Leonard E. Ross

Major Department Psychology

Minor(s) Distributed

Full Name Thomas Bernard Ward

Place and Date of Birth Montclair, NJ; July 14, 1952

Colleges and Universities: Years attended and degrees

Rider College 1970-1974 BA

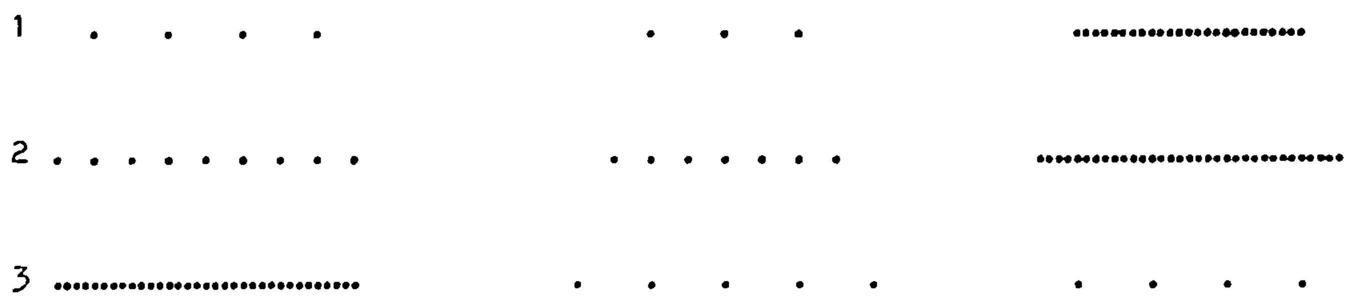
University of Wisconsin 1974-1978 MS, PhD

Membership in Learned or Honorary Societies

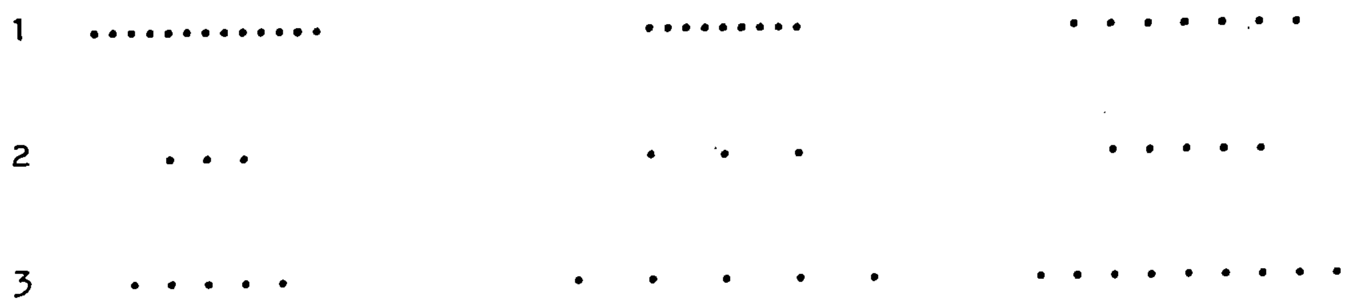
Publications See attached.

Date August 16, 1978

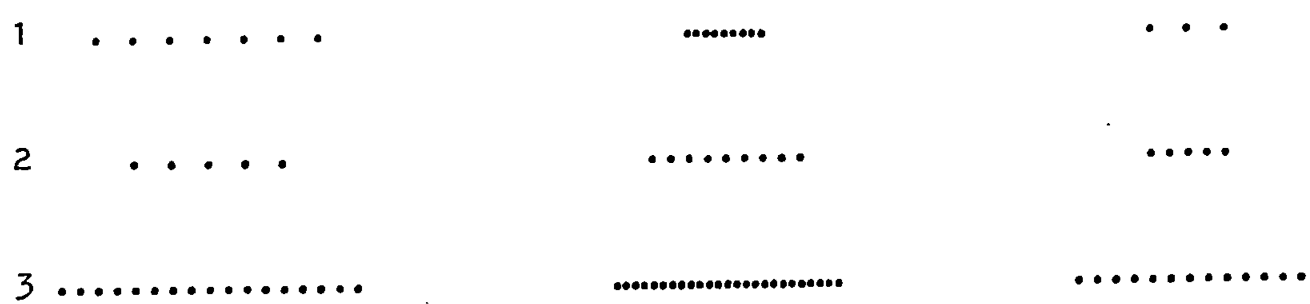
## Type V Preference Triads



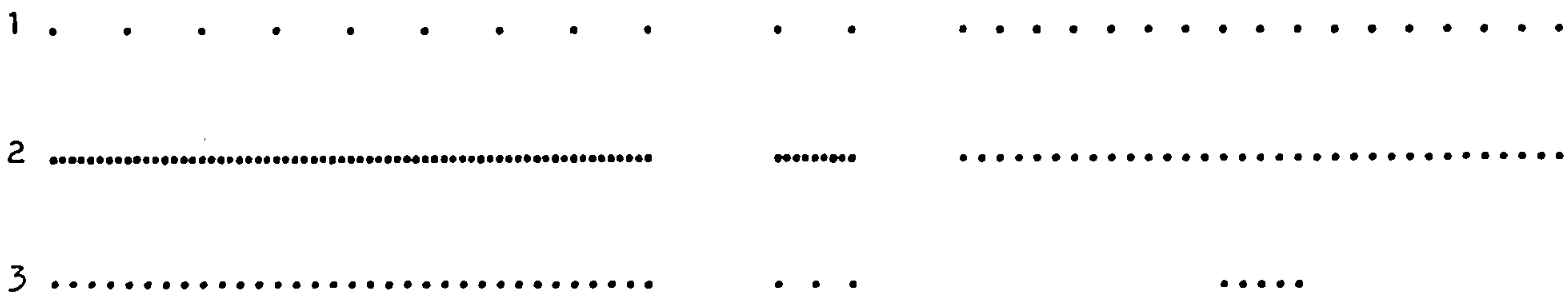
Type III Preference Triads



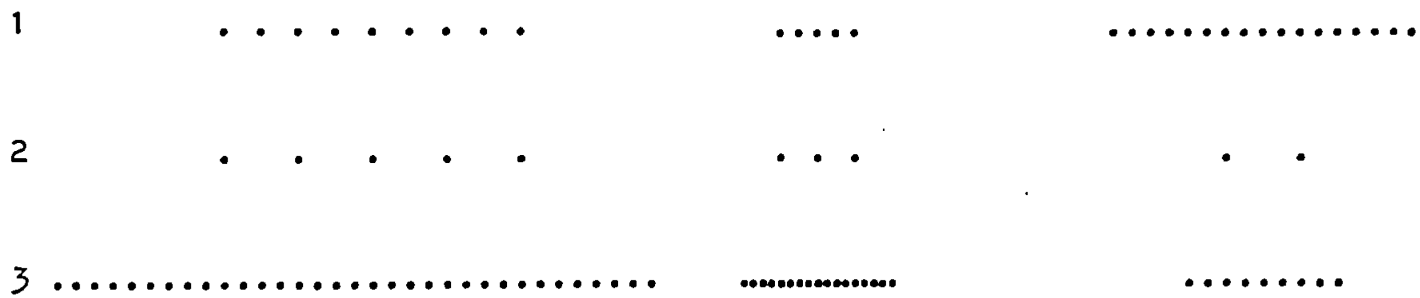

Type IV Preference Triads

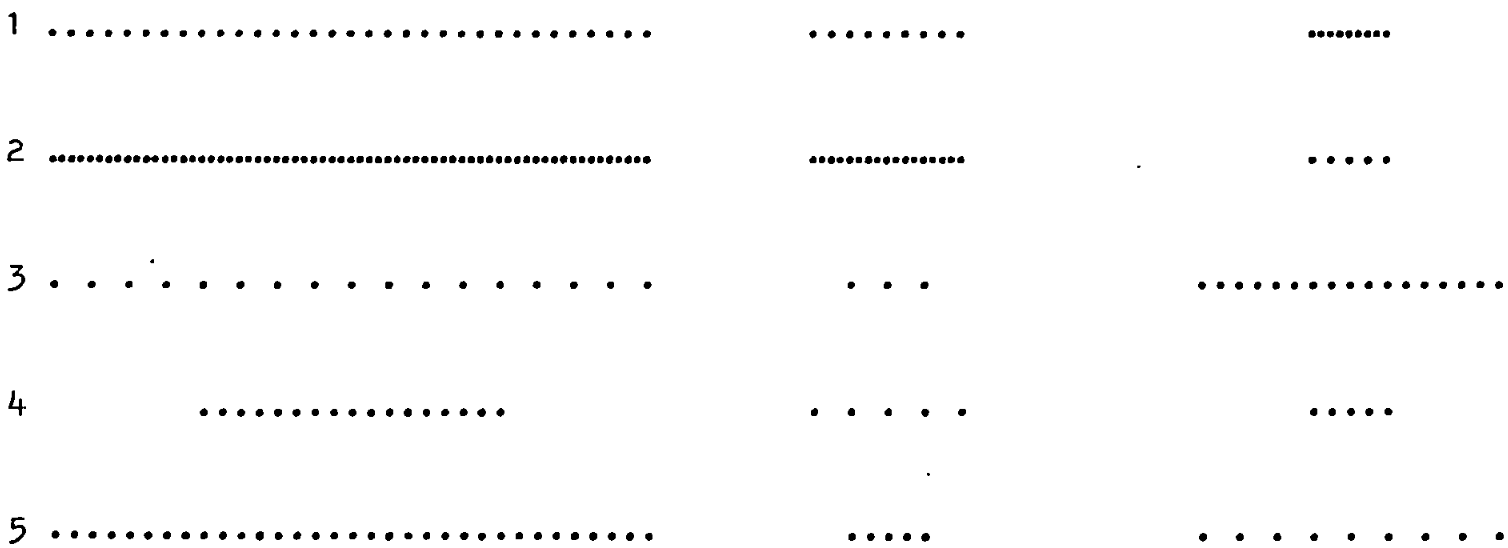


## Type I Preference Triads

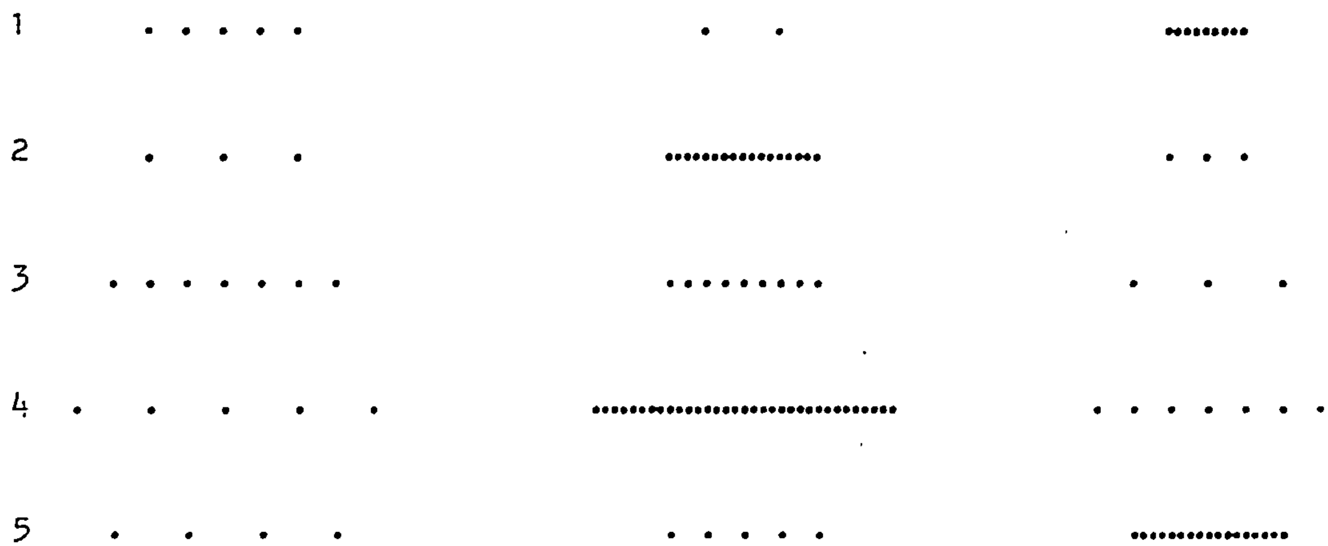


## Type II Preference Triads






Density-Shared Triads



Length-Shared Triads

# APPENDIX C

## Triads Used in Restricted Classification and Preference Studies

Table 10.2 Analysis of variance using the number of dimensional responses as a dependent variable with adults in the control condition only

| Source | df | Mean Square | F |
|---|---|---|---|
| S | 11 | 7.923 | |
| A (Triad Type) | 1 | 147.347 | 18.60** |
| SA | 11 | 7.923 | |
| B (Trials) | 2 | 1.931 | 3.70* |
| SB | 22 | .521 | |
| AB | 2 | .014 | .02 |
| SAB | 22 | .726 | |

* $p < .05$

** $p < .001$

Table 10.1 Analysis of variance using the number of dimensional responses as a dependent variable with adults and children in both conditions

| Source | df | Mean Square | F |
|---|---|---|---|
| A (Age) | 1 | 122.840 | 29.55*** |
| B (Condition) | 1 | 70.840 | 17.04*** |
| AB | 1 | 2.507 | .60 |
| S(AB) | 20 | 4.157 | |
| C (Triad type) | 1 | 3.674 | .55 |
| AC | 1 | 50.174 | 7.47* |
| BC | 1 | 68.062 | 10.13** |
| ABC | 1 | 1.563 | .23 |
| S(AB)C | 20 | 6.718 | |
| D (Trials) | 2 | 2.111 | 2.80 |
| AD | 2 | .111 | .15 |
| BD | 2 | .361 | .48 |
| ABD | 2 | .528 | .70 |
| S(AB)D | 40 | .753 | |
| CD | 2 | .361 | .69 |
| ACD | 2 | .194 | .37 |
| BCD | 2 | .250 | .48 |
| ABCD | 2 | .583 | 1.12 |
| S(AB)CD | 40 | .522 | |

* $p < .025$

** $p < .005$

*** $p < .001$

Table 9.1 Analysis of variance using the number of dimensional responses as the dependent variable

| Source | df | Mean Square | F |
|---|---|---|---|
| A (Condition) | 1 | 1.200 | .18 |
| S(A) | 18 | 6.611 | |
| B (Triad type) | 1 | 252.300 | 66.27* |
| AB | 1 | 7.500 | 1.97 |
| S(A)B | 18 | 3.807 | |
| C (Trials) | 2 | 2.133 | 2.39 |
| AC | 2 | 1.600 | 1.79 |
| S(A)C | 36 | .894 | |
| BC | 2 | 1.300 | 2.24 |
| ABC | 2 | .100 | .17 |
| S(A)BC | 36 | .580 | |

* $p < .001$

Table 8.2 Analysis of variance using the number of dimensional responses as a dependent measure, excluding the control group

| Source | df | Mean Square | F |
|---|---|---|---|
| A (Temporal Condition) | 1 | 24.000 | 6.73** |
| S(A) | 14 | 3.568 | |
| B (Triad type) | 1 | 228.167 | 39.87*** |
| AB | 1 | 3.375 | .59 |
| S(A)B | 14 | 5.723 | |
| C (Trials) | 2 | 1.885 | 3.93* |
| AC | 2 | .406 | .85 |
| S(A)C | 28 | .479 | |
| BC | 2 | .073 | .11 |
| ABC | 2 | 1.344 | 2.03 |
| S(A)BC | 28 | .661 | |

* $p < .05$

** $p < .025$

*** $p < .001$

Table 8.1 Analysis of variance using the number of dimensional responses as a dependent measure with the control group included

| Source | df | Mean Square | F |
|---|---|---|---|
| A (Temporal Condition) | 2 | 12.028 | 2.84 |
| S(A) | 21 | 4.235 | |
| B (Triad Type) | 1 | 280.562 | 31.83** |
| AB | 2 | 4.750 | .54 |
| S(A)B | 21 | 8.814 | |
| C (Trials) | 2 | 2.174 | 5.11* |
| AC | 4 | .278 | .65 |
| S(A)C | 42 | .426 | |
| BC | 2 | .063 | .10 |
| ABC | 4 | .688 | 1.09 |
| S(A)BC | 42 | .630 | |

* $p < .025$

** $p < .001$

Table 7.1 Analysis of variance using the number of dimensional responses as the dependent measure

| Source | df | Mean Square | F |
|---|---|---|---|
| A (Age) | 1 | 45.047 | 11.16* |
| B (Temporal Condition) | 1 | .422 | .10 |
| AB | 1 | 2.755 | .68 |
| S(AB) | 28 | 4.035 | |
| C (Triad type) | 1 | 166.880 | 41.54** |
| AC | 1 | 148.755 | 37.03** |
| BC | 1 | .880 | .22 |
| ABC | 1 | 12.505 | 3.11 |
| S(AB)C | 28 | 4.017 | |
| D (Trials) | 2 | .109 | .27 |
| AD | 2 | .109 | .27 |
| BD | 2 | .109 | .27 |
| ABD | 2 | .130 | .32 |
| S(AB) D | 56 | .412 | |
| CD | 2 | 1.161 | 1.48 |
| ACD | 2 | .099 | .13 |
| BCD | 2 | 1.724 | 2.20 |
| ABCD | 2 | .099 | .13 |
| S(AB)D | 56 | .783 | |

* $p < .005$

** $p < .001$

Table 6.3 Analysis of variance using the number of haphazard responses as the dependent variable

| Source | df | Mean Square | F |
|---|---|---|---|
| A (Age) | 1 | 136.125 | 17.92* |
| B (Slow/Fast) | 1 | 2.000 | .26 |
| AB | 1 | .000 | .00 |
| S(AB) | 28 | 7.598 | |

* $p < .001$

Table 6.2 Analysis of variance using the number of dimensional responses as the dependent measure with adults only

| Source | df | Mean Square | F |
|---|---|---|---|
| A (Slow/Fast) | 1 | 25.010 | 4.48 |
| S(A) | 14 | 5.588 | |
| B (Triad type) | 1 | 231.260 | 32.41*** |
| AB | 1 | .010 | .00 |
| S(A)B | 14 | 7.135 | |
| C (Trials) | 2 | 2.260 | 7.71** |
| AC | 2 | 1.635 | 5.58* |
| S(A)C | 28 | .293 | |
| BC | 2 | .010 | .02 |
| ABC | 2 | .760 | 1.54 |
| S(A)BC | 28 | .493 | |

* $p < .01$

** $p < .005$

*** $p < .001$

Table 6.1 Analysis of variance using the number of dimensional responses as the dependent measure, including children and adults

| Source | df | Mean Square | F |
|---|---|---|---|
| A (Age) | 1 | 78.797 | 20.84*** |
| B (Slow/Fast) | 1 | 8.755 | 2.32 |
| AB | 1 | 16.922 | 4.48* |
| S(AB) | 28 | 3.781 | |
| C (Triad type) | 1 | 155.880 | 37.78*** |
| AC | 1 | 81.380 | 19.72*** |
| BC | 1 | .130 | .03 |
| ABC | 1 | .255 | .06 |
| S(AB)C | 28 | 4.126 | |
| D (Trials) | 2 | .161 | .26 |
| AD | 2 | 3.391 | 5.39** |
| BD | 2 | .724 | 1.15 |
| ABD | 2 | .953 | 1.52 |
| S(AB)D | 56 | .629 | |
| CD | 2 | .568 | 1.14 |
| ACD | 2 | .568 | 1.14 |
| BCD | 2 | .255 | .51 |
| ABCD | 2 | .880 | 1.77 |
| S(AB)CD | 56 | .496 | |

* $p < .05$
** $p < .01$
*** $p < .001$

Table 5.1 Analysis of variance using the number of density responses as the dependent measure

| Source | df | Mean Square | F |
|---|---|---|---|
| A (Age) | 1 | 305.256 | 9.07* |
| B (Arrangement) | 1 | 79.806 | 2.37 |
| AB | 1 | 26.406 | .78 |
| S(AB) | 28 | 33.662 | |
| C (Triad type) | 4 | 32.469 | 14.76** |
| AC | 4 | 2.506 | 1.14 |
| BC | 4 | 1.494 | .68 |
| ABC | 4 | 2.844 | 1.29 |
| S(AB)C | 112 | 2.200 | |

* $p < .01$

** $p < .001$

Table 4.4 Analysis of variance with the number of similarity responses as the dependent measure for adults in Experiments IVa and IVb

| Source | df | Mean Square | F |
|---|---|---|---|
| A (Arrangement) | 1 | 115.600 | 5.16* |
| B (IVa vs IVb) | 1 | 650.104 | 29.00** |
| AB | 1 | 168.334 | 7.51** |
| S(AB) | 36 | 22.416 | |

* $p < .05$

** $p < .001$

Table 4.3 Analysis of variance using the number of similarity responses as the dependent variable

| Source | df | Mean Square | F |
|---|---|---|---|
| A( Age) | 1 | 96.267 | 6.00* |
| B (Arrangement) | 1 | 109.350 | 6.82* |
| AB | 1 | 109.350 | 6.82* |
| S(AB) | 36 | 16.037 | |

* $p < .025$

Table 4.2 Analysis of variance using the number of haphazard responses as the dependent variable

| Source | df | Mean Square | F |
|---|---|---|---|
| A (Age) | 1 | 119.004 | 31.49* |
| B (Arrangement) | 1 | .104 | .03 |
| AB | 1 | .704 | .19 |
| S(AB) | 36 | 3.779 | |

* $p < .001$