

Developmental Changes in the Effect of Dimensional Salience on the Discriminability of Object Relations

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Two experiments explored three issues regarding the nature of perceptual development in 5- and 10-year-old children and adults: (a) the role of featural discriminability, (b) the facilitatory role of identity relations, and (c) the role of salience in a task context designed to minimize the likelihood of attention-switching between dimensions during perceptual processing. In Experiment 1, perceptual salience for size and achromatic color dimensions was determined for each participant based on their best-fitting triad classification task response pattern. These same persons participated in Experiment 2, which employed a speeded visual discrimination task. The primary finding was that preassessed salience significantly influenced the 5-year-olds' ability to discriminate between two objects, while salience did not affect 10-year-olds' or adults' response times. The results of both experiments support Odom & Cook's (1992) differential-sensitivity view of perceptual development, but these data contribute important information by showing that salience effects in perceptual processing occur even when the observer is selectively attending to a particular dimension, likely during early component processes prior to classification.

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Imagine a 5-year-old boy in a large toy store, looking for a birthday gift. He wants to buy a plastic monster. In the monster aisle there are hundreds, poised to strike from within their colorful cages. An adult might notice the many dimensions of the toys—their sizes, shapes, colors, facial expressions, weapons. The young child seems to compare the dimensions of the toys, but is he really selectively attending to them? If so, which toy-object dimensions does he attend to first? Does he notice all possible toy-object relations? Is he as fast at identifying similarities and differences as an adult? Is he as capable as an adult at discriminating only slight features along the dimension he is attending to, such as slight differences in skin tone?

Several recent studies of perceptual development during childhood can aid our understanding of the above questions. By analyzing individual patterns of responses, many studies have shown that young children are indeed capable of basing their object comparisons on visual dimensions which are perceived

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as separable to adults (Cook & Odom, 1992; Odom & Cook, 1996; Thompson, 1994; Thompson & Massaro, 1989; Wilkening & Lange, 1987). For example, using a nonspeeded restricted triad classification task, Thompson (1994) found that 4-, 5-, 10-year-old children, and adults based their classifications of objects primarily on one dimension. That is, when instructed to "put together the two (squares) that go together best," across trials, most children attended selectively to either the size or the brightness dimension. Dimensional selectivity was also revealed in 5-year-old children and adults when individuals compared a viewed object to two remembered objects (Thompson & Massaro, 1989, Experiment 2). Cook and Odom (1992) provided further convincing evidence that young children are selective in their processing of multidimensional stimuli. Using a nonspeeded free-classification task with objects containing distinctive values along the dimensions of color, size, and orientation, they found that 5-year-olds, 11-year-olds, and adults all avoided classifications based on overall similarity of objects; instead, their classifications were based on attention to single dimensions.

Yet, there are many developmental differences which are apparent in perceptual classification task findings, some striking and others more subtle. As an example of a striking age difference, Cook and Odom (1992, Experiment 1) asked 4-year-old children and adults to compare drawings of geometric figures in terms of their similarities. Preschool children named far fewer similarities and differences than did adults. As for subtle developmental changes, compared to younger children, older children's triad classifications were more consistently based on their dominant dimension (Thompson, 1994), and older children showed no interference of the unattended dimension for orthogonal sorts in a speeded card-sorting task, while younger children did show interference (Cook & Odom, 1992, Experiment 4). In a more conceptually based classification task, Kimchi (1993) had children categorize basic-level objects and found that children as young as 5 years of age were sensitive to parts and part-whole relationships and that this sensitivity improved with age. These results, as well as others (e.g., Smith, 1989) form a strong foundation of support for the conclusion that children of all ages are selective in how they visually perceive and process objects, yet become more highly selective with development.

However, there are still many unresolved issues which form the basis for the research questions addressed by the present study. One of them concerns featural discriminability. Do children develop a better ability to discriminate featural differences along dimensions which are for them perceptually separable? Thompson and Massaro's (1989) model-fitting results suggested that size and brightness featural representations were not as discriminable to young children as they were to adults. Researchers have long acknowledged the notion that stimuli become increasingly discriminable during perceptual development (E. J. Gibson, 1969), although this factor does not play a central role in current accounts of perceptual development (Cook & Odom, 1992; Smith, 1989).

A second issue concerns perceiving objects in terms of their identical relations. Smith posited that perceived similarities and identities between objects are valued in the process of making classification judgments. With development, children place a higher value on identity and less value on similarity as a criterion for grouping objects. However, Smith's (1989) claim that "identity becomes increasingly special" with age contrasts with the findings of other perceptual development studies. Odom and Cook (1996) showed that identity is a highly valued criterion for classification in children as young as 4 years. Further, the results of Cook and Odom's experiment mentioned above (1992, Experiment 1) showed that stimulus differences were more salient than identities, not only for young children, but for all age groups tested. In another study, Thompson (1994) did find support for the claim that young children place a low value on identity relations in their triad classifications. However, older children and adults also seemed to place a low value on identity relations, due to the low percentage of individuals within all age groups who grouped objects by identities on both dimensions.

Of central importance to the present study is a third issue concerning the perceptual processing level at which dimensional salience effects operate. Many classification studies have shown that some dimensions are more salient to individuals than are other dimensions (e.g., Aschkenasy & Odom, 1982; Odom & Cook, 1984, 1996; Cook & Odom, 1988, 1992; Thompson, 1994; Thompson & Massaro, 1989). For instance, subjects used primarily one dimension for matching objects in free classification tasks (Cook & Odom, 1992) and in triad classification tasks (Thompson, 1994; Wilkening and Lange, 1987). Dimensional salience is also inferred from a task involving naming similarities and differences between objects (Cook & Odom, 1992, Experiment 1), where particular dimensions named first are assumed to be most perceptually salient to individuals. Cook and Odom (1992) claim that dimensional salience "operates at the level of perception, and it is automatic and unconscious" (p. 216). However, the tasks in which dimensional salience has been well demonstrated actually leave unanswered the question, "At what processing level(s) are dimensional salience effects operating?" Since subjects are given a choice of dimensions upon which to base their judgments in free and triad classification tasks, and since the nonspeeded nature of the task leaves ample time to reconsider their choices, their responses showing dimensional salience could be reflecting mostly later perceptual processes involving switches of attention between object dimensions.

The differential-sensitivity account offered by Cook and Odom (1992) posits that, for each individual, stimulus dimensions are organized into a salience hierarchy through direct perception (J. J. Gibson, 1979). The salience hierarchy represents the individual's perceptual sensitivity to the dimensional relations perceived. Relations to which the individual is more sensitive reside near the top of the hierarchy, while less salient dimensions fall toward the bottom of the hierarchy. Relations that have not yet been detected have no salience value to that

person. Increased perceptual experience with the environment facilitates detection of more relations, leading to heightened perceptual sensitivity to previously discovered dimensions. Evidence supporting their account is derived from a variety of tasks. For example, 5- and 11-year-old children compared two objects in terms of how large the featural differences were along color, size, or orientation dimensions. For both age groups, featural difference estimates were larger for the dimensions which were identified as the most salient to each individual based on responses to an independent task (Cook & Odom, 1992, Experiment 3). Finally, experience allows dimensional salience levels to become elevated, potentially altering the ordering of dimensions composing the salience hierarchy (e.g., Cook & Odom, 1992, Experiment 2; Thompson, 1994).

Since nonspeeded perceptual classification tasks are not designed for answering questions about the nature of perceptual processing during the earliest moments of an observer's scene analysis (Thompson & Massaro, 1989) more evidence is needed to investigate possible developmental changes in the effect of salience in task contexts which reduce the effects of later perceptual processing. Cook and Odom (1992, Experiment 4) did not find salience effects in a speeded card-sorting task, where subjects were instructed to attend to a particular dimension for sorting. Thus, they suggested a boundary condition for predicted salience effects, stating, "Perceptual salience effects may not appear when information requirements are explicitly clear and when all relevant information is above zero in salience" (1992, p. 245). Our investigation is aimed primarily at testing this claim. Specifically, when individuals are comparing objects under speeded conditions and have clear instructions to selectively attend to one dimension, will salience affect their reaction time responses? Will there be any developmental differences? Our primary hypothesis stems from the theoretical position of Cook and Odom (1992), which assumes that salience effects occur at an early perceptual level. Thus, the hypothesis follows that dimensional salience effects will be apparent in individuals' responses in a task designed to reduce the opportunities for switching attention between dimensions prior to making a perceptual response—speeded discrimination of two objects. Compared to nonspeeded free classification or triad classification, this task reduces attention switching strategies in three ways: (a) participants are told which of two relevant dimensions to focus on prior to making their responses for a block of trials, (b) they must compare only two objects on each trial, and (c) participants are told to make their responses quickly.

The present investigation will also explore the relationship between dimensional salience, as determined by a triad classification task, and salience as determined by a speeded discrimination task. That is to say, assuming dimensional salience is easily assessed for individuals in a restricted triad classification task (Thompson, 1994), do the same object relations turn out to be salient for individuals in the speeded discrimination task? If so, is this relationship clearly observed within all age groups or not? To better understand this issue, we relied

on converging evidence from two tasks based on data collected from the same individuals. Specifically, perceptual salience as assessed by the triad classification task was used to predict perceptual sensitivity to separable object relations in the speeded discrimination task. For example, those children showing greater perceptual sensitivity to the achromatic color dimension than to the size dimension in the triad classification task should show faster response times for achromatic color-based than size-based comparisons when making speeded discriminations. Evidence in favor of our hypothesis would help to strengthen the assumption that perceptual salience, which has been revealed thus far only with classification measures, actually originates at an early level of processing and that it is automatic and unconscious.

Developmental changes in salience should also be apparent in responses on the speeded discrimination task. Cook and Odom (1992) claim that, "With development, task performance and problem solving should improve as children detect more relations and become more perceptually sensitive to them" (p. 247). It follows that later developmental change would involve a reduction in sensitivity differences across dimensions, eventually reaching a point where perceptual sensitivity is equally high across all experienced dimensions. Using the speeded discrimination task paradigm to explore perceptual salience, we predict that the effects on response times for both dimensional salience and featural differences between objects should diminish across development.

EXPERIMENT 1: TRIAD CLASSIFICATION

In Experiment 1, a nonspeeded restricted triad classification task was presented to 5-year-old children, 10-year-old children, and adults. Subjects viewed three objects (circles presented on a computer screen) and matched two together. The objects were represented by a range of values along the dimensions of size and achromatic color. The stimulus structures resembled the Type 1, 2, and 3 triads originally used by Smith and Kemler (1977, Experiment 1). In addition, a fourth triad (Type 4) was also employed. The fourth triad type pits values of the two dimensions against each other which are equidistant in multidimensional space.

There are three objectives to Experiment 1. First and primary, Experiment 1 assesses individual's perceptual sensitivity to separate object relations, in order to determine each individual's most salient classification dimension for use in Experiment 2. Second, the triad classification task employed in Experiment 1 also looks at consistency of using a particular classification response pattern across development (Thompson, 1994). Third, Experiment 1 provides a replication of Thompson (1994), which demonstrated that size and brightness dimensions are separably perceived by children. The present experiment replicates these findings using the dimensions of size and achromatic color.

Thompson (1994) developed a rule-testing framework that describes individuals' primary perceptual classification response patterns in the triad classification task. Following Thompson (1994), three basic response patterns describe clas-

sifications based on proximity relations, identity relations, or attention to a single dimension. Within each of these basic patterns, we attempted to discriminate those individuals whose classifications showed size to be more perceptually salient from those individuals whose classifications showed achromatic color to be more perceptually salient. The best-fitting response pattern also serves as a measure of the consistency of each individual's responses across the two halves of the experiment. Additionally, it is assumed that the particular dimension used most often for classification is higher in an individual's perceptual salience hierarchy (Cook & Odom, 1992). Figure 1 illustrates two of the six response patterns tested against classification data from the present study. Response patterns which account for a switch halfway through the experiment were also tested, but are not illustrated.

There are two types of one-dimensional response patterns that could be reflected in an individual's perceptual classification data. For example, a person could "put together the two that are most similar in size." A person following a Dimensional-Size response pattern would generally group the two circles which are most similar in size. Looking at Fig. 1, the first three boxes in the first row correspond to the three possible matches for that particular triad structure. When A and B are identical in size, an individual following the Dimensional-Size response pattern would group circles A and B together and would not put B and C together, nor would A and C be put together (see "DS" row of first three schematic responses for Types 1, 2, 3, and 4 in Fig. 1). When A and B are identical in achromatic color (illustrated in the next three boxes of the first row), the Dimensional-Size response pattern would predict the same individual to combine stimuli B and C, because circles B and C are more similar in size than are any other pairs. Likewise, someone who followed a Dimensional-Color response pattern would match the two stimuli most alike in achromatic color. Someone demonstrating the Identity-Size response pattern would generally put in a group the two circles which are identical on one dimension (AB matches on Types 1 & 2), preferring the size match when there are two identity matches available. A person whose classifications followed an Identity-Color response pattern would respond similarly, except for preferring the color match when identity matches are possible on both dimensions.

A person whose classifications are based on overall similarity, or proximity, relations would choose stimuli containing values which are closest in multidimensional space in Type 1 and Type 2 triads. The Proximity-Color and Proximity-Size response patterns predict that, for Type 1 and Type 2 triads, participants will group stimuli B and C together, regardless of which dimension each axis represents, because these two circles are nearer in proximity in the stimulus space. For Type 3 and Type 4 triads, the Proximity-Color response pattern predicts that when Dimension X is achromatic color and Dimension Y is size, an individual following the Proximity-Color response pattern would group A and B together. On Type 3 and Type 4 trials where Dimension X is size and Dimension

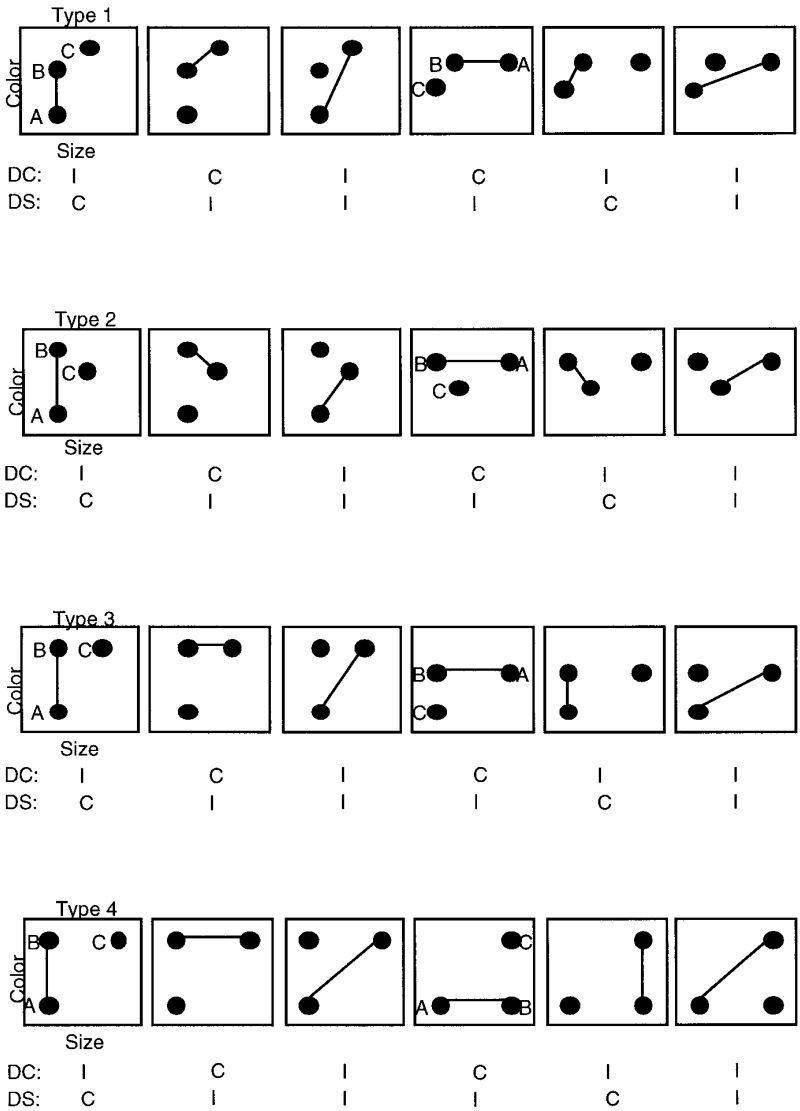


FIGURE 1

Y is achromatic color, the Proximity-Color response pattern predicts the same individual to combine stimuli B and C, because circles B and C are most similar in color. The Proximity-Size response pattern predicts similar matches with selective attention to the size dimension.

It is predicted that the majority of individuals in all three age groups will classify according to a single dimension and that there will be a developmental

increase in the proportion of trials consistent with a single-dimensional response pattern (Thompson, 1994). For a replication of Thompson (1994), very few participants' responses are predicted to follow the identity or proximity classification response patterns. Most importantly, the particular dimension used most often in classification is assumed to be higher in an individual's salience hierarchy than the competing dimension (Cook & Odom, 1992).

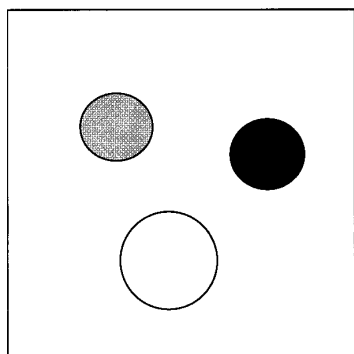
Method

Participants. Sixteen individuals from each of the three age groups participated: 5-year-olds (M age = 5 years 6 months; range = 5 years 0 months to 5 years 11 months), 10-year-olds (M age = 10 years 6 months; range = 9 years 10 months to 11 years 2 months), and adults (undergraduate students). One-half of the 5-year-olds were boys and one-half were girls. The 10-year-old group was comprised of 10 boys and 6 girls, and the adults consisted of 6 males and 10 females. Five-year-olds received a small toy, 10-year-olds earned \$5.00, and adults received course credit in return for their participation. Participants were recruited from local preschools, the university summer sports camp, and the psychology department subject pool.

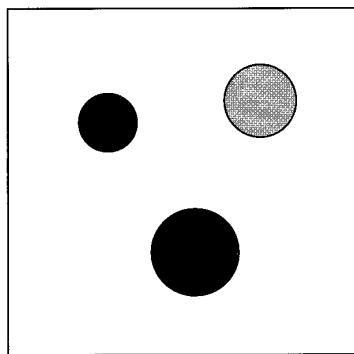
Design and stimuli. Forty-nine unique stimulus circles were created from the factorial combination of 7 levels of size and 7 levels of achromatic color. The diameters of the circles were 1.60, 1.75, 1.90, 2.05, 2.20, 2.35, and 2.50 centimeters. The shades of achromatic color varied within the range of whitish-gray to charcoal gray.

All one-dimensional, one-step differences were highly discriminable to children. This was predetermined by means of an oddity task (Smith, 1989), in which 8 preschoolers (M age = 4 years 5 months; range = 4 years 0 months to 5 years 1 month) participated. In this oddity task, each of the 12 possible one-step differences (6 on each dimension) was detected greater than 75% of the time by every participant. The two dimensions were tested separately, by holding dimensional values constant across one dimension, while varying them along the other dimension. For example, to test whether the steps along the size dimension were discriminable, a child was presented with three circles that were identical in color, but one circle differed in size from the other two circles. The child was instructed to point to the circle which was different in size. This method insured that the values along each dimension were discriminable to children and adults who participated in the remainder of the study.

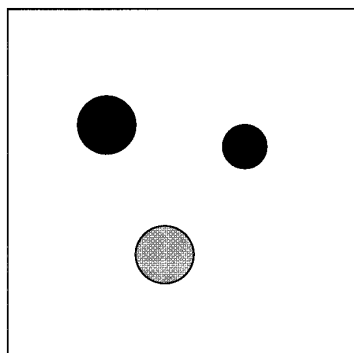
Each of the four types of triads used in the first experiment consisted of three circles presented together in a trial (see Fig. 2). In Type 1 and Type 2 triads, two stimuli (A and B) share an identical value on one dimension (X) but differ on the other dimension (Y). Circle B differs only slightly on both dimensions (X and Y) from the third circle (C) in the triad, while circle A differs substantially from circle C. The sum of the two-dimensional difference between stimuli B and C (two steps) was always smaller than the one-dimensional difference between stimuli A and B (three steps). Type 1 and Type 2 triads differ only in the



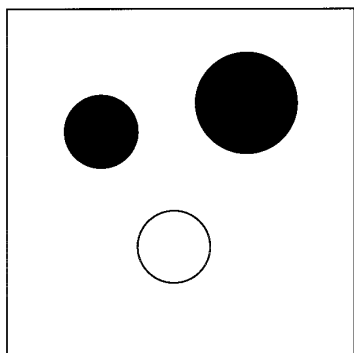
Type 1



Type 2



Type 3



Type 4

FIGURE 2

noncritical relation between stimuli A and C. Specifically, stimuli A and C are further apart in multidimensional space in Type 1 triads (two-dimensional difference of five steps), compared to Type 2 triads (two-dimensional difference of three steps).

Type 3 and Type 4 triads resemble Type 1 and Type 2 triads in that stimuli A and B share an identical value on dimension X. The difference lies in the relationship between B and C. In Type 1 and Type 2 triads, there is always a two-dimensional difference between B and C, but in Type 3 and Type 4 triads, there is always a one-dimensional difference between B and C, since the pair shares an identical value on dimension Y. The difference between Type 3 and Type 4 triads is that in Type 3 triads the one-dimensional difference between A and B (three steps) is always greater than the one-dimensional difference between B and C (two steps), but in Type 4 triads, the one-dimensional difference between pair A and B is always equal to the one-dimensional difference between

pair B and C (three steps for both). For all triad types, stimuli A and B share a value on one dimension, stimuli B and C are always nearest to each other in multidimensional space (except on Type 4 triads where the distance between pair AB and pair BC is equal), and stimuli A and C are more different from each other (greatest distance apart in the stimulus space) than any of the other possible combinations, producing "haphazard classifications" when grouped together (cf. Smith & Kemler, 1977).

Forty unique triads, ten of each of the four triad types, were created for the restricted triad classification experiment. Half of the Type 1 and Type 2 triads contained a size-dimensional match and half contained an achromatic color-dimensional match. All Type 3 and Type 4 triads possessed identical matches on both dimensions. Half of the Type 3 triads had the size match as more similar overall (2-step difference on the color dimension), and half had the color match as more similar overall. The resulting 40 triads were presented in random order within a block of trials. All subjects received two 40-trial blocks, for a total of 80 trials.

Stimuli were presented in triads of equidistant circles (positioned as if they were the vertices of a triangle), with their centers approximately 5 centimeters apart. Triads were displayed in foveal view on a computer screen, with a bright blue background. A ready screen prompted the participant to press any key to begin the experiment. Prior to every trial, the computer released a high-pitched tone to remind participants to look at the screen. Stimuli remained on the screen until a response was made, followed immediately by the presentation of the next trial.

Apparatus and procedure. The stimuli were presented on a Macintosh RGB color monitor with a 13-inch screen, controlled by a Macintosh IIcx computer and keyboard.

The restricted triad classification task was administered individually to each participant. The younger children, adults, and some of the older children were tested in the cognitive development lab. The remainder of the older children were tested in a room in the physical education building. A photometer was used to establish equivalent lighting in both settings. The experimenter sat next to the individual, in front of the computer screen, and displayed the first experimental trial. Subjects were instructed to look at the stimuli carefully and to "put the two together that go together best." To control for the potential influence of labeling on classifications (Markman & Hutchinson, 1984), the experimenter never mentioned the words, "similar," "identical," "size," "color," "circle," or any other related category term.

The adults and 10-year-olds used the keyboard to make each response, and a line appeared connecting the two stimuli they chose. The 5-year-old children pointed to the screen indicating which two circles "go together best," and the experimenter entered their responses using the keyboard. The triads remained on the screen until a response was made. Participants were under no pressure to

respond quickly and were free to change their response prior to the presentation of the next trial. The experimenter periodically encouraged the children, but no evaluative feedback was given to subjects regarding their selections. The experimental session lasted approximately one-half hour.

Results and Discussion

Two 5-year-olds, one 10-year-old, and one adult were replaced by new subjects, due to too many haphazard responses (>20%). In the final sample of 48 subjects, there was a decrease with age in the number of haphazard responses. The 5-year-olds made the highest percent of haphazard responses (11%), the 10-year-olds made considerably fewer (5%), and the adults very few (2%). This is the same pattern reported by both Smith and Kemler (1977) and Thompson (1994).

The data were analyzed with a model-fitting program designed to determine the proportion of responses consistent with each given perceptual classification response pattern: (a) Dimensional-Color, (b) Dimensional-Size, (c) Proximity-Color, (d) Proximity-Size, (e) Identity-Color, and (f) Identity-Size. The program analyzed each block of 40 trials separately; thus every individual had two outcomes. The pattern producing the greatest proportion of consistent responses was considered to be the best-fitting response pattern for an individual for that block of trials. For example, Block 1 data for Participant 1 revealed that merely 7.5% of her responses were consistent with a Dimensional-Color response pattern, but that 85% of her responses followed a Dimensional-Size response pattern. Potentially, two or more outcomes could tie for the highest value. Furthermore, the highest value for Blocks 1 and 2 may not be represented by the same response patterns.

T tests were performed on the consistency values for participants' best-fitting response patterns and their next best-fitting patterns (which, in a few cases, was a tied value). For each age group and within each block of trials, participants' best-fitting response pattern fit their data significantly better than participants' next-best-fitting response pattern (p 's < .001 in each case).

In the 5-year-old group, six children adhered predominantly to the Dimensional-Size response pattern, three made a majority of their responses consistent with the Dimensional-Color pattern, and two of the children's responses corresponded best to the Proximity-Size pattern. One 5-year-old child had three response patterns that fit his data equally well. His data showed an equal proportion of responses consistent with the Dimensional-Size, Proximity-Color, and Identity-Color patterns. The remaining four younger children switched response patterns halfway through the experiment. Of these four, one child started with the Dimensional-Color response pattern and switched to the Identity-Size pattern. Another child followed the Proximity-Color response pattern most closely and then switched to the Dimensional-Size pattern. The final two 5-year-olds both adhered to the Proximity-Size response pattern in the first block of

trials but, for the second block, one switched to using the Dimensional-Size pattern and the other to the Proximity-Color pattern.

Eleven of the older children had their highest proportion of responses consistent with the Dimensional-Size response pattern. One child's responses followed the Identity-Size pattern. The remaining four older children switched response patterns halfway through the experiment. Two followed the Identity-Color response pattern for the first block of trials and then switched to the Dimensional-Color response pattern for the second block. One 10-year-old adhered strictly to the Proximity-Color response pattern for the first block of trials, but he switched patterns halfway through the experiment, so that both the Dimensional-Size patterns and the Identity-Size pattern fit his data equally well in the second block of trials. The other child followed the Identity-Size pattern for the first block and also switched response patterns for the second block of trials.

Eight adult subjects' classifications were consistent with the Dimensional-Size response pattern. Three of the adults had their highest proportion of responses consistent with the Identity-Size pattern. One subject's responses were best fit by the Dimensional-Color pattern. The remaining four adults switched response patterns halfway through the experiment. The response pattern of one adult showed that her classifications were equally consistent with both the Proximity-Size and the Identity-Size patterns for the first half of the experiment, but that she followed only the Proximity-Size in the second half. One person followed the Identity-Size response pattern for the first block of trials and then switched to using the Dimensional-Color pattern in the second block. Another participant adhered to the Proximity-Size response pattern in the first block of trials and then switched halfway through the experiment to the Dimensional-Size or Proximity-Size pattern. Finally, the majority of the last subject's responses were consistent with the Dimensional-Size response pattern during the first half of the experiment, but followed the Identity-Size pattern for the second half of the experiment.

Overall, size was the most salient dimension across age groups. Nine of the 5-year-olds, 12 of the older children, and 14 adults were found to be most sensitive to size in the triad classification task. Achromatic color appeared to be most salient for three of the 5-year-olds, two older children, and one adult. For six individuals, size and achromatic color were approximately equal in salience, due to the fact that their classification response patterns changed between dimensions across the two blocks of trials. Four of the 5-year-old children, two of the 10-year-olds, and one adult switched dimensions across the two halves of the experiment. The data from the majority of subjects in all three age groups conformed best to response patterns based on groupings according to single dimensions.

Thompson (1994) and Aschkenasy and Odom (1982) found that when the distance between levels of one dimension was expanded to increase distinctiveness, children's classifications tended to be based on the more discriminable

dimension. In the current study, the data indicate that the steps along the dimension of size were slightly more discriminable than the steps along the dimension of achromatic color to most individuals in all three age groups.

There is a developmental trend toward greater consistency with age in adhering to a preferred response pattern. The 5-year-old children had the lowest consistency value (M value = .69; range = .425 to .975), the older children's mean value was much greater than the younger ones' (M value = .82; range = .525 to .975), and the adults had a slightly higher average consistency value than did the children (M value = .86; range .55 to 1.0). This difference was statistically significant between the younger children and adults, $t(15) = 4.107$, $p < .0009$, and also between the younger and older children, $t(15) = 2.236$, $p < .05$, but not between older children and adults, $t(15) = 1.158$, $p > .05$. These data support earlier findings showing an increase in consistency values between younger and older children, but not between older children and adults (Thompson, 1994, Experiments 2 & 3).

In summary, the analysis fulfilled multiple objectives. First, dimensions of high and low salience were determined for each participant, and those few who switched dimensions were identified as such. The analysis also provides evidence for two main points: (a) young children (5-year-olds) have the ability to selectively attend to separate object dimensions in a triad classification task¹ (Cook and Odom, 1992; Thompson, 1994) and (b) there is a developmental increase in consistency of adhering to an initially adopted perceptual classification response pattern (Thompson, 1994). Moreover, Thompson's (1994) findings were replicated using the dimension of achromatic color in place of brightness, showing that previous results can be generalized to a different combination of perceptually separable dimensions.

EXPERIMENT 2: SPEEDED VISUAL DISCRIMINATION

In the second experiment, a speeded visual discrimination task was presented over three days of testing to the same children and adults who participated in the triad classification task. We reduced the likelihood of participants switching attention between dimensions during the time interval between stimulus onset and response by specifying the dimension to attend to when making object comparisons on the first two days of testing. On the third day of testing, participants were to decide whether or not the objects were the same on either relevant dimension. Four types of pairs were used (illustrated in Fig. 3), which differed on zero, one, or two stimulus dimensions (size and achromatic color). Unlike Experiment 1, the importance of accuracy and speed was emphasized to the participants in Experiment 2.

¹ Earlier studies in perceptual classification overlooked the young child's ability to selectively attend to separate dimensions because only group averaged data was considered (Smith & Kemler, 1977), resulting in erroneous conclusions. Recent research in perceptual development has addressed this problem, demonstrating the necessity of individual data analysis to identify classification strategies (Cook & Odom, 1992; Thompson, 1994).

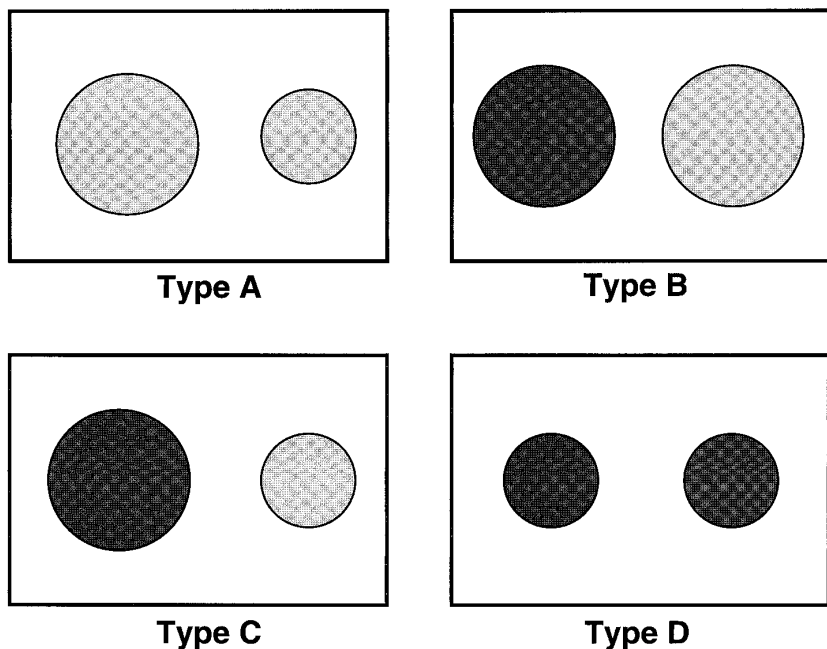


FIGURE 3

The speeded visual discrimination task introduces a new methodology to test perceptual sensitivity to separate object dimensions in children and adults. Responses were also analyzed using a signal detection analysis. The goal of using signal detection theory (Green & Swets, 1966) in perceptual studies like the speeded visual discrimination task is to obtain a sensitivity parameter for each individual's level of salience, which is not influenced by the decision process. The difference between the two means of the distributions for the trials on which there is an identical match (signal + noise trials), where the correct response is "yes (match)," and the trials on which there is not an identical match (no-signal trials—noise only), where the correct response is "no (no match)," is known as d' , the measure of perceptual sensitivity. Beta values measure the response bias, or the tendency to say "yes" or "no," regardless of whether or not the signal is present. We aimed to find converging evidence from signal detection and reaction time measures concerning two developmental issues: the effect of dimensional salience on speeded discrimination performance and sensitivity to identity relations in speeded discrimination.

The primary issue concerns the influence of salience on speeded discrimination responses. Across age groups, speeded discriminations should be greatly affected by preassessed salience if salience effects originate at an early or automatic level of perceptual processing. Following Cook and Odom (1992),

young children have greater perceptual experience with their high salience dimensions compared to their low salience dimensions. Thus, it is predicted that when discriminations are based on the dimension of highest salience, d' values should be higher and responses should be faster compared to responses made when the task relevant dimension is low in salience. Cook and Odom (1992) also found children to show greater sensitivity to featural relations along their high salience dimensions compared to their low salience dimensions. That is, with low predisposed salience to a given dimension, children need the higher distinctiveness of values to draw their attention to the dimension. With higher predisposed salience, they do not need the values to be as distinct from each other. Therefore, young children's reaction times for high salience dimensions should not vary greatly as a function of the featural similarity between the discriminated objects, while discrimination responses for objects differing on participants' low salience dimensions should vary greatly according to featural similarity. The pattern of responses for low salience dimensions should more closely approximate the pattern for high salience dimensions with increasing age.

Smith (1989) has proposed that as young children get older, identity becomes increasingly valued as a type of similarity classification. This claim is neutral with regard to the level of perceptual processing exhibiting developmental gains (lower perceptual level or a more strategic level). If identity valuing influences discriminability at a fairly low perceptual level, identical values on unattended dimensions should facilitate responses that are made when identity is being assessed on a different dimension. Specifically, participants' responses should be faster when making speeded discrimination responses on object pairs that are identical on all dimensions (identical pairs) compared to responses on object pairs which are identical on the dimension being attended to and nonidentical on the other dimension (one-dimension-different pairs). Furthermore, Smith's (1989) developmental claims regarding identity would be supported by a small difference in response times between completely identical and one-dimension-different pairs for younger children compared to a larger difference between identical and one-dimension-different pairs for older children and adults.

Method

Subjects. The participants were the same 48 subjects from each of three age groups (16 younger children: 5-year-olds; 16 older children: 10 year-olds; and 16 adults: undergraduates), who participated in the final sample in Experiment 1. Subjects were informed at the beginning of Experiment 1 that they would be requested to participate in a second experiment. Young children received a small toy, 10-year-olds were paid \$5.00, and adults earned course credit for each of three experimental sessions.

Design and stimuli. Stimuli were the same 49 circles used in Experiment 1, except they were presented in pairs instead of triads. The two circles were displayed in a row, with their centers approximately 6 cm apart (as illustrated in

Fig. 3). Dimensions of high and low salience were determined for each participant in Experiment 1.

Figure 3 shows the four types of stimuli pairs presented to participants in the speeded visual discrimination task. All pair types were presented across three experimental conditions, on three separate days, in a repeated measures design. Type A pairs shared an identical value on the color dimension, but varied in size by one to four steps. Type B pairs shared an identical value on the size dimension, but varied in achromatic color by one to four steps. Type C pairs either differed on both dimensions by one step or on both dimensions by two steps, or they differed on one dimension by one step and on the other dimension by two steps. Type D pairs were exactly the same on both dimensions.

On each trial, participants were requested to decide whether a specified match between two displayed circles was present. Thus, all responses were either “yes/same” (the specified match is present/the two circles are the same on the relevant dimension) or “no/different” (the specified match is absent/the two circles are different on the relevant dimension). Participants were instructed to search for a size-dimensional match (the two circles are identical in size), an achromatic color-dimensional match (the two circles are identical in color), or a match on either dimension (the two circles are identical in *either* size or color, or both). On the first two days of testing, participants were to decide if the two circles were the same or not on a specified dimension (size or achromatic color). The specified dimension remained the same dimension throughout the entire session. The third day of testing differed from the first two in that subjects were instructed to determine if *either* size or achromatic color values were identical or not in the two stimuli.

Each individual participated in all three conditions of the visual discrimination task: high-salience, low-salience, and high- and low-salience. Half of the participants received their predetermined high-salience condition on Day 1 of testing and their low-salience condition on Day 2 of testing, while the remaining participants received these two conditions in the reverse order. For every participant, the high- and low-salience condition was administered on the third day of testing.

Forty-eight unique pairs, 12 of each of the 4 types of pairs, were created for the size and achromatic color instruction conditions of the visual discrimination task. The resulting 48 pairs were presented in random order within a block of trials. Subjects received 2 blocks of trials in all 3 experimental sessions, resulting in 96 trials for each of the 3 conditions. To maintain an equivalent number of correct “yes” and “no” responses, the condition presented on Day 3 required 3 times the standard amount of Type C pairs. In this condition, 8 each of Type A, B, and D pairs were presented, in addition to 24 Type C pairs. Thus, participants still received 2 blocks of 48 random pairs, but half of the block consisted of Type C stimuli pairs. Participants received a total of 288 trials across the 3 experimental sessions.

Stimuli were displayed in foveal view on a bright blue background. A ready screen prompted the participant to press any key to begin the experiment. Prior to each trial the computer made a high-pitched tone to remind subjects to look at the screen. The stimuli remained on the screen until a response was made.

Apparatus and procedure. The stimuli were presented on a Macintosh RGB color monitor with a 13-inch screen, controlled by a Macintosh IIcx computer and keyboard.

The experimenter sat next to the individual, facing the computer screen. The participant was instructed to look at the two circles carefully, and decide if there was an identical match on the relevant dimension for that block of trials. For example, in a block of trials where size was the relevant dimension, these instructions were given, "Are the two circles the same size?" The participant responded by pressing the appropriate key on the keyboard to indicate that "yes" the circles were identical in size or "no" they differed in size. The relation of any other dimension was irrelevant at this time. Stimuli remained on the screen until a response was made. Because the keypress response was too difficult for the 5-year-olds to complete independently, the younger children responded vocally, with either a "yes" or "no" response, and the experimenter (who did not look at the pairs on the screen) entered their responses with the keyboard.

The goal was to achieve fast responding without sacrificing accuracy. Therefore, participants were encouraged to make the correct response as quickly as possible, but to make few errors. To enhance performance, feedback was provided by the computer after every trial, and summary information was provided halfway through each block of trials. If the individual made the correct response, a smiling face appeared in the center of the computer screen prior to the presentation of the next trial. If an incorrect response was made, a frowning face was displayed on the screen. Immediately following the feedback, the next trial appeared on the screen. Each experimental session took approximately one-half hour. Children were provided with a short break between blocks to alleviate boredom and distraction.

Results and Discussion

Participants whose classifications in Experiment 1 switched dimensions across the two test blocks were labeled "bidimensional" responders and their data were not included in the analyses reported here, due to their lack of an apparent high-salient dimension. Thus the data of four young children, two older children, and one adult were eliminated from the analyses. Mean response times and standard deviations for "match" and "no match" responses were obtained for the 41 remaining participants. The dataset was truncated by removing all data points with response times greater than two standard deviations from each individual's mean in each condition (in either direction, higher or lower). An average of 10 trials, from a possible 288 trials, was deleted per participant. In addition, only correct responses were included in the reaction time analyses (75% of total responses).

Salience. Response times for Day 1 and Day 2 of testing, and for Type A & Type B pairs only, were submitted to a 3 (Age: 5; 10; adults) \times 2 (Salience: High; Low) \times 4 (Discriminability: 1; 2; 3; 4 dimensional steps) Analysis of Variance which revealed significant main effects for age, $F(2,38) = 106.69, p < .0001$, for salience, $F(1, 38) = 12.95, p < .001$, and for discriminability, $F(3,114) = 8.34, p < .0001$. The Salience \times Age interaction was also significant, $F(2,38) = 4.24, p < .05$. All other interactions failed to reach statistical significance ($p > .05$). As expected, there was a marked difference in response times between age groups. The adults were the fastest responders, followed by the 10-year-olds, and the 5-year-olds were the slowest responders. Response time means for each age group, collapsed across Type A & Type B pairs, are presented in Fig. 4. This resembles typical response time data for developmental studies of cognitive processes (Kail, 1993), showing faster speeds with increasing age to adulthood.

To better understand the nature of the interaction between age and salience, the response time data were analyzed for each separate age group collapsing across discriminability. Data were submitted to separate one-way analyses of variance using the salience factor. The main effect of salience was statistically significant for the 5-year-olds, $F(1,11) = 14.75, p < .003$, showing faster response times for their high salient dimensions. The effect of salience was not significant in the 10-year-old group nor in the adult group ($ps > .05$). Further, paired comparisons revealed that when salience was collapsed across high and low salience dimensions, responses were significantly faster for the average of the two most discriminable stimuli ($M = 1015$) compared to the two least discriminable stimuli ($M = 1053$), $t(40) = -4.12, p < .001$. Greater dimensional differences speeded discriminability of object pairs in all age groups.

The preceding analyses examined the effect of salience when it was task relevant, that is, when subjects were specifically instructed to attend to the object dimension of size or of color. We then asked whether subjects responded more quickly to their high salient dimension when they were not given explicit instructions to compare the circles on a particular dimension (Day 3 of testing). The question is, when subjects are instructed to look for a match on either dimension, are they faster to respond when a match is found on their high salient dimension than when a match is found on their low salient dimension? If this were the case, it would imply that people process their high salient dimensions first, even without explicit instructions to do so. To examine this, we performed a 3 (age) \times 2 (salience) Analysis of Variance on Type A and B pairs and for Day 3 of testing only, which uncovered no main effect for stimulus salience and no significant interaction between age and salience, $ps > .05$.²

Signal detection analysis. In order to investigate developmental changes in perceptual sensitivity to object dimensions differing in salience, d primes (sen-

² It is possible that salience effects of this nature may have been present if they had been tested for on the first day of testing, rather than on the third day of testing.

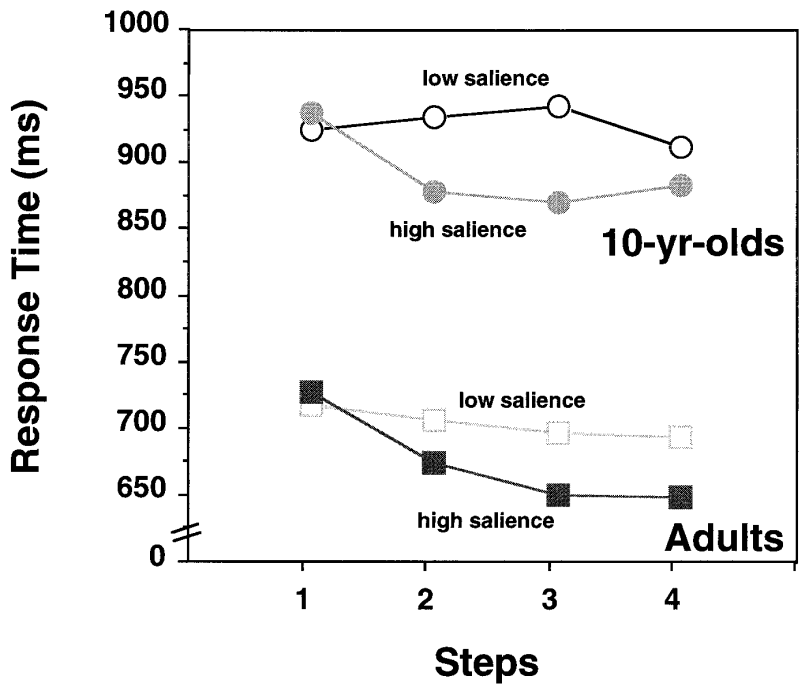
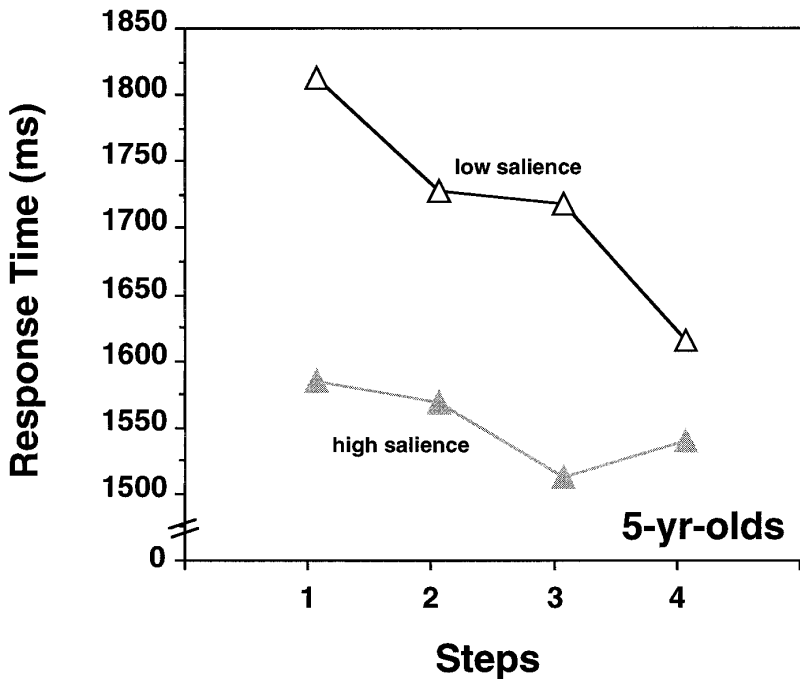


TABLE 1

Mean D Prime and Beta Scores (and Standard Deviations) for Each Age Group in the Three Salience Conditions from the Speeded Discrimination Experiment

| Age group | Salience condition | | | |
|------------|--------------------|-------------|-------------|-------------|
| | High | | Low | |
| | D Primes | Betas | D Primes | Betas |
| 5-yr-olds | 2.59 (1.26) | 0.53 (0.36) | 2.42 (0.92) | 0.56 (0.38) |
| 10-yr-olds | 2.19 (1.34) | 0.74 (0.28) | 1.77 (0.47) | 0.77 (0.21) |
| Adults | 2.43 (0.93) | 0.61 (0.31) | 2.58 (1.0) | 0.53 (0.35) |

sitivity) and betas (bias) were calculated using signal detection analysis. This was accomplished by dividing the data from 41 subjects into six subsets, determined by the factorial combination of age and salience conditions. The resulting six datasets were submitted separately to the signal detection program. Two d' scores and two β scores were derived for each of the 41 participants whose data were analyzed for salience effects on response times, one for performance on their high salience dimension and one on their low salience dimension. A single d' score and a single β score represented each participant's data across Day 1 and Day 2 sessions.

Table 1 shows that d' scores were generally high for all three age groups, indicating that participants were sensitive to the differences along the two stimulus dimensions. A 3 (Age: 5-, 10-year-olds, adults) \times 2 (Salience: high vs low) analysis of variance was conducted on d' scores to ascertain if perceptual sensitivity was affected by dimensional salience and age. The analysis on d' s revealed no significant main effects or interactions (all p 's $>$.05), although, d' values for high and low salient dimensions were in the predicted direction in both children's age groups.

It is desirable that β scores not vary too drastically between conditions or across age groups. A β of 1 indicates that an individual is not biased toward any response. A β value of .5 means that an individual is biased to say "yes," whereas a β value of 1.5 means that an individual is biased to say "no." Table 1 shows that mean β scores for all age groups were always less than one, implying that subjects in the present study were generally biased to say "yes, the circles are the same/match." A second ANOVA with β as the dependent measure showed no significant effects of age and salience and a nonsignificant interaction ($p >$.05). Thus, in contrast to the response time data, the signal detection data were not sensitive to the effects of salience and discriminability in a speeded discrimination task.

Selective attention and identity. Data from the same 41 participants described above were submitted to additional analyses to explore a specific question concerning early perceptual processing of identity relations. The question under

consideration was whether or not identical values on the unattended dimension facilitate identity processing on the attended dimension. Therefore, only responses to the Type A and B stimulus pairs actually containing a "match" on the attended dimension were compared to "match" responses for Type D pairs. Since Type D pairs contained matches on both the attended and the unattended dimensions, responses on all Type D pairs were analyzed. Further, Type A and Type B pairs were pooled for all subsequent analyses, since both consisted of a one-dimension difference, and because there was not a significant difference in responding to Type A and Type B pairs ($p > .05$).

A 3 (Age: 5-, 10-year-olds, adults) \times 2 (Identity Type: one-dimension-identity pairs vs identical pairs) Analysis of Variance on the data for Days 1 and 2 revealed that responses became faster as age increased, $F(2,38) = 90.13$, $p < .0001$. Identical pairs were responded to significantly faster than one-dimension-identity pairs, $F(1,38) = 12.31$, $p < .002$. However, the interaction between age and identity type did not reach significance. Thus, identical values on the unattended dimension facilitated the speed of processing identical relations on the attended dimension for participants in all age groups.

GENERAL DISCUSSION

The experiments addressed three current issues regarding the nature of perceptual development in children: (a) Do children become better able to discriminate featural differences along dimensions which are for them perceptually separable?; (b) Are identity relations processed more quickly than difference relations, and how might this change across development?; and most importantly, (c) Are perceptually salient dimensions processed more accurately and/or more quickly than less salient dimensions in a task context designed to minimize the possibility of switching attention between dimensions prior to making a response? In Experiment 1, we employed the triad classification task to determine which of two dimensions was primarily used as a basis for classification for each individual. A "high salient" dimension, either the size or achromatic color of circles, could be assessed for 41 of 48 individuals by comparing individuals' classifications against many different response patterns that support specific triad classification strategies. Preassessed salience was predicted to influence both the speed and the accuracy of discriminating between two circles in Experiment 2, and this effect was predicted to diminish across development.

The differential-sensitivity view of perceptual development (e.g., Cook & Odom, 1992) posits that "age-related change in the classification of objects is crucially affected by the perceptual system's sensitivity to separate relations, with greater sensitivity occurring to more relations as development proceeds" (1992, p. 174). Previous work has shown that young children's performance on a variety of tasks is more accurate for the dimensions that are higher in preassessed salience, compared to performance on dimensions that are lower in salience (see Cook & Odom, 1992, for a review). The present study was mainly

concerned with testing Cook and Odom's (1992) hypothesized boundary condition for perceptual salience effects which predicts that perceptual salience effects may not occur when participants are told which dimension to selectively attend to. Cook and Odom suggested that the lack of perceptual salience effects may have been caused by additional conceptual processing, overtly explicit directions, or all task relevant information's having some perceptual value.

The present Experiment 2 alleviated some of those factors believed to be the cause of this lack of effect of salience on speeded classifications in Cook and Odom's (1992) study, and the outcome was in favor of differential-sensitivity, but without their stated boundary condition. The results of the speeded discrimination task clearly confirmed our hypothesis that young children's perception would be affected by preassessed salience. Averaged discrimination times were significantly slower on children's low salience dimensions compared to their high salience dimensions. Consequently, our results indicate that the boundary condition does not hold for young children's perceptual processing. When young children are told to attend selectively to either size or achromatic color of two objects, less time is required to make "same" and "different" responses for children's high salience dimensions as compared to their low salience dimensions. In contrast, neither 10-year-olds' nor adults' discrimination times showed a significant main effect for salience, suggesting that, by the age of 10, children's perceptual systems are sufficiently trained to quickly detect difference relations along the dimensions tested.

One challenge for researchers of perceptual development is to devise tests which can illuminate the nature of developmental change in components of perceptual processing which occur early in the sequence of processes leading up to the categorization of an object. Most of the theoretical work in this area has relied on tasks that yield evidence questionably related to these early perceptual processes. Our findings show that 5-year-olds' perceptual salience levels preassessed on triad classification tasks are predictive of performance on speeded discrimination tasks. It is impossible to know from these data whether all components of perceptual processing are influenced by salience, such as feature encoding, feature integration, and classification, but the parsimonious assumption is that salience effects do originate at an early level and persist until objects are perceptually classified. Furthermore, our cross-experiment comparisons in the 10-year-old and adult age groups revealed that preassessed salience based on triad classification data does not guarantee obtaining perceptual salience effects in the speeded discrimination task context.

Perhaps the reason that our study was able to support differential-sensitivity, whereas two of Cook and Odom's experiments (1992, Experiments 2 & 4) could not, lies in the physical differences of the two speeded tasks. In their speeded card sorting task, participants were able to see the last card sorted, which could have influenced the processing of subsequent cards in the deck. In the speeded discrimination task, participants were presented with one stimulus pair at a time,

and once a response was made they could no longer view the stimulus pair from a previous trial.

It is also likely that perceptual processing of simple and familiar stimuli is performed so efficiently that it is difficult to avoid ceiling effects using accuracy measures. While the speeded discrimination task was affected by perceptual salience, the evidence from Experiment 2 did not reveal greater accuracy for high salient discriminations. That is, signal detection analyses showed no main effects for salience in any age group. Consequently, while salience effects were obtained in a speed measure, the effect was not robust enough to show up in an accuracy measure. This finding is not problematic however, because d' values were high and did not differ across age.

The speeded discriminability data obtained also conform to a developmental prediction that could be made on the basis of Smith's (1989) model of perceptual classification. Using a free classification methodology, Smith found that when stimuli varied on two dimensions, the perceived similarity between objects increased as the magnitude of the physical differences along a dimension decreased. More importantly, the power parameter (P) of the function relating perceived similarity and the magnitude of stimulus differences changed with development. Specifically, P equaled 1 in the case of 2-year-old children, and P increased with age. Her model would predict that speeded discrimination responses should be a steep function of physical differences for the youngest age group and that the function should become less steep as age increases. This is the general developmental trend found in Experiment 2. The implication of the Experiment 2 data for Smith's model is that separate P parameters may be necessary to fit perceptual classification data when the object dimensions differ greatly in terms of salience.

More recently, Lamberts (1995) extended Smith's model by using a deadline procedure with adults in a free classification task. The power function decayed less steeply in the (600-ms) deadline procedure compared to the nonspeeded procedure, mimicking Smith's earlier results for young children. Moreover, dimensional weights for various features of the objects (e.g. eyes and ears of a schematic face) were determined by perceptual salience in both deadline and nonspeeded procedures. Lambert's results illustrate how strongly perceptual salience can affect categorization even when adult participants are under severe time constraints. Further mathematical models should incorporate assumptions regarding perceptual salience as it relates to developmental changes in perceptual processing.

Our results concur with the differential-sensitivity view and with Smith's (1989) developmental theory of perceptual classification on another important claim, that selective attention to dimensions is possible by at least the age of 5. The results from Experiment 1 demonstrated that most individuals' perceptual classification response patterns were based on selective attention to one of the dimensions. These results, along with others (Cook & Odom, 1992; Odom &

Cook, 1996; Thompson, 1994), refute the findings of the original integrality–separability theory (Smith & Kemler, 1977), which claimed that children younger than 6 years of age process separate object dimensions integrally, as undifferentiated wholes. Although this theory of perceptual development is clearly outdated, children’s inability to visually attend to separate object dimensions is still being inaccurately reported in current research (e.g., Berger & Hatwell, 1993; Medin, Goldstone, & Gentner, 1993).

The results of the speeded discrimination task also uncovered new evidence regarding perceptual processing of identity relations (Smith, 1989). For all age groups, identical values on the unattended dimension facilitated the speed of processing identical relations on the attended dimension. This adds to what is already known about the special status of identity relations in perception by showing that identity valuation influences occur at an early, automatic level of perception. Smith (1989) also proposed that children value identity relations to a greater degree as they develop. Evidence from Experiment 2 did not support this claim, since the degree of facilitation of identity relations on speeded discriminations did not differ across age groups. However, it is as yet unknown whether or not children younger than 5 years would exhibit a weaker identity facilitation effect in this task.

The results from the present study demonstrate the subtle nature of development between childhood and adulthood in visual perceptual processing. As children get older, their perceptual systems become more finely tuned to the slight variations between similar objects, and consequently, they become faster at noticing object differences. Children’s speed of detecting differences is highly dependent on perceptual experience with particular dimensions. This differential experience with more and less salient dimensions plays a larger predictive role in the behavior of younger, compared to older, children. Eventually, all object relations should become equally high in perceptual salience, as the differential-sensitivity view logically predicts. The results of the present study emphasize the need for innovative tests to examine perceptual development.

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