# How children combine vision and touch when perceiving the shape of objects

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Descriptive findings are now available on developmental changes in the ways children explore objects by eye and by hand in order to perceive their characteristics. The major question for this research was how vision and touch cooperate perceptually to gather information about unfamiliar shapes. We assumed that by ages 4 and 5, a cooperative division of labor for purposes of information gathering would be established between the two perceptual systems. Both observational and performance data supported the conclusion that for the perception of shape characteristics, the eyes are given an almost exclusive role, with hands serving mainly to orient objects for visual inspection. These findings are contrary to those of some Soviet researchers and suggest a different interpretation of the relations between vision and touch during the course of growth.

Study of the development of perceptual activity and exploration seeks, among other things, to define how a S explores an object or surface for purposes of acquainting himself with it. The assumption is that the perceptual activity of a S while engaged in visual investigation or haptic (active touch) scanning of objects and surfaces informs us about what he attends to and how he organizes his "perceptual acts" (cf. Gibson, 1966). Processes of this sort have important implications for the development of knowing and awareness. A number of studies (Piaget, 1961; Zaporozhets, 1965; Zinchenko, Van Chzhitsin, & Tarakanov, 1962; Mackworth & Bruner, 1966) have provided information that describes perceptual activity changes with age and, to a lesser extent, with variations in object or surface properties (Abravanel, 1968a; Mackworth & Otto, 1970). Most research has concentrated on how a S deploys either the visual or haptic systems for information gathering. The approach taken in the present investigation was to compare haptic perceptual activity under two conditions: (1) where it occurred without visual inspection, and (2) where haptic and visual exploration could be combined. Several earlier investigations provide the background and setting for the research undertaken and help place it in perspective.

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Zinchenko and Ruzskaya (1960) studied the visual and haptic perception of children between 3 and 6 years of age while engaged in perceiving unfamiliar shapes for the first time. They report characteristic changes in perceptual activity with age. When viewing a shape, 3-year-olds generally centered visual inspection on some parts while avoiding others and failed to explore the entire contour. Between 4 and 6 years, there was a progressive increase in the number of sweeps across the shape (increase in activity) and systematic exploration of the contour. There was, as well, a corresponding decrease in perceptual centrations, such that all parts of the shape were visually scanned. Zinchenko and Ruzskaya (1960) also filmed activity of their Ss while haptically exploring these shapes with vision occluded. They found a number of similar age-related changes in perceptual activity under both haptic and visual exploration.

Abravanel (1968a) observed and recorded the haptic exploration of children between 3 and 13 years while engaged in exploring objects for length and circumferential magnitudes. He observed marked changes with age in the forms of perceptual activity. Three- and 4-year-olds explored for length in a way that did not greatly differentiate the perceptual and performatory functions of the hand. They characteristically engaged in holding, rotating, and palpating movements of the solid objects whose lengths they were supposed to determine. By 5 years of age, many Ss demonstrated new techniques of securing length information which capitalized on kinesthetic and interoceptive forms of information pickup. Seven-year-olds utilized additional methods of length exploration, and these were clearly better suited to accurate length estimation.

In yet another investigation with similar aims, Vurpillot (1966) recorded eye movements of children between 3 and 9 years while engaged in a task of comparing paired drawings of houses in order to determine whether they were similar or different. She found that truly effective scanning strategies were not present in a majority of Ss prior to 6½ years.

Given this growing body of descriptive information on changes in perceptual activity with growth, a further question was posed. We assumed that the preschool child would have evolved a form of eye-hand cooperation and, given a shape recognition problem, that he would show us how he had produced a division of labor between perception by hand and by eye. Accordingly, we set forth to compare two exploratory conditions, one where the S perceives a series of solid shapes by hand alone (haptic perception) and second, where the S perceives these shapes by the combined operations of hand and eye (haptic + visual perception). We expected to observe a difference in the perceptual processes of the hand under these two conditions of exploration, and our aim was to describe the quality of the difference. In addition, the procedure would enable us to assess relative accuracies of shape recognition under the two conditions of shape exploration.

## METHOD

### Design

The original design called for three conditions of matching standard and comparisons with two sets of stimulus shapes. Set I was intended to study the quality of perceptual activity with a simpler shape discrimination, while Set II was included for purposes of assessing perceptual activity with a more difficult shape discrimination. Pilot data suggested that the wooden shapes of Set I were, in fact, easier to differentiate than the solid sculptured shapes of Set II. All Ss received both sets of shapes, serving as members of equivalent groups across sets. A period of 2 weeks separated data collection with the two sets, and Set I always preceded Set II.

During the course of collecting the data, it occurred to us that a different pattern of hand-eye division of function might appear if the procedure used with the combined haptic-visual group were modified such that all comparisons were presented haptically. Presenting comparisons haptically might be expected to increase the difficulty of the task (Rudel & Teuber, 1964; Abravanel, 1968b) and might be expected to

  

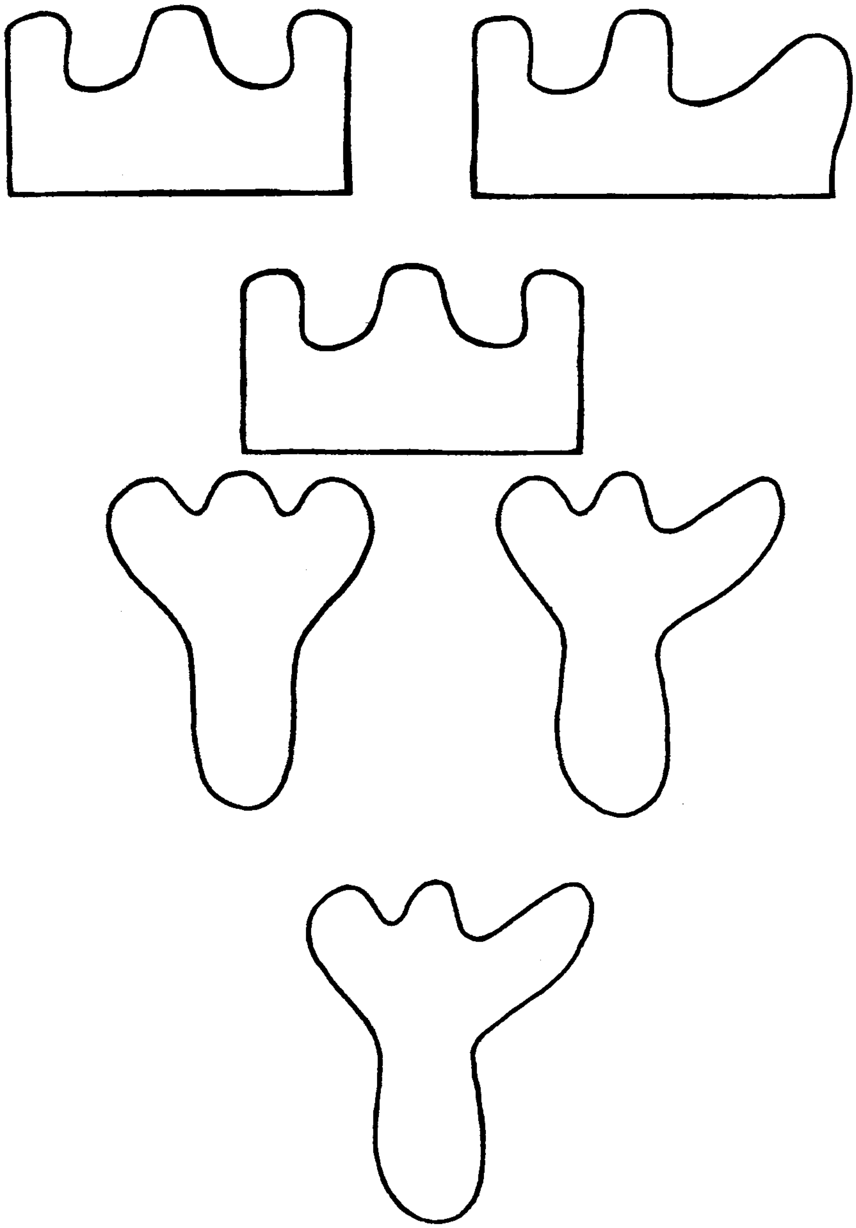

Fig. 1. Examples of shape triads from Set I.

enhance exploration of the standard shape. A group of 20 4-year-olds was added to test this possibility.

### Subjects

Children were obtained from the nursery school and kindergarten classes of two private preschools in metropolitan Washington, D.C. A total of 80 Ss (43 boys and 37 girls; mean = 4 years 4 months) comprised the younger sample. An additional 20 Ss (12 boys and 8 girls; mean = 5 years 7 months) made up an older sample which was added later to the study. There is usually more attentiveness and a better understanding of instructions at 5 years than at 4 years, and subsequent inclusion of the older sample was considered a useful check on the consistency of findings with an older preschool group. For all groups, children were selected randomly from the rolls of the two schools; the disparity in numbers of boys and girls resulted from the larger enrollment of boys. Racial composition was approximately 80% caucasian and 20% negro. The children were from middle-income families.

### Apparatus and Materials

A large screen (90 x 45 cm) shielded the experimental objects from the S. An opening (30 cm) in the lower half of the screen was draped with a dark curtain which enabled the S to place his hands behind the screen and to handle the objects freely without being able to see them.

A 16-mm Bolex motion-picture camera equipped with a 50-mm Angenieu lens and mounted on a tripod was used for filming each S's haptic exploration. Film was 16-mm Kodak Tri-X. Additional room illumination was obtained from a Sylvania Sun Gun.

*Set I.* Materials consisted of 10 triads of wooden shapes cut from grained hardwood 2 cm in thickness (Fig. 1). The shapes were designed to be unfamiliar to the average child. Each triad consisted of a standard, an identical comparison, and second comparison. The two comparison shapes possessed at least one significant feature that differentiated them. For some triads, the difference involved the size of an area; for others, it was the shape of a part, or the relative positions of parts within the entire object. Sizes of standard and comparisons were similar. The entire series varied between 4.5 x 6.5 cm at the small end and 8 x 14 cm at the large end.

*Set II.* Stimulus materials consisted of a set of free-form solid (stereometric) objects originally designed by Gibson (1962). The objects were smooth, black, and of nearly equal size and weight (150 g). The rear half of each object was convex, and the front consisted of five protuberances around a central hump. Thus, the number of protuberances was the same for all shapes but the sizes varied, as did the spaces and depths among the protuberances. The entire set consisted of 10 identical pairs, each pair different in shape from every other.

Some advantages of these shapes for the study of haptic perceptual activity are that they are stereometric (therefore graspable), unfamiliar (therefore requiring active perception), and not easily labeled or associated with familiar objects. As such, these shapes require an active process of exploration to be distinguished, which may not always have been true in studies of haptic perception.

Each object was mounted on 12 x 15 mm white cardboard such that the distinguishing features could be fully explored. Objects were mounted on cardboard in order to safeguard against the likelihood that Ss would rotate them and create orientation differences between standard and comparisons.

### Procedures for Sets I and II

Each S was randomly assigned to one of the three groups described below. All Ss received 10 shape

Table 1
Means and Standard Deviations for Numbers of Correct Matches Between Standard and Comparison Shapes

| | | | Set I: Wooden Shapes | | Set II: Solid Sculptured Shapes | |
|---|---|---|---|---|---|---|
| Group | Standard | Comparisons | Mean Number Correct | SD | Mean Number Correct | SD |
| 4-Year-Olds | | | | | | |
| 1 | Haptic | Visual | 6.35 | 1.56 | 5.00 | 1.79 |
| 2 | Visual | Visual | 9.00 | .89 | 8.50 | 1.07 |
| 3 | Haptic + Visual | Visual | 8.95 | .86 | 8.35 | 1.11 |
| 4 | Haptic + Visual | Haptic | 6.55 | 1.36 | 5.11 | 1.71 |
| 5-Year-Olds | | | | | | |
| | Haptic + Visual | Visual | 9.70 | .30 | 9.35 | .73 |

*Trials per S = 10* *N = 5 X 20 = 100*

matching trials where a standard was matched against two comparisons, with one of the comparisons equivalent to the standard. Order of the trials was randomized, and each combination of standard and comparison was presented only once. The Ss were encouraged with praise and smiles, but were not given feedback concerning the correctness of their matches.

Prior to administration of the experimental series of shapes, Ss were given warm-up trials with simple, familiar materials such as spools, keys, crayons, etc.

*Group 1: Haptic-visual.* The standard was presented behind an opaque screen for haptic exploration with both hands (but the S was not prevented from using only one hand if he preferred) for an unlimited length of time, which was usually under 30 sec. Visual inspection of the standard was prevented by the screen. After 10 sec of haptic exploration, S was instructed to select between a pair of visually presented comparisons. Standard and comparisons were then available simultaneously with all objects at table level. Orientation of standard and comparisons was equated by E in order to avoid changes that would make the task more difficult.

For all Ss, haptic exploration was continuously recorded on 16-mm motion-picture film.

*Group 2: Visual-visual.* For this group, the standard was placed on the table alongside the S, and he was instructed to inspect it only visually. After 10 sec, the visual comparisons were placed on the table to the side opposite the standard. S was asked to match the standard with the equivalent comparison. No filming was done with this group.

*Group 3: Haptic + visual-visual.* The standard was placed on the table alongside the S in easy reach, and he was encouraged to inspect it both haptically and visually. After 10 sec, during which the S could concentrate attention on the standard, the visual comparisons were placed on the table to the side opposite the standard. S was asked to match the standard with the equivalent comparison.

Again, all haptic exploration of the standard shapes was continuously recorded on 16-mm motion-picture film.

*Group 4: Haptic + visual-haptic.* As in Group 2, Ss were encouraged to inspect the standard both haptically and visually. After 10 sec of inspection, S was requested to place either one or both hands (his choice) behind the screen and to select the one comparison shape that matched the standard. S was free to reexamine the standard at will.

Once again, haptic exploration was recorded on 16-mm black and white film.

## RESULTS

### Perceptual Activity

*Set I: Wooden shapes.* The reason for filming exploratory movements of Ss' hands while operating under haptic or haptic + visual information pickup conditions was to determine how the hands were used for exploration when visual inspection was also possible (Group 2) and when the S had to rely fully on a single system, the haptic system (Group 1). The most outstanding finding was that 18 of the 20 Ss in Group 2 (haptic + visual-visual) used their hands as "pedestals" more than as perceptual tools. The dominant approach involved using either one or both hands to lift and position each shape for proper visual inspection. Thus, Ss used their hands to orient and direct the shapes for visual regard, but rarely for purposes of exploration. Ss in Group 1 (haptic-visual) were prevented from visually perceiving the standard shapes and did, of course, engage in haptic exploration. For this group, tracing surfaces, gripping parts, and locating features were all carried out by hand, indicating that 4-year-olds will engage in haptic exploration of the objects when they are prevented from seeing them.

*Set II: Solid sculptured shapes.* Even the considerably complex and more difficult to discriminate solid sculptured shapes were treated similarly by Ss in Group 2 (haptic + visual-visual). Once again, the large majority (18 of 20 Ss) did not haptically palpate or explore the surfaces of these complex objects. Instead, they treated the solid sculptured shapes as they had the wooden shapes—i.e., positioning the object for visual regard, occasionally turning it to view from another angle. And, often, Ss chose not to handle them at all. In effect, matches were made almost totally on the basis of visually derived information. As noted for Set I, Ss in the haptic-visual group did, by contrast, examine and palpate the surfaces of the objects in order to perceive shape properties.

### Accuracy

*Set I: Wooden shapes.* Matching standard and comparison shapes was more accurate for visual-visual and for haptic + visual-visual groups than for the haptic-visual group (see Table 1). A one-way ANOVA was significant ($F = 39.96$, $df = 2/57$, $p < .01$). Newman-Keuls multiple comparisons indicated that visual-visual and haptic + visual-visual groups were not significantly different from each other in accuracy of matching, whereas both groups were significantly ($p < .01$) more accurate than the haptic-visual group.

*Set II: Solid sculptured shapes.* Findings for the more difficult solid sculptured shapes paralleled those for Set I. A one-way ANOVA across groups was significant ($F = 33.06$, $df = 2/57$, $p < .01$). Newman-Keuls multiple comparisons again indicated that visual-visual and haptic + visual-visual groups were not significantly different in accuracy of shape matching but that both groups were significantly more accurate ($p < .01$) than the haptic-visual group.

There were no significant sex differences in accuracy of matching for either experiment.

### Five-Year-Olds: Haptic + Visual-Visual

*Perceptual activity.* The quality of hand utilization among 5-year-olds was comparable to that observed for 4-year-olds in this group. At times, Ss used their hands for turning or positioning an object in order to improve visual inspection. No S palpated or haptically explored the contours of either the simpler wooden shapes or the more difficult solid sculptured shapes. This preference to perceive the shapes visually occurred in the face of explicit instructions, with each trial, that "you may look at and feel the object all over."

*Accuracy.* Five-year-olds were significantly more accurate than 4-year-olds (Table 1) in matching standard and comparisons under haptic + visual-visual conditions with both the wooden shapes ($t = 3.69$, $df = 38$, $p < .01$) and the solid sculptured shapes ($t = 3.37$, $df = 38$, $p < .01$).

Accurate matches for all 10 trials (100%) were achieved by the following numbers of Ss: Group 2 (Set I = 7, Set II = 4); Group 3 (Set I = 6, Set II = 3); 5-year-olds (Set I = 15, Set II = 10).

Group 4: Haptic + Visual-Haptic

*Perceptual activity.* Of the 20 Ss observed under conditions of haptic inspection of comparisons, only three Ss haptically explored the standard when also given the opportunity to visually inspect it. Haptic exploration occurred only with the more difficult solid sculptured shapes, never with the wooden shapes. One S did a considerable amount of checking of the standard's features by hand, while the other two Ss made only occasional haptic excursions over the standard. By contrast, the large majority of Ss chose to make the shape differentiation and match totally on the basis of the information they could gather visually.

*Accuracy: Set I—wooden shapes.* Matching with haptic comparisons proved more difficult (see Table 1) than matching with visual comparisons, and the difference was highly significant ($t = 6.68$, $df = 38$, $p < .001$). However, even with haptic comparisons, Ss were performing at better than chance ($\chi^2 = 9.61$, $df = 1$, $p < .01$).

*Accuracy: Set II—solid sculptured shapes.* A similar pattern of results emerged here. The shift to haptic comparisons made matching more difficult than with visual comparisons ($t = 7.11$, $df = 38$, $p < .001$). In fact, accuracy was no greater than might be expected by chance ($\chi^2 = .09$, $df = 1$, n.s.).

## DISCUSSION

On the basis of the evidence presented, it is tempting to conclude that by 4 years, and perhaps by a good deal earlier, the young child has created a division of labor between eye and hand in which visual perception is given the major role for shape differentiation. The overwhelming emphasis on visual exploration of the standard shapes in all the experiments reported comes as a surprise. One might have expected greater use of the hands for gathering information about the shapes of objects. Information gathered haptically is not identical with that obtained visually (Pick, Pick, & Klein, 1967) and might be expected to add materially to a difficult discrimination. Also, the suggestion of research (Zaporozhets, 1961), observation, and common wisdom is that from infancy young children are prone to handle objects and investigate them manually. Thus, in glaring contradiction to expected performance, the 4- and 5-year-old Ss in this investigation chose to ignore the possible advantages of haptic information when given an opportunity to combine handling and viewing of shapes for purposes of matching.

The results of Group 4 showed that even where the comparison shapes were presented haptically, thereby making the discrimination more difficult, and presumably encouraging haptic investigation of the standard shape, very little haptic exploration occurred. A direct correspondence between the haptic impressions of the standard and the comparisons could have been constructed, but Ss, once again, chose to inform themselves about the standard visually and attempt an intersensory match with the haptic comparisons on the basis of visual information. This is the strongest piece of evidence to suggest that by 4-5 years of age, the preferred mode of exploring unfamiliar and complex shapes is visual. The findings may hold principally for shape differentiation, while other properties of things, such as hardness or texture, might produce a different pattern of hand-eye interactions.

The relative accuracies of shape matching across groups were generally consistent with other research results (Birch & Lefford, 1963; Rudel & Teuber, 1964; Milner & Bryant, 1968; DeLeon, Raskin, & Gruen, 1970). Matching between visually presented shapes is easier for children and adults than is matching between shapes presented haptically.

We obtained very similar levels of accuracy for visual-visual and haptic + visual-visual groups, and this is readily understandable in terms of our Ss' preferences for relying on visual input. The superior performance of the 5-year-old as compared with the 4-year-old Ss confirms other evidence (White, 1965; Zinchenko, Van Chzhi-tsin, & Tarakanov, 1962; Abravanel, 1968b) for the rapid improvement in discrimination functions between these two ages.

Yet the discrepancy between the current findings and those of Zinchenko and Ruzskaya (in Zaporozhets, 1965) are not easily reconciled. These authors report better shape matching where children were permitted to handle and view, as against viewing, the standard shapes. There may be a sampling effect that is responsible for the difference in findings, and this is plausible if we consider the emphasis on and encouragement of haptic exploration and action in the Soviet school system (Zaporozhets, 1965; Leontiev, 1961).

A significant clarification of our problem may be achieved by a consideration of two additional studies of the effects of handling on memory. A study by Denner and Cashdan (1967) has indicated that young children recalled a shape better after exposure that involved both looking and handling than after only visual exposure. However, Weiner and Goodnow (1970) have followed up with a variation on this study. Their results indicate that handling served principally to direct attention to the shape and that this function could be achieved in other ways. In the case of the present investigation, when an opportunity for haptic information gathering was added to visual inspection, the hand, where used, was given a performatory rather than perceptual role. Handling was used to orient objects for visual shape perception, but the hand was rarely utilized in its capacity as an exploratory and information-gathering system. As Gibson (1966) pointed out, "The perceptual capacity of the hand goes unrecognized because we usually attend to its motor capacity, and also because the visual dominates the haptic in awareness [p. 123]." It seems that much of the research on effects of handling objects for information gathering or retention has not clearly distinguished the different functions the hand may perform. Nor has there been given proper consideration to how such functions might relate to important questions of eye vs hand dominance (cf. Rock & Victor, 1964), improvements in discrimination with use of the hands (Montessori, 1914; Zaporozhets, 1965), or what might be the proper conceptualization of how the eye and the hand work together at different stages in human growth.

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