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ABSTRACT

Tests of dimensional dominance with planometric stimuli in either the visual or haptic modality were given to 108 children, 36 from each of the grade levels preschool, kindergarten, and first. Visual dimensions were form and color; haptic dimensions were form and texture. Following initial dominance assessment, one-third of the subjects were presented familiar forms and novel colors (visually) or textures (haptically), one-third were presented novel forms and familiar colors or textures, and one-third were presented novel forms and novel colors or textures. Results indicated that the shift to form dominance occurred relatively later in the haptic modality (first grade) than in the visual modality (kindergarten). The effects of the novelty manipulation were opposite in the two modalities: Visually, introduction of novel color cues with familiar forms produced the greatest shift towards color dominance; haptically, introduction of novel form cues produced the greatest shift towards texture dominance. (Author)

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VISUAL AND HAPTIC DIMENSIONAL DOMINANCE: THE EFFECTS OF NOVELTY

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Abstract

One hundred and eight children, 36 from each of the grade levels preschool, kindergarten, and first, were given tests of dimensional dominance with planometric stimuli in either the visual or haptic modality. Visual dimensions were form and color; haptic dimensions were form and texture. Following initial dominance assessment, one-third of the subjects were presented familiar forms and novel colors (visually) or textures (haptically), one-third were presented novel forms and familiar colors or textures, and one-third were presented novel forms and novel colors or textures. Results indicated that the shift to form dominance occurred relatively later in the haptic modality (first grade) than in the visual modality (kindergarten). The effects of the novelty manipulation were opposite in the two modalities: Visually, introduction of novel color cues with familiar forms produced the greatest shift towards color dominance; haptically, introduction of novel form cues produced the greatest shift towards texture dominance.

Visual and Haptic Dimensional Dominance: The Effects of Novelty[1]

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Dimensional dominance or preference is typically inferred when a subject consistently responds (without external reinforcement) on the basis of one stimulus dimension when other dimensions are also present. Much of the developmental research in dimensional dominance has been done in the visual modality, using a variety of paradigms (Brian & Goodenough, 1929; Corah, 1964; Mitler & Harris, 1969; Siegel & Vance, 1970; Suchman & Trabasso, 1966). These studies indicated a shift from color to form dominance sometime before five and one-half years of age, with some variation as to the specific transition point depending on the kinds of stimuli and method of dominance determination used.

Haptic dimensional dominance also shows developmental changes, but the age of transition to form dominance seems to be more a function of whether the stimuli are planometric or stereometric. Gliner, Pick, Pick, and Hales (1969) found that both kindergarteners and third-graders were form dominant visually, but that haptically, kindergarteners were texture dominant while third-graders were form dominant. The generality of these results is questionable, however, because visual stimuli were presented simultaneously, whereas haptic stimuli were presented successively. Abravanel (1970) tested a group of preschool children (age range 4-0 to 5-4) and a group of kindergarteners (age range 5-6 to 6-5)

[1] The authors wish to thank the principals and teachers at Shady Lane Preschool and Churchill Elementary School for their helpful cooperation in this study.

in a haptic recognition task with stereometric stimuli varying in form and texture, and Abravanel found that kindergarteners made significantly more matches on the basis of form (79%) than did the preschoolers (63%).

Siegel and Vance (1970) controlled for mode of presentation and type of stimuli, and tested the same children in both visual and haptic tasks. Stereometric stimuli were presented simultaneously to preschoolers, kindergarteners, first-graders, and third-graders. The pattern of preference scores was essentially identical in both visual and haptic tasks. For both tasks, all age groups except the preschoolers (whose mean percentage of form choices in the visual and haptic tasks was .49 and .54 respectively) showed marked form dominance (the combined mean proportion of form choices for the three oldest groups in the visual and haptic tasks was .79 and .81 respectively).

One of the purposes of the present study was to see if similar developmental trends would be found if children were tested with planometric stimuli in visual and haptic tasks. Suchman and Trabasso (1966) used planometric stimuli while Siegel and Vance (1970) used stereometric stimuli, yet both studies found the shift to visual form dominance occurring at around five years. On the basis of these studies, it could be argued that developmental trends in visual form dominance should be unaffected by whether planometric or three-dimensional stimuli are used. Thus, we expected that a shift from visual color to form dominance should be found in the present study between preschool and kindergarten. However, given that Gliner et al.'s (1969) kindergarteners showed texture dominance haptically when planometric stimuli were used, whereas Abravanel's (1970) kindergarten group showed form dominance when stereometric stimuli were used, it was expected that in the present study the shift to haptic form dominance should occur relatively later than that to visual form dominance.

In light of previous research, it is apparent that a more detailed analysis of the transition period in both modalities is required. Specifically, assessment of the direction of preference is insufficient; the strength of preference must also be determined. The most direct approach to the problem would appear to involve the manipulation of various parameters as hue saturation (Suchman & Trabasso, 1966), location of the color value on a given form (Katz, 1971), symmetry of contour (Corah, 1966), and degree of training (Gaines, 1970). However, these manipulations have been restricted to the visual modality and the necessary developmental analysis of the various stimulus manipulations has not been considered.

Since many attentional theories assume that novel cues on a dimension will differentially elicit more orienting or observing responses to those cues (Berlyne, 1960; Fowler & Siegel, 1971; Zeaman & House, 1963), then strength of initial dimensional dominance can be assessed by looking at the extent to which novelty can override initial dominance (or the extent to which initial dominance is resistant to a novelty manipulation). Additionally, if there are developmental differences in strength of dominance, then one should also find developmental differences in the extent to which novelty can override the initial dominance. Thus, a second purpose of this study was to assess the strength of dimensional preference by examining developmentally the differential effects of stimulus novelty on both visual and haptic dimensional dominance. Following initial preference assessment, novelty of one or both dimensions was systematically varied in a between-groups design (i.e., novel forms - familiar colors or textures; familiar forms - novel colors or textures; novel forms and novel colors or textures).

Method

Subjects

The subjects were 108 white, middle-class children, 36 from each of the grade levels preschool (Mean CA = 4 years - 5 months, Range = 3-6 to 5-1), kindergarten (Mean CA = 5-8, Range = 5-2 to 6-0), and first grade (Mean CA = 6-9, Range = 6-1 to 8-0).

Stimuli

Stimuli for both initial assessment and novelty tasks were cut from 3.2 mm. masonite and painted or covered on the whole exposed upper surface. Stimuli for the initial visual preference assessment were red and blue circles (8.9 cm. in diameter) and squares (7.6 cm. on a side). The stimuli for the novelty task were a curved asymmetrical figure and an angular asymmetrical (both of approximately the same area as the circles and squares; see Figure 1), painted aurora pink or saturn yellow (both fluorescent and very bright).

Stimuli for the initial haptic preference assessment were rough (60 grit sandpaper) and smooth circles (8.9 cm. in diameter) and squares (7.6 cm. on a side). The stimuli for the novelty task were the same curved and angular asymmetrical figures used in the visual novelty tasks, covered with bunny fur or suede.

Pretesting had indicated that all textures, colors, and shapes were readily discriminable even by the youngest children. Since most children, when asked, reported that they had not seen or felt the "novel" stimuli before, it can be assumed at the least that these stimulus values were relatively novel.

Apparatus

Apparatus for the visual task was a wooden board 50 cm. long, 15 cm. wide, and 1 cm. thick. Stimuli were attached to the board by

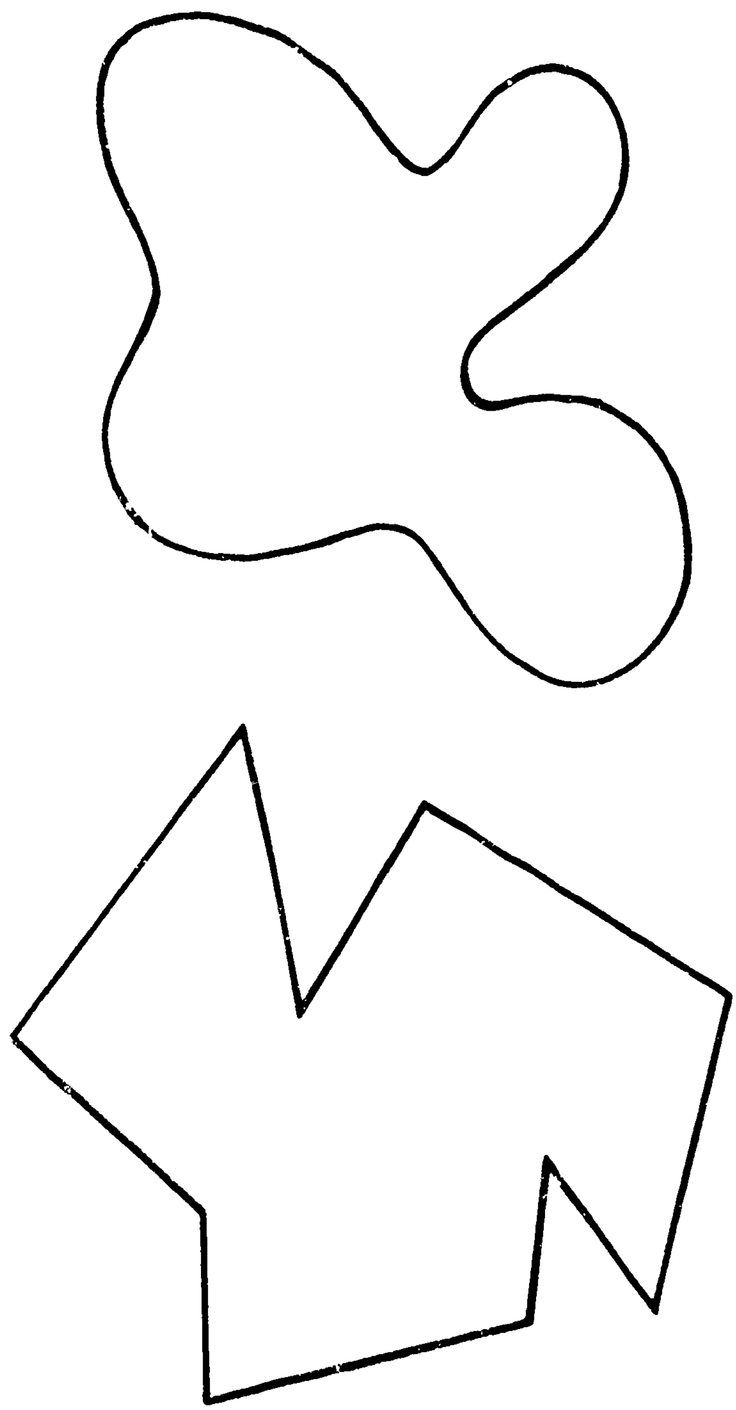

Figure 1. The Curved and Angular Asymmetrical Shapes Used in the Novelty Manipulation.

means of Velcro patches glued to the board and to the bottom of each stimulus, thus allowing rapid removal and rapid, accurate, and stable placement of stimuli. The three stimulus locations were equally spaced in a horizontal line on the board. Asymmetrical stimuli of the same shape were always attached in identical and constant orientations for every trial.

In the haptic task this tray was presented to the subject through the back of a plywood box which was 60 cm. high at the experimenter's side of the box, 60 cm. wide, and 30 cm. deep. The front of the box was a 30 x 60 cm. panel, joined at the top by a 43 cm. long panel which sloped upward to the experimenter's side. Two 10 cm. diameter holes were cut into the front panel; their centers were 30 cm. apart and 15 cm. from the bottom of the panel. An elastic cuff was set in each hole so that the subject could insert his hand (up to the elbow) and feel the stimuli. The experimenter's side of the apparatus was open so that he could arrange the stimuli, present the stimulus tray, observe the subject's exploration, and note when the subject made his "choice" response.

Procedure

Each subject was tested individually in both the visual and haptic tasks. The experimenter seated the subject opposite him at a desk and told him that they would play some games.

In the visual task the child was shown the four familiar stimulus attributes to be used in the initial preference assessment and was told that he was going to see three things, and that he was to point to the two things that were the same. The subject was told that this was a game, not a test, and that there were no right or wrong answers. Following these instructions, each subject was given the initial preference task, consisting of eight trials in which the familiar stimuli were presented. On each trial three stimuli were presented simultaneously, two of which were the same form, and two of which were the same color. For example, on trial n the subject was presented a red circle, a red square, and a blue circle. If the subject indicated that the red circle and the red square were the same, color was scored as the child's preferred dimension for this comparison; if the subject indicated that the red circle and the blue circle were the same, form was scored as the child's preferred dimension.

Following the initial preference assessment, a third of the children at each grade level were assigned to one of three novelty conditions, defined on the basis of the stimulus values used. Subjects in the Novel Color condition were shown saturn yellow and aurora pink (novel colors) circles and squares (familiar forms); subjects in the Novel Form conditions saw red and blue (familiar colors) asymmetrical curved and angular figures (novel forms); subjects in the Novel Both condition saw saturn yellow and aurora pink asymmetrical curved and angular figures. The Novelty task consisted of another eight trials in each of which the subject had to pick the two stimuli that were the same.

In the haptic task the child felt the four familiar stimulus attributes and was told that he was going to feel three things, and that after he felt all three he was to leave his hands on the two that were the same. The initial preference task consisted of eight trials in which the familiar stimuli were presented. On each trial three stimuli were presented simultaneously, two of which were the same form, and two of which were the same texture. Dimension preference was determined as in the visual task.

Following the initial haptic preference assessment, a third of the children at each grade level were assigned to one of three novelty conditions: Subjects in the Novel Texture condition felt circles and squares (familiar forms) covered with bunny fur and suede (novel textures); subjects in the Novel Form condition felt rough or smooth (familiar textures) asymmetrical curved and angular figures (novel forms); subjects in the Novel Both condition felt asymmetrical curved and angular figures covered with bunny fur or suede. The novelty task consisted of another eight trials on each of which the subject had to pick the two stimuli that were the same.

For all tasks (visual and haptic initial preference and novelty), stimuli were chosen such that for each set of four stimuli, each of the four possible combinations of three stimuli was presented twice. Order of presentation and position of the stimuli on the board were randomized.

Half of the subjects were tested in the visual tasks first and then tested in the haptic tasks. The other half of the subjects were tested in the reverse order. Due to severe confounding that might have been caused by the influence of novelty in one modality on initial preference in the other modality, only the data for a subject's <u>first</u> modality were considered in any of the formal analyses.

Experimental design

Separate 3 (Grade x 3 (Novelty condition) analyses of variance with 6 subjects/cell (3 boys, 3 girls) were performed on initial preference scores and novelty scores in both modalities. Preliminary *t*-tests performed on these scores yielded no significant differences on any of the measures (all *t*'s < 1), and thus sex was not included as a factor in any of the analyses.

Results

Analyses of visual preference data

The number of subjects at each grade level showing consistent dimensional dominance (defined as making at least seven out of eight choices on one stimulus dimension, a rigorous criterion) on the initial preference assessment is shown in Table 1. Although more kindergarteners than preschoolers were form dominant, and more preschoolers than kindergarteners were color dominant, this difference was not significant ($X^2 < 1$).

The proportion of form choices for each subject on the initial preference task was computed and the mean of these proportions for each grade level is also presented in Table 1. Analysis of variance performed on these proportions indicated that neither the main effect of Grade Level or Condition, nor the Grade x Condition interaction was significant. As a group, however, only the preschoolers failed to choose form over color at a level significantly greater than chance ($t = 1.50$, $df = 16$, $.05 < p < .10$, one-tailed), whereas both kindergarteners and first-graders showed a significant preference for form over color ($t \geq 2.85$, $df = 16$, $p < .01$). Thus, preschoolers as a group were neither color nor form dominant (61% of the subjects were form dominant; mean proportion of form choices = .64); kindergarteners and first-graders were clearly form dominant (78% of the subjects were form dominant; mean proportion of form choices = .78).

To assess the relative strength of visual dimensional dominance (i.e., its resistance to the novelty manipulation), the number of children who shifted their dominant dimension from form to color or color to form on the novelty task was tallied, and is also presented in Table 1. Since

Table 1

Visual Preference Data

Group	N	Number of Form Dominant Subjects	Number of Color Dominant Subjects	Mean Proportion of Form Choices on Initial Task	Number of Subjects Shifting Dominance	Mean Change Score
Preschool	18	11	6	.64	1	-.02
Novel Form	6	4	2	.67	0	00
Novel Color	6	2	4	.83	0	-.02
Novel Both	6	5	0	.94	1	-.04
Kindergarten	18	14	4	.78	3	+.17
Novel Form	6	4	2	.67	0	.00
Novel Color	6	5	1	.83	3	+.50
Novel Both	6	5	1	.83	0	.00
First Grade	18	14	4	.78	1	+.05
Novel Form	6	4	2	.67	0	.00
Novel Color	6	5	1	.83	0	.00
Novel Both	6	5	1	.83	1	+.16
All Novel Form	18	12	6	.67	0	00
All Novel Color	18	12	6	.67	3	+.16
All Novel Both	18	15	2	.87	2	+.04
All Subjects	54	39	14	.73	5	+.07

the novel form and color values were thought to be quite novel, it is surprising that only 5 of the 54 subjects showed such a shift (all 5 shifted from form to color dominance).

To assess the resistance of initial dimensional dominance to novelty, a change score was computed for each subject by subtracting the proportion of form choices made on the initial assessment task. Thus, a positive change score represents some degree of shift away from form and towards color dominance. The change scores are presented in Table 1. A 3 (Grade) x 3 (Novelty condition) analysis of variance was performed on these change scores. The main effect of grade level was marginally significant ($F = 2.86$, $df = 2/45$, $.05 < p < .10$; an orthogonal comparison indicated that 84% of the variance was accounted for by the significant difference between the combined mean change score of the preschoolers and first-graders (.03) and that of the kindergarteners (.17) ($F = 4.78$, $df = 1/45$, $p < .05$). Although the main effect of Novelty condition was not significant ($F = 2.20$, $df = 2/45$, $p > .10$), a post-hoc orthogonal comparison indicated that, in line with the prediction, the mean change score of subjects in the Novel Color condition (.16) was significantly greater than that of subjects in the Novel Form and Novel Both conditions combined (.02) ($F = 4.13$, $df = 1/45$, $p < .05$). As can be seen from Table 1, the highly significant Grade x Condition interaction ($F = 3.88$, $df = 4/45$, $p < .01$) was due primarily to kindergarteners in the Novel Color condition--the novel colors produced a 50% shift away from form and towards color dominance in this group of Ss.

Analyses of haptic preference data

The number of subjects at each grade level showing consistent dimensional dominance (defined as making at least seven out of eight choices on one stimulus dimension) on the initial preference assessment is shown in Table 2. The apparent trend of an increasing number of form dominant children and a decreasing number of texture dominant children with increasing grade level was statistically significant ($\chi^2 = 5.3$, $df = 2$, $p < .05$). Out of 36 preschoolers and kindergarteners, 17 were form dominant and 16 were texture dominant; out of 18 first-graders, 15 were form dominant while only 3 were texture dominant.

The proportion of form choices for each subject was computed and the mean of these proportions for each grade level is also presented in Table 2. Analysis of variance yielded only a marginally significant main effect of grade level ($F = 3.16$, $df = 2/45$, $.05 < p < .10$). An orthogonal comparison indicated that the combined mean proportion of form choices for the preschoolers and kindergarteners (.52) was significantly lower than that of the first-graders (.84) ($F = 6.07$, $df = 1/45$, $p < .025$), and this accounted for 98% of the marginally significant effect of grade level. Both the preschool and kindergarten groups failed to sh[illegible]nificant preference for form over texture (t's < 1), whereas the first-graders were markedly form dominant ($t = 4.20$, $df = 16$, $p < .001$).

To assess the relative strength of haptic dimensional dominance, the number of children who shifted their dominant dimension from form to texture or texture to form on the novelty task is presented in Table 2. In contrast to only 5 out of 54 children shifting dominance on the visual task, 22 of 54 children shifted on the haptic task towards more texture choices (17 went from form to texture dominance; 2 went from inconsistent to texture dominance; and 3 went from form to inconsistent dominance). It is apparent that although the number of subjects shifting at each grade level is approximately the same, the number of subjects within each novelty condition is markedly different; only 1 child shifted under the Novel Texture condition, 8 under the Novel Form condition,

Table 2

Haptic Preference Data

Group	N	Number of Form Dominant Subjects	Number of Texture Dominant Subjects	Mean Proportion of Form Choices on Initial Task	Number of Subjects Shifting Dominance	Mean Change Score
Preschool	18	7	8	.49	7	+.31
Novel Form	6	1	3	.35	2	+.21
Novel Texture	6	3	3	.50	1	+.15
Novel Both	6	3	2	.62	4	+.56
Kindergarten	18	10	8	.55	8	+.38
Novel Form	6	3	3	.52	8	+.38
Novel Texture	6	2	4	.33	0	.00
Novel Both	6	5	1	.81	5	+.79
First Grade	18	15	3	.84	7	+.44
Novel Form	6	6	0	1.00	3	+.56
Novel Textur	6	5	1	.83	0	+.06
Novel Both	6	4	2	.69	4	+.69
All Novel Form	18	10	6	.62	8	+.37
All Novel Texture	18	10	8	.55	1	+.07
All Novel Both	18	12	5	.71	13	+.68
All Subjects	54	32	19	.63	22	+.37

and 13 under the Novel Both condition ($\underline{X}^2 = 6.15$, $\underline{df} = 2$, $\underline{p} < .05$). That is, haptic dominance was least affected when novel textures were combined with familiar forms.

As in the visual data, a change score was computed for each subject by subtracting the proportion of form choices made on the novelty task from the proportion of form choices made on the initial assessment task. Again, a positive change score represents some degree of shift from form to texture dominance. These change scores were subjected to a 3 (Grade level) x 3 (Novelty condition) analysis of variance. Although neither the main effect of age nor the Grade x Condition interaction was significant ($\underline{F} < 1$), the main effect of Novelty condition was highly significant ($\underline{F} = 13.66$, $\underline{df} = 2/45$, $\underline{p} < .001$). Examination of the mean change scores indicated directly opposite results to those found in the visual modality. Post-hoc orthogonal comparisons indicated that the scores of all three conditions were each significantly different from the others ($\underline{F} \geq 6.83$, $\underline{df} = 1/45$, $\underline{p} < .025$). Interestingly, novel textures combined with familiar forms produced only a 7% change in preference, but when combined with novel forms produced a 68% change. The combination of novel forms with familiar textures produced a large but intermediate change of 37%.

<u>Comparisons of intra-subject dimensional consistency</u>

As mentioned previously, after each subject had completed both the initial preference task and the novelty task, he or she was tested in the other modality. Although these data were not considered in any of the formal analyses, it is instructive to examine the relative frequency with which subjects showed clear-cut dominance in both modalities so as to assess (a) the degree of intra-modal dimensional consistency and (b) its relationship with age. Table 3 presents the frequency of within-subject

Table 3

Frequency of Within-Subject Dominance Patterns on Both Visual and Haptic Initial Preference Tasks

Dominance Pattern		Number of Subjects at Each Grade Level Showing the Dominance Pattern (N=36/Grade)		
Visual Task	Haptic Task	Preschool	Kindergarten	First Grade
1. Form	Form	9	17	26
2. Form	Texture	17	12	3
3. Color	Form	6	5	4
4. Color	Texture	7	1	2
Consistent Dominance Between Tasks (1 + 4)		16	18	28
Inconsistent Dominance Between Tasks (2 + 3)		13	17	7

17

dominance patterns on both visual and haptic preference assessments. (It is assumed that visual and haptic form are analogous and consistent insofar as form information is contained solely in the boundary or perimeter of the stimuli. It is also assumed that visual color and haptic texture are analogous and consistent insofar as the information concerning that dimension is contained solely in the surface area bounded by the perimeter.) If one compares developmentally the frequency of subjects who were consistent between tasks (i.e., form dominant on both tasks, or color dominant visually - texture dominant haptically) with the frequency of subjects who were not consistent between tasks (color visually - form haptically or form visually - texture haptically), it can be seen that intra-modality consistency increased from preschool to first grade while inconsistency decreased ($\underline{X}^2 = 7.05$, $\underline{df} = 2$, $\underline{p} < .05$). Additionally, one can see from Table 2 that the frequency of children who were form dominant in both modalities increased from preschool to first grade ($\underline{X}^2 = 8.32$, $\underline{df} = 2$, $\underline{p} < .01$), while the frequency of children who were form dominant visually but texture dominant haptically decreased from preschool to first grade ($\underline{X}^2 = 9.45$, $\underline{df} = 2$, $\underline{p} < .01$).

Discussion

As expected, a shift to visual form dominance was found between preschool and kindergarten, thus replicating with planometric stimuli what Siegel and Vance (1970) had found with stereometric stimuli. Also, as we predicted, the shift to haptic form dominance was found later (between kindergarten and first grade) when planometric stimuli were used (corroborating the findings of Gliner et al., 1969) than when stereometric stimuli were used (e.g., Abravanel, 1970). Although in both modalities this dominance was quite marked when group data were considered, when the number of subjects making at least seven out of eight form choices was considered, the shift to form dominance was more marked in the haptic task.

Thus it appears that, at least in the age range studied, visual form dominance comes about earlier, and is relatively unaffected by whether stimuli are planometric or stereometric. However, haptic form dominance occurs at the same time that visual form dominance does when stereometric stimuli are used, but occurs later when planometric stimuli are used. It would thus seem that at a certain transition point (i.e., kindergarten in this study), form information is more readily picked up and attended to haptically when the form is three-dimensional.

The effects of the novelty manipulation were clearly greater for the haptic than for the visual modality. In the visual task, form dominance was relatively unaffected by the introduction of novel cues along either dimension. However, mean change scores indicated that generally, introduction of a novel color with a familiar form produced the most shift towards color preference.

The effects of the novelty manipulation were more striking in the haptic modality. Whereas the mean change score in the visual task was only .07, that in the haptic was .37. As is clear from Table 2, the single most striking effect is the differential degree to which the various novelty conditions produced a pull towards texture dominance. Interestingly and surprisingly, the results were precisely opposite to those in the visual task. Children who were given novel textures combined with the familiar forms shifted hardly at all towards texture (only one subject out of eighteen shifted). Novel forms, whether combined with novel or familiar textures, however, produced a marked shift toward <u>form</u> dominance. These results are puzzling and there appears no reasonable explanation for them. It would appear that the mechanism or process operating in the visual shift task is somehow different, or produces very different effects, than that in the haptic shift task.

Bearing in mind the probable contamination of shift task in one modality on initial preference in the other modality, it seems that cross-modal consistency increases with grade level, as does cross-modal form dominance; however, this trend is not as strong as that found by Siegel and Vance (1970). This might indicate that stereometric stimuli tend to produce a stronger cross-modal dominance consistency than planometric stimuli.

A final caveat: Although all children were readily able to discriminate all familiar and novel forms, textures, and colors, there may still have been a difference in relative discriminability between any two cue values. The fact that in the present study the novelty manipulation could well be confounded with an inadvertent discriminability manipulation or a color intensity effect (Huang, 1945) would seem to argue that further work in the area of dimensional dominance should be held in abeyance until some systematic psycho-physical scaling of novelty and discriminability of stimuli has been accomplished (à la Gliner et al., 1969) with both planometric and stereometric stimuli.

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