Natural visual capture in bilateral length comparisons*

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In left-right comparisons of perceived length, objects on the left were slightly overestimated by vision alone but not by touch alone. This conflict between vision and touch occurred in the absence of any experimentally induced distortion or illusion. Judgments made with concurrent vision and touch were similar to those made with vision alone regardless of whether the Os were judging which object *felt* longer, *looked* longer, or *was* longer. The resolution of a natural conflict between vision and touch is an example of natural visual capture.

Visual capture is the resolution of sensory conflicts in favor of vision. For example, when an O views a straight rod through curvature-producing prisms while stroking the rod with the fingers, the rod looks curved and feels curved as well (Gibson, 1933). The felt position of an O's hand viewed through displacement-producing prisms is strongly influenced by the seen position (Hay, Pick, & Ikeda, 1965). Rock and Victor (1964) showed that an object viewed through a minifying optical system feels, as well as looks, smaller than it really is. Walker (1971) has shown that two classical visual illusions produce visual capture when the test portions of the illusions can be seen and felt while the induction portions can be seen but not felt.

The conflict between vision and touch has been experimentally induced, as opposed to *naturally* induced, in every demonstration of visual capture (see for example, Tastevin, 1937; Rock, 1966; Kinney & Luria, 1970; Pick & Pick, 1970) prior to that of Teghtsoonian and Teghtsoonian (1970); these last workers used a magnitude estimation procedure to show that the exponent for length perceived concurrently by vision and touch differed from the exponent for touch alone but was the same as the exponent for vision alone. The Teghtsoonians called this effect natural visual capture, a very descriptive term since their Os presumably brought to the experimental situation their own naturally existing conflict between vision and touch.

Natural conflicts between vision and touch might occur in other situations. McPherson and Renfrew (1953) and Wertheimer (1954) found that the size of an object in the left hand is significantly overestimated by touch

alone, while by vision alone, the size of an object in the left visual field has sometimes been underestimated (Brown, 1953). These studies suggest that vision and touch are both asymmetrical with regard to left-right comparisons and further suggest that the two senses may be asymmetrical in opposite directions. Thus, a natural conflict between vision and touch might occur in the absence of any experimentally produced distortion or illusion. Weak evidence of natural visual capture under such conditions was noted in a control group in a study of visual capture in visual illusions (Walker, 1971). The present experiments were designed to investigate further the possible occurrence of natural visual capture in bilateral comparisons of perceived length.

EXPERIMENT 1

Each O made bilateral comparisons of perceived length under the following conditions: by vision alone (V); by touch alone (T); by touch with concurrent vision T(V); and by vision with concurrent touch V(T). Judgments under Condition T(V) were designed to provide evidence of visual capture and under Condition V(T) evidence of the influence of touch on visual judgments.

Observers

Sixteen male and 16 female introductory psychology students at the University of Missouri-St. Louis participated as a course requirement. Only right-handed Os were used.

Apparatus

The *standard* and *comparison* lengths were blocks of black-lacquered Plexiglas about 12.5 mm in cross section. The standard was 100 mm long, and the comparisons were chosen from a graded series of lengths differing by 2-mm steps. The set of comparison blocks ranged from 66 to 120 mm. The standard and a comparison were presented 30 cm

apart lying on a table top, one on the left and the other on the right, with their long axes parallel. Each block was held in place by two pins attached to the table top and fitting snugly into holes in the undersides of the blocks. The table top was clear Plexiglas overlying white posterboard; the top was inclined 15 deg from the horizontal so that the surface and the long axes of the blocks would be more nearly perpendicular to the O's line of sight. Each block was about 45 cm from the O's eyes. Os viewed the blocks binocularly, without fixation, and were allowed to look back and forth from the block on the left to the one on the right as often as they wished. A white cardboard screen was used to hide the blocks from view when judgments were made by touch alone.

Procedure

Instructions given under the four judgment conditions are listed below:

Condition V. O was instructed to indicate, without touching the blocks, "Which looks longer, the left block or the right?"

Condition T. A screen hid the blocks from the O's view. O grasped the left and right blocks simultaneously with the thumbs and index fingers of both hands and was asked, "Which feels longer, the left block or the right?"

Condition T(V). O grasped the blocks as above and was asked, "Which feels longer, the left block or the right? Be sure to tell me which *feels* longer, not which *looks* longer, or which you think *really is* longer, but which *feels* longer." Any O who initially did not look at the blocks was instructed to do so.

Condition V(T). Instructions were the same as under Condition T(V), above, except for the interchanging of *feels* and *looks*.

Under all conditions, judgments of equality were allowed but were discouraged.

Four orders of judgment conditions were balanced across male and female Os: (1) V, T, V(T), T(V); (2) T, V, T(V), V(T); (3) V(T), T(V), V, T; and (4) T(V), V(T), T, V. Using the method of limits, two ascending series of trials and two descending series were presented under each judgment condition. A single series order, ADDA or DAAD, was used for each O. Series orders were balanced across the sexes and also balanced across orders of judgment conditions. Since Costello (1961) showed that the tactually perceived length of a standard tended to be overestimated independently of its presentation to the left or right hand, in the present experiment the position of the standard (left or right) was

*This project was supported in part by a University of Missouri summer research fellowship.

Table 1
Percent Overestimation (Positive Data) and Underestimation (Negative)
of Left Block with Respect to Right*

	Judgment Condition			
	Touch	T(V)	V(T)	Vision
Mean	-1.65	-.06	.76	1.10**
Variance (Between Os)	37.08	5.06	5.39	2.97
Variance (Within Os)	12.47	5.17	4.39	4.11

*Means and variances in italics differ from others at .05 level.

**Differs from zero ($p < .01$).

alternated in successive series to avoid confounding overestimation of the standard with left-right asymmetry of perceived length. Within an ascending or descending series of trials, however, the standard was presented in a constant position. Under successive judgment conditions the standard was presented to each O in a single order (LRLR or RLRL), and these orders were balanced across sexes, series orders, and judgment condition orders.

The first ascending series under any given judgment condition began with a comparison block 92 mm long, that is, four steps (8%) shorter than the 100-mm standard. If the O indicated that the comparison seemed shorter than the standard, the next longer comparison was presented. This procedure was continued until the O indicated that the comparison was longer than the standard on two successive trials. If, on the first trial of an ascending series, the O indicated that the comparison seemed longer than the standard, a comparison two steps shorter was presented; this procedure was followed until the O indicated that the comparison seemed shorter, and at that point the ascending series was started. On the second ascending series under any given judgment condition, the first comparison block presented was the block which had been two steps below the lower limit of the O's interval of uncertainty in the preceding ascending series. The first descending series under any given judgment condition always began with a comparison block 108 mm long, four steps (8%) longer than the standard. The remaining procedures for descending series were analogous to those for ascending series.

When the perceived length of the left block is overestimated relative to that of the right, if the comparison block is on the left a shorter comparison will be equated with the standard, but if the comparison is on the right a longer comparison will be equated with the standard. The point of subjective equality (PSE), the middle of the O's interval of uncertainty, was averaged for each judgment condition. The difference between the PSE and the 100-mm standard was expressed as a percentage

of the standard. Positive percentages indicate that the left block, whether standard or comparison, was overestimated relative to the right, while negative percentages indicate that the left was underestimated.

Since a natural conflict between vision and touch is a prerequisite for the demonstration of natural visual capture, one O, a woman, was replaced because her judgments by vision alone and touch alone were precisely equal. Another O, also a woman, was replaced after a few trials because she volunteered the information that she had sometimes indicated which block was shorter, rather than longer, as the procedure required.

Results

There was a significant conflict between judgments by vision alone and by touch alone. This conflict was resolved in favor of vision when the two senses were used concurrently.

Table 1 presents the basic results. The data were subjected to a two-way analysis of variance (Sex by Judgment Condition), with repeated measures on the second factor. Since the within-Os variances are heterogeneous (see Table 1), conservative F tests with reduced degrees of freedom (Winer, 1962) were used in testing the judgment condition factor and the Sex by Judgment Condition interaction. Since there was no significant sex effect or significant interaction, the results for men and women were combined. By a conservative F test, there was a significant judgment-condition effect ($F = 5.26$, $df = 1/30$, $p < .05$). The means for vision alone and touch alone differ at the .01 level by the Newman-Keuls test for ordered means (Winer, 1962), thus indicating a significant conflict between vision and touch. The mean for touch with vision does not differ significantly from the mean for vision alone, while this first mean does differ significantly from the mean for touch alone ($p < .05$), as would be expected if the visual-tactual conflict were resolved in favor of vision.

The visual bias of touch (VBT) is a ratio which indicates the extent to which tactual judgments are influenced by vision, while the tactual bias of vision (TBV) shows the

influence of touch on vision (Warren & Pick, 1970). Using the equations below, these ratios were calculated individually for each O:

$$VBT = \frac{T(V) - T}{V - T}$$

$$TBV = \frac{V(T) - V}{T - V}$$

If vision were completely dominant over touch, things would feel exactly as they looked if tactual judgments were made with concurrent vision, and in that case the VBT would take on a value of 1.00, while the value would be zero if vision did not influence touch at all. Similarly, the TBV shows the influence of touch on vision. The bias ratios were subjected to a two-way analysis of variance (Sex by Visual and Tactual Bias), with repeated measures on the second factor. Since there was no significant sex effect or any significant interaction, the bias ratios were combined for men and women. The VBT was significantly greater than the TBV ($F = 4.19$, $df = 1/30$, $p < .05$), which indicates that vision biases touch more than touch biases vision. The mean TBV (.34) differs significantly from zero ($t = 2.21$, $df = 31$, $p < .05$), which shows that visual judgments are biased by concurrent touch. The mean VBT (.89) differs highly significantly from zero ($t = 5.57$, $df = 31$, $p < .001$). Thus, visual capture occurs.¹

Within-Os measures of sensitivity were derived for each judgment condition from separate two-way analyses of variance carried out for each sex under each condition. The factors were standard position (left and right) and series (ascending and descending), with repeated measures on both factors (Kirk, 1968). The mean square for the Position by Series interaction may be taken as an inverse measure of sensitivity under each judgment condition, since this variance is free of any main effects of standard position and series and also free of any interaction between these factors. The variances for men and women were compared under all judgment conditions. For touch with vision, the variance for men was significantly greater ($F = 2.49$, $df = 15/15$, $p < .05$), but since no other variance comparison between the sexes approached significance, and since the pooled variances across judgment conditions did not differ significantly between men and women ($F = 1.25$, $df = 60/60$, $p < .25$), the variances for men and women were combined under each judgment condition. The within-Os variances are shown in Table 1. The variance for touch alone

is significantly greater than for vision alone ($F = 3.07$, $df = 30/30$, $p < .01$), which shows that vision is the more sensitive modality. The variance for touch with vision is significantly smaller than the variance for touch alone ($F = 2.45$, $df = 30/30$, $p < .01$) but does not differ from the variance for vision alone; thus, vision strongly influences tactual judgments when the two senses are used concurrently. The variance for vision with touch does not differ significantly from vision alone, which shows that the influence of touch on the sensitivity of visual judgments is slight. Thus, the pattern of within-Os variances in Table 1 strongly supports the occurrence of visual capture.

EXPERIMENT 2

The results of Experiment 1 demonstrate that vision has a marked influence on tactual judgments and that touch has some, but not much, influence on visual judgments. The instructions in Experiment 1 emphasized the separation of vision and touch and also emphasized the perceptual, as opposed to objective, nature of the judgments. The present experiment was designed to assess the effects of concurrent vision and touch on judgments under instructions making no reference to the way things *look* or *feel*. Under all conditions, the Os were simply asked to indicate whether the left or right block was longer.

Observers

Twelve men enrolled in undergraduate psychology courses at the University of Missouri-St. Louis participated as a course requirement. None of the Os had previously served in Experiment 1. Only right-handed Os were used.

Apparatus

The apparatus used in Experiment 1 was also used here.

Procedure

As in Experiment 1, the method of limits was used. Each O compared the lengths of the left and right blocks under the following judgment conditions: (1) Vision alone. O was not allowed to touch the blocks. (2) Touch alone. A screen hid the blocks from the O's view. O grasped the blocks as described earlier. (3) Concurrent vision and touch. Under all judgment conditions each O was asked the same question: "Which is longer, the left block or the right?" If an O said that a block *looked* or *felt* longer, he was instructed to make his best judgment of which block *really* was longer. Unless it was necessary, the "objectivity" of the questions was not emphasized.

Three sequences of judgment conditions were determined by the rows of a 3 by 3 Latin square. Four Os were assigned to each order. The remaining procedures were identical to those used in Experiment 1.

One O was replaced because his judgments by vision alone and touch alone differed by only .25%. For all Os whose data were utilized, the absolute difference between vision alone and touch alone was at least 1.00%.

Results

A significant conflict occurred between vision and touch, as in Experiment 1, and again the conflict was resolved in favor of vision. Table 2 shows the basic results.

A repeated-measures Latin-square analysis of variance was carried out (Winer, 1962). The factors were sequence of judgment conditions (rows), temporal order of judgment, and judgment condition (vision alone, touch alone, and concurrent vision and touch), with repeated measures on the last factor. Since the within-Os variances are heterogeneous (see Table 2), as in Experiment 1, conservative F tests (Winer, 1962) were used in testing the main effects of the judgment-condition factor and its interaction with temporal order. The analysis showed only a significant judgment-condition effect ($F = 6.59$, $df = 1/9$, $p < .05$). The means in Table 2 for vision alone and touch alone differ significantly by the Newman-Keuls test ($p < .05$), showing that a natural conflict occurred between vision and touch. The mean for concurrent vision and touch does not differ from the mean for vision alone but does differ from the mean for touch alone ($p < .05$), thus indicating that visual capture occurred.

A VBT ratio was calculated for each O, as in Experiment 1. In the present experiment, the VBT is a measure of the influence of both vision and touch on the objective judgments made with concurrent vision and touch. The VBT would take on a value of 1.00 if vision were completely dominant, a value of zero if touch were completely dominant, and a value of .50 if the objective judgments were equally influenced by vision and touch. The

mean VBT (1.06) differs highly significantly from zero ($t = 7.99$, $df = 11$, $p < .001$) but does not differ from 1.00. Thus, the VBT supports the occurrence of visual capture.

The pattern of within-Os variances in Table 2 also supports the occurrence of visual capture. The variances for vision alone and touch alone differ significantly ($F = 6.14$, $df = 11/11$, $p < .01$), while the variance for concurrent vision and touch does not differ significantly from vision alone but does differ from touch alone ($F = 5.46$, $df = 11/11$, $p < .05$).

DISCUSSION

By vision alone, the left block was significantly overestimated in both present experiments, a finding consistent with the studies of Hochberg and Bitterman (1951) and Mefferd and Wieland (1969), but not consistent with that of Brown (1953). However, these earlier studies involved size comparisons of stimuli in the left and right *visual fields*, and thus required the use of fixation points, while no fixation was used in the present study.

In neither of the present experiments does the mean for touch alone differ significantly from zero, a finding contrary to the results of two earlier studies. McPherson and Renfrew (1953), using the method of constant stimuli, found that metal disks ranging from 39.7 to 44.4 mm were significantly overestimated by the left hand. Wertheimer (1954) found that a 38.1-mm standard presented to the left hand was significantly overestimated relative to a wedge-like series of comparison steps presented to the right hand. However, Costello (1961), using the same sizes of stimuli as Wertheimer, presented the standard to the left hand on half the trials and to the right on the others; there was no significant left-right difference, but the standard was significantly overestimated independently of its presentation to the left or right hand. In a control group in an earlier study (Walker, 1971), the left block was significantly underestimated by concurrent vision and touch; the standard was always

Table 2
Percent Overestimation (Positive Data) and Underestimation (Negative)
of Left Block with Respect to Right*

	Judgment Condition		
	Touch	V and T	Vision
Mean	-1.61	.78	1.17**
Variance (Between Os)	19.00	4.36	2.83
Variance (Within Os)	19.20	3.52	3.13

*Means and variances in italics differ from others at .05 level.

**Differs from zero ($p < .05$).

presented to the left hand, and no judgments were made by vision alone or touch alone.

The discrepancies among the above studies suggest that left-right comparisons may be influenced strongly by differences in psychophysical methods, experimental procedures, and perhaps even size of stimuli. While the directions and magnitudes of bilateral asymmetries in vision and touch are not entirely clear, the demonstrations of natural visual capture in the present experiments rest on *changes* in judgment when vision and touch are used concurrently, rather than on any absolute measures of direction or magnitude of bilateral asymmetry.

The evidence for visual capture in the present experiments is closely comparable to the evidence in earlier studies. In Experiment 2, under objective instructions, judgments made with concurrent vision and touch were completely dominated by vision, a finding that agrees with the results of the single earlier study of natural visual capture (Teghtsoonian & Teghtsoonian, 1970). In Experiment 1, where the Os made visual judgments with concurrent touch and tactual judgments with concurrent vision, vision biased touch more than touch biased vision; these results compare closely with those of earlier studies of experimentally induced visual capture (Pick, Warren, & Hay, 1969; Warren & Pick, 1970). The similarities between the above studies suggest that the same processes may underlie the resolution of natural and induced sensory conflicts.

In view of the great plasticity of perceptual systems, particularly touch (Harris, 1965; Rock, 1966), it is initially surprising that there should exist any natural conflict between vision and touch in adult Os. After so many years of simultaneously grasping and looking at objects, how is it that touch has not long since been brought into complete harmony with vision?

There is an extensive literature (see, for example, Berlyne, 1960; Festinger, 1964) which suggests that people behave so as to reduce conflicts in many situations. Aronson and Rosenbloom (1971) have recently shown that a conflict induced by grossly discrepant auditory and visual stimulation is distressing to infants as young as 30 days. Thus, the human infant should be motivated from its earliest days to reduce perceptual conflict. There is also considerable evidence that perceptual learning occurs in the absence of awareness of any discrepancy between sensory inputs. For example, Rock and Victor (1964) found that tactual adaptation to visually perceived size occurred

even though most of their Os were unaware of the great discrepancy induced between vision and touch.

In a study of adaptation to displaced vision (Dewar, 1970), the Os pointed to visual targets with unseen hands after exposure to wedge prisms of various strengths. When the observed adaptation was expressed as a proportion of the maximum possible adaptation at each prism strength, Dewar found that the proportion of adaptation was high at greater prism strengths and very much less at lower strengths, even though vision had considerably influenced touch at lower prism strengths *during* the exposure procedure. These findings, together with the comparable results of Efstathiou (1969), suggest that little or no perceptual learning, in the form of adaptation lasting beyond the period of exposure to displaced vision, is to be expected when induced discrepancies between vision and touch are small.

While the differences between judgments by vision alone and touch alone in both present experiments are statistically significant, these differences are very small, both in an absolute sense and in relation to the sensitivities of the visual and tactual modalities. The variance of the difference between judgments by vision alone and touch alone is related to the sensitivities of these modalities, and this variance is the sum of the within-Os variances of these judgments. The standard deviations of the difference between vision and touch in Experiments 1 and 2 are 4.09% and 4.73%, respectively, and the probable errors of the differences (PED) are, respectively, 2.88% and 3.33%. Since the observed differences between vision and touch in Experiments 1 and 2 (2.75% and 2.78%, respectively) both lie within 1 PED of zero, these differences are not reliably detectable by individual Os and therefore represent very small discrepancies between vision and touch. In the light of Dewar's (1970) and Efstathiou's (1969) findings, it seems possible that the very small discrepancy between vision and touch existing in the adult may be essentially impervious to change; reductions in this discrepancy would appear unlikely, unless the sensitivities of these modalities were increased substantially.

Natural visual capture was demonstrated in Experiment 1, where the Os made visual judgments with concurrent touch. In Experiment 2, where the Os made objective judgments without reference to the way things *looked* or *felt*, natural visual capture was again demonstrated. Since the resolution of natural conflict

between vision and touch so closely parallels the resolution of induced conflicts between these modalities, it is possible that the same processes may underlie the resolution of both kinds of conflicts.

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NOTE

1. The mean bias ratios presented here are the means of the individual bias ratios calculated for each O. It would be possible to calculate the VBT and TBV using the

means in Table 1, but such ratios would not lend themselves so readily to statistical analysis; further, bias ratios so calculated would not be identical to the means of the individual bias ratios because the denominators of the individual ratios, and the ratios themselves, vary across Os.

(Accepted for publication October 13, 1971.)