Perception & Psychophysics
1975, Vol. 18 (1), 55-60

The "ventriloquist effect": Visual dominance or response bias?

CHONG S. CHOE, ROBERT B. WELCH, ROBB M. GILFORD, and JAMES F. JUOLA
University of Kansas, Lawrence, Kansas 66045

The interaction between vision and audition was investigated using a signal detection method. A light and tone were presented either in the same location or in different locations along the horizontal plane, and the subjects responded with same-different judgments of stimulus location. Three modes of stimulus presentation were used: simultaneous presentation of the light and tone, tone first, and light first. For the latter two conditions, the interstimulus interval was either 0.7 or 2.0 sec. A statistical decision model was developed which distinguished between the perceptual and decision processes. The results analyzed within the framework of this model suggested that the apparent interaction between vision and audition is due to shifts in decision criteria rather than perceptual change.

One of the most controversial issues in psychology concerns the genesis of perceptual abilities and the relations that exist among the sense modalities. Until recently, it was strongly believed that "vision is educated by touch." Many scholars, such as Berkeley and Helmholtz, argued that since visual perception is grossly different from the image on the retina, it must be acquired through tactual experience. Although many experiments were conducted to test the empiricistic doctrine of visual space perception (e.g., Stratton, 1897), there has been no unequivocal evidence supporting the position. Indeed, the argument has been challenged by recent studies of intersensory relations. Harris (1965), for example, demonstrated that vision "dominates" and modifies the proprioceptive sense when the two modalities are made to provide discrepant information. Thus, a person viewing the image of his hand through deflecting prism lenses comes to feel his hand where he sees it rather than where it actually is. Rock and Harris (1967) reported several experiments which further demonstrated the dominance of vision over touch. They concluded that rather than touch educating vision, the reverse appears to be true.

The finding of visual dominance over proprioception led other researchers to investigate conflict situations involving other sensory modalities. Pick, Warren, and Hay (1969) examined the interaction of vision and proprioception, proprioception and audition, and vision and audition. For vision and audition, the discrepancy was created by displacing the visual image of a speaker by means of a 20-diopter prism. A bias measure was defined as the amount that the judged position of one source was shifted toward the discrepant source. Thus, visual bias over audition was defined as the difference between the subject's localization of the *heard* position of the speaker with and without the discrepant visual information. The results indicated that vision biases auditory localization but audition has no effect upon visual localization. In fact, the phenomenon of visual dominance over audition had repeatedly been demonstrated before Harris's (1965) finding of visual dominance over proprioception (e.g., Jackson, 1953; Thomas, 1941; Witkin, Wapner, & Leventhal, 1952). All of these studies employed dependent variables that were basically similar to, but less quantitative than, the bias measure. The observed phenomenon involving vision and audition has sometimes been called the "ventriloquist effect."

One of the inherent problems in perceptual research is whether one is measuring changes in the perceptual system or changes in the response system (Garner, Hake, & Eriksen, 1956). The bias measure is especially vulnerable to this problem, and its validity as an index of the perceptual process is questionable. Auditory localization, even without interference from other sensory information, is clearly a much more difficult task than visual localization. When a subject is asked to point to where he hears the sound coming from in a conflict situation, it is possible that his pointing response is influenced toward the visible source simply because the latter is easier to localize. Thus, one could argue that the subject's *auditory perception* is not affected by visual perception. That is, he might hear the sound in the same place whether or not there is a disparate visual source, but he simply "chooses" to point toward the visible source when it is present.

Another measure of change commonly employed in

This research was supported in part by funds from Biomedical Sciences Support Grant RR-07037 from the National Institutes of Health, a University of Kansas General Research Grant, and Grant MH 24631-01 from the National Institute of Mental Health to the fourth author. The authors thank Carl McFarland and Juliet Shaffer for their assistance. Reprint requests should be addressed to Chong S. Choe, Department of Psychology, University of Kansas, Lawrence, Kansas 66045.

perception research is the aftereffect. In the present context, an aftereffect measure is obtained by testing the subject on auditory localization before and after a period of exposure to the visual-auditory conflict. The aftereffect measure is generally considered to be a better index of perceptual processes than the bias measure. That is, if there is a pre-post shift in localization of the auditory stimulus presented alone, it must be due to a change in auditory perception. This argument rests on the assumption that since the visual stimulus is no longer present when the subject is tested, it cannot possibly influence the response system. Several investigators (e.g., Bermant, 1973; Canon, 1970, 1971) have demonstrated aftereffects in the visual-auditory conflict situation. The rationale for accepting aftereffect as a manifestation of perceptual change is valid, and observed aftereffects might well be free of response bias. However, it seems that another nonperceptual change, response learning, might have contributed to the observed aftereffects. In experiments by Canon (1970, 1971), auditory aftereffects were obtained following a conflict period in which subjects pointed at the apparent visual position of the target. Since aftereffects were measured by having the subject point at the auditory target, it is possible that the observed aftereffects represented shifts in the pointing response itself. That is, the subject might have developed a tendency to place the pointer away from the actual sound source and toward the direction of the exposure-period visual target position. Even in experiments in which the subject points to the auditory source rather than to the visual source during the conflict period, the same type of response learning could take place (e.g., Bermant, 1973). As argued earlier, auditory localization during the conflict period might be biased toward the visual source, and the tendency to point toward the visual source during the exposure period might persist to the postexposure phase.

The main inerest of intersensory interaction studies lies in the effect that stimulation of one sensory modality has upon *perception* of sensory input in the other modality. Therefore, demonstration of aftereffects would be regarded important only to the extent that they represent perceptual events. The finding of aftereffects is of less importance if they represent only a manifestation of motor learning or of the development of a specific response tendency. Thus, it is crucial to isolate the effects of intersensory discrepancy on perceptual processes from those on response processes. The isolation of effects was attempted in the present study by employing the theory of signal detectability. A light and tone were presented either in the same location (no discrepancy) or in different locations (discrepancy). The tone was to the right or left of the light equally often when their locations differed. The subjects responded with same-different judgments of stimulus location. A statistical decision model was proposed here which assumes that the subject makes a decision based on the estimated distance between the locations of the light and tone on each trial. More specifically, the subject makes his judgments by evaluating the subjective locations of the two stimuli against three probability distributions, one for each of three different types of trials (no discrepancy, tone left, and tone right), as shown in Figure 1. The model assumes that the subject responds with "same" when the estimated distance is less than some criterion, x_c. When the estimated distance exceeds x_c, the subject responds with "different." It is further assumed that the probability distributions and response proportions are symmetric for tone-right trials and tone-left trials. That is, the subject's decisions that the distance is greater than x_c on tone-right and tone-left trials are equally represented in "different" response. Based on the proportions of "same" responses, on no-discrepancy trials and on discrepancy trials, indices of perceptual sensitivity (d′) and response bias (β) were determined. In addition to a simultaneous condition in which the light and tone were presented at the same time, successive conditions were included in which the two stimuli were presented with a temporal separation. The order of the presentation (tone-first or light-first) and the interstimulus interval (0.7 or 2.0 sec) were varied in these conditions. It could be argued that conflict did not exist in the successive

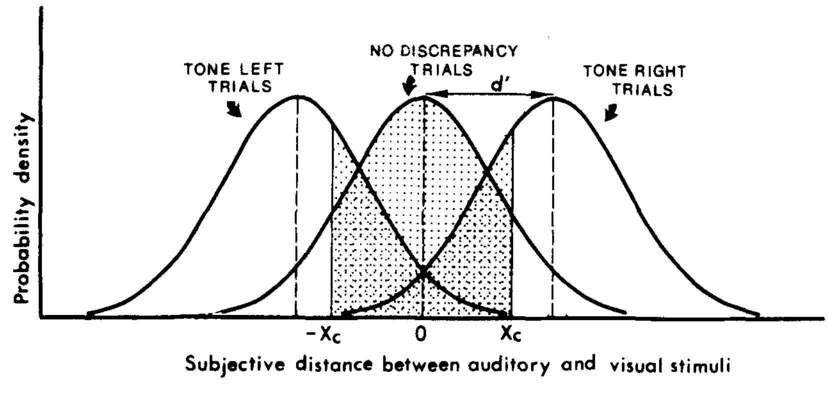

Figure 1. A statistical decision model showing the probability distributions of the judged distance between auditory and visual stimuli for three different types of trials (tone-left trials, tone-right trials, and no-discrepancy trials), and areas corresponding to p(Hits) and p(FA) for a given criterion x_c.

conditions, especially in the tone-first condition, where the location of the auditory source is perceived before the onset of visual stimulus. Thus, these conditions were expected to produce results different from those of the simultaneous condition. It was possible to examine the nature of the different processes by comparing the simultaneous condition with the successive conditions in terms of the sensitivity and response bias measures. In terms of the model in Figure 1, the problem is to estimate how far the distributions are apart and where the subject sets his criteria in different stimulus presentation conditions.

METHOD

Subjects

Thirteen undergraduate students (nine males and four females) from introductory psychology classes at the University of Kansas participated in the experiment in order to fulfill a course requirement. All reported normal vision and hearing, and were naive as to the purpose of the experiment.

Apparatus

The subjects were run individually in a 2.74 x 3.66 m IAC anecoic chamber, which was soundproof and nearly echo-free. The subject sat facing a vertical pegboard panel which was curved into an arc with a radius of 130 cm and its center at the subject's head position. Nine 6.4-cm-diam loudspeakers were evenly spaced 25 cm apart (approximately 11 deg) on the back of the panel, 105 cm above the floor at approximately ear level for a seated subject. The middle speaker was positioned directly in front of the subject. The tone was produced by a pulse generator and had a frequency of 600 Hz and an intensity of 60 dB. A vertical array of four light-emitting diodes was placed at each of the nine speaker positions, on the interior surface of the board. The diodes emitted a red light of 660-nm wavelength, and the brightness was 1,200 fL, as measured by a Research spectra spot brightness meter with Spectrar L-175 lens in the brightest region of the emitting surface. The lamps were the only light source in the room, and were of insufficient luminance to reveal any details of the apparatus to the subject.

A chinrest was used to stabilize the subject's head position and to minimize head movement. Situated outside the chamber was a panel containing a series of switches and three timers which were used by the experimenter to control the visual and auditory target positions. The subject and experimenter communicated through an intercom system.

Procedure

The experiment consisted of 216 trials with a 13-sec intertrial interval. On every trial, a light and tone were presented for .15 sec each. The modes of stimulus presentation were varied systematically. On one-third of the trials, the tone was presented first, followed by the light (T/L trials). The order of presentation was reversed for another third of the trials (L/T trials). For both T/L and L/T trials, the interstimulus interval (ISI) was either 0.7 or 2.0 sec (T/L-0.7, T/L-2.0, L/T-0.7, and L/T-2.0, respectively). The remaining trials were simultaneous trials, on which the light and tone were presented at the same time. For each of these presentation conditions, the light and tone were presented in the same place on half of the trials (no-discrepancy trials). Each of the nine target positions was used equally often for these trials. On the other half of the trials, the light and tone were laterally separated by 11 deg (discrepancy trials). The direction of the discrepancy was symmetrical; that is, the tone was to the right of the light on half the trials and it was to the left on the remaining half of the trials.

Each subject was assigned to one of four different random sequences of 216 trials. The subjects were told of the two different spatial arrangements and three different modes of stimulus presentation. The subjects were informed of the random order of presentation, and were instructed to respond "same" if they thought the light and tone had been presented in the same location, and "different" if the two stimuli seemed to originate from different locations. Finally, the subjects were asked to say either "one" or "two" to indicate their confidence after making "same" or "different" responses. The subjects responded with "one" if they were sure and with "two" if they were not sure and therefore had guessed about the relative locations of the stimuli.

The subjects were asked to look straight ahead after each response to be prepared for the next trial. The subject's chin remained on the chinrest throughout the experiment. Prior to actual testing, 15 practice trials were administered. The entire session lasted approximately 1 h.

RESULTS AND DISCUSSION

The frequencies of the four response types ["same one" (S1), "same two" (S2), "different two" (D2), "different one" (D1)] were obtained for each subject under the five different stimulus presentation conditions (T/L-2.0 trials, T/L-0.7 trials, simultaneous trials, L/T-0.7 trials, L/T-2.0 trials). Figure 2 shows the mean proportions of the four different response types for all subjects in the five different conditions for no-discrepancy trials (solid line) and for discrepancy trials (dotted line). The most striking difference in response frequency patterns can be observed between simultaneous trials and the other conditions. The simultaneous trials produced more S1 response than other trials, both in no-discrepancy and in discrepancy trials. The simultaneous trials most closely resemble the conflict situation employed in previous research demonstrating visual bias, and since in the simultaneous trials high frequency of S1 response was obtained for *discrepancy trials* (dotted line), it can be asserted that the present results are in general agreement with the previous findings. However, the use of a signal detection method allows for a further examination of the nature of the apparent "ventriloquist effect." High S1 response frequency in simultaneous trials *regardless* of whether or not there was a spatial discrepancy implies the existence of another factor—that is, response bias. The basic argument is illustrated in Figure 3, which shows highly correlated proportions of "same" responses (S1 and S2 combined) between no-discrepancy and discrepancy trials.

The crucial evidence for the hypothesis that the greater proportion of "same" responses in the simultaneous trials was due to response bias rather than to a change in sensitivity for these trials, however, comes directly from the signal detection analysis. The analysis produced two indices, that of sensitivity (d') and that of response bias (β), which were based on two probabilities computed from the

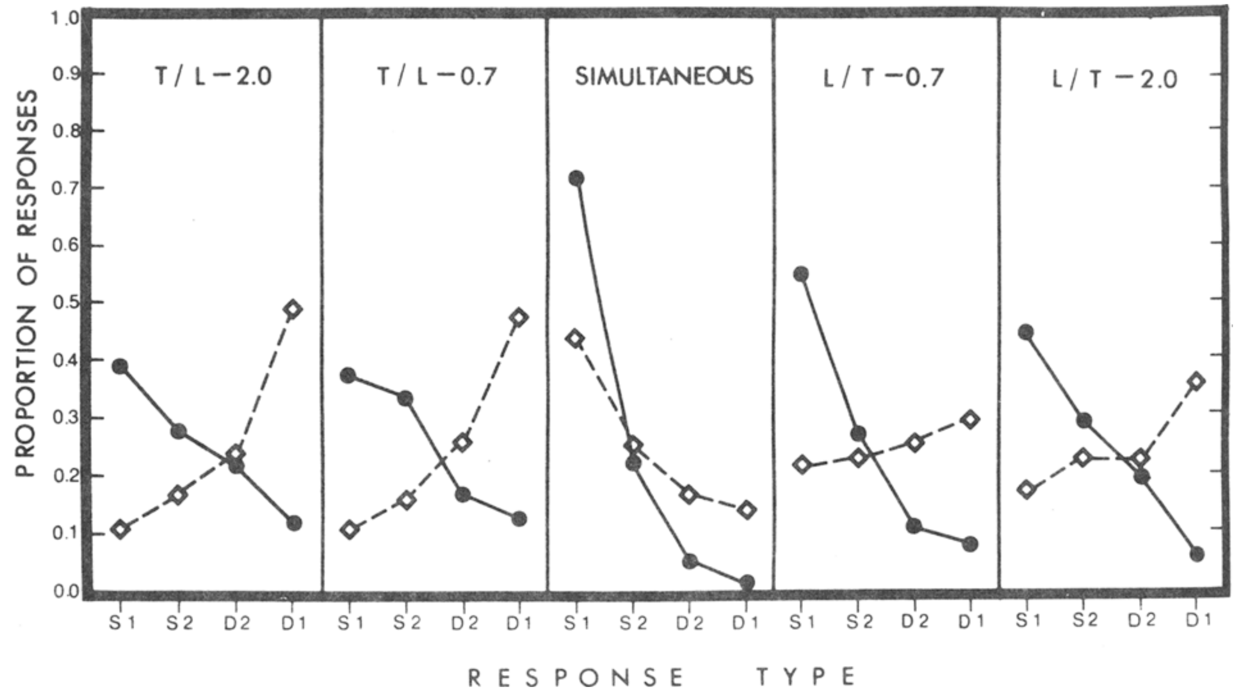

Figure 2. Mean proportions of the four different responses in the five different stimulus presentation conditions for no-discrepancy trials (solid line) and for discrepancy trials (dotted line). Response types: S1 = same location, sure; S2 = same location, not sure; D2 = different locations, not sure; D1 = different locations, sure.

frequency data. The probability of hits [p(Hits)] was defined as the proportion of the "same" responses, both S1 and S2, on no-discrepancy trials. The probability of false alarms [p(FA)] was the proportion of the "same" responses on discrepancy trials. In the present model (see Figure 1), d′ is the distance between the means of the probability distributions of the judged distance between the light and tone for discrepancy and no-discrepancy trials. The subject's decision criteria determine β values. Measures of d′ and β were calculated for each subject under the five stimulus presentation conditions.[1] The means are presented in Table 1. A one-way analysis of variance was carried out on each measure. The results indicated no difference among the five d′ values, $F(1,12) = 1.22$, $p > .05$. The analysis of the βs, on the other hand, showed a significant effect of stimulus presentation condition with the Box (1953) conservative test, $F(1,12) = 5.11$, $p < .05$, suggesting a shift in decision criteria for different conditions. Multiple comparisons with the Tukey b test showed that the mean β for the simultaneous trials was significantly smaller than the mean βs for T/L trials. All other differences were nonsignificant. Thus, the discrepancy created by simultaneous presentation of the light and tone in different locations influenced only the subject's decision processes and not sensitivity.

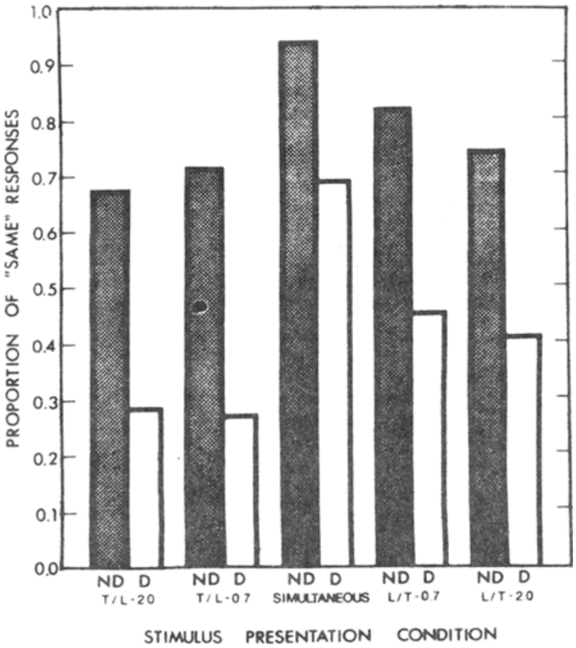

Figure 3. Mean proportions of "same" responses (S1 and S2 combined) in the five different stimulus presentation conditions for no-discrepancy trials (ND) and for discrepancy trials (D).

GENERAL DISCUSSION

The so-called "ventriloquist effect" reported in earlier studies was also demonstrated in the present experiment, as illustrated by the high proportion of "same" responses when simultaneously presented light and tone originated from different locations. Thus, the present results are not incompatible with previous findings. However, the signal detection analysis made it possible to reexamine the nature of apparent sensory interaction between vision and audition. Perceptual sensitivity (d′) was equivalent in all five presentation conditions. The lack of difference among d′s, combined with the unequal βs suggest that shifts in decision criteria were mainly responsible for the different frequencies of different response types in the five conditions.

It was recognized that the interpretation of the signal detection analysis is not as straightforward here as in simple threshold studies. In the latter, "false alarm" refers to a detection response in the absence of a stimulus. The nature of a false alarm is not as easily specified in the present study, however, since the presence or absence of the "stimulus" is ambiguous. When the subject responds with "same" to the spatially disparate light and tone stimuli, it may represent either a "false alarm" or an actual interaction at the sensory level. Therefore, no unequivocal conclusion can be derived from an examination of the frequencies of "same" responses in the simultaneous trials alone. Only when d′s and βs were compared among the conditions, could conclusions be made concerning the nature of the apparent sensory interaction. The critical finding is that there was no difference in sensitivity between the simultaneous trials and the T/L trials. Since the tone was terminated before the presentation of the light, visual dominance over audition should not have been possible in T/L trials unless one postulates that the *memory* of an auditory location can be biased by vision. This hypothesis seems implausible for two reasons. First, if auditory memory is influenced by vision, overall accuracy would be expected to decrease. Examination of correct responses indicate that this was not the case. Although the frequency of "same" responses on no-discrepancy trials was lower in the T/L trials, a higher frequency of "different" responses was obtained on discrepancy trials (see Figure 2). Secondly, one would expect an even higher frequency of "same" responses in the T/L trials if the memory of the sound location was affected by the light, simply because memory for the location of the tone should decay and auditory localization should, therefore, be more easily modified. Neither of these expectations was observed in the data.

The results of the signal detection analysis, i.e., different βs in the absence of sensitivity difference, required re-interpretation of the frequency data. What appeared to be a sensory interaction in simultaneous trials was due to the subject's decision bias. Although the visual-auditory conflict situation has been investigated as an extension of the visual dominance over proprioception, the present re-interpretation may not apply to the visual-proprioceptive conflict. The nature of the interaction

Table 1
Mean d′s and βs in Each Stimulus Presentation Condition

	T/L-2.0	T/L-.7	Simul-taneous	L/T-.7	L/T-2.0
d′	1.71	1.92	1.49	1.76	1.62
β	1.01	.93	.29	.49	.52

in visual-proprioceptive conflict may be basically different from that in visual-auditory conflict. Furthermore, the differences in the consequences of the discrepancy may be explained in terms of the normal relations within each pair of modalities. A one-to-one correspondence exists between the visual and proprioceptive senses in the normal situation. This correspondence is disrupted in a conflict situation, and observed visual dominance may be thought of as a mechanism utilized to restore normality, i.e., one-to-one correspondence. Although implicit, the assumption in the studies of visual-auditory conflict is that this same process operates. However, this assumption might be entirely unwarranted. Clearly, the normal relation between visual and auditory perception is far from the one-to-one correspondence, that exists for vision and proprioception. Thus, the discrepancy between vision and audition might not be comparable to that between vision and proprioception, and the same consequences would not be expected in the two situations. In fact, one may even argue that there is no "conflict" at all in the visual-auditory discrepancy situation.

Indirect support can be found for the argument that the two pairs of modalities interact differently when early studies on visual dominance are examined. In a study by Pick, Warren, and Hay (1969), the mean visual bias of audition was 48%, compared to 72% for visual bias of proprioception. More important for the present argument is the difference between the distributions of the percent bias scores obtained in the two cases. In the case of vision over proprioception, the bias scores were normally distributed around the mean. However, the distribution of percent bias scores for vision over audition was bimodal. The two modes were found around 98% and 12% visual bias, indicating that some subjects localized exclusively in terms of vision and others in terms of audition. One interpretation for the bimodal distribution is that these two groups of subjects had different perceptual experiences. However, an alternative speculation is that the observed bimodality was due to different response strategies, and that there might have been no difference in their perception. The latter argument is plausible when one considers the criticized nature of the bias measure, possibly manifesting a change in the response system. Another relevant observation for this discussion is the different degrees of the subject's awareness of a discrepancy. Few subjects experienced discrepancy between vision and proprioception, while many of the subjects were aware of visual-auditory discrepancy. That is, the subjects realized that the light and sound originated from different sources, and therefore no conflict was experienced. Thus visual dominance was not needed in this situation. In line with this argument, Welch (1972) showed that if subjects believed that what appeared to be a discrepancy between felt and seen position of the hand was actually no conflict at all, they revealed significantly less adaptation than if they experienced the two sensory modalities to be in conflict.

In retrospect, it is interesting to note that the effect of response bias was actually recognized in one of the earliest studies on auditory rearrangement. Willey, Inglis, and Pearce (1937) failed to find any adaptation to auditory right-left reversal after 8 days of wearing pseudophones. Even the change in auditory localization with the object in view ("visual auditory localization") was not complete or gradual. They stated that "the 'development' of normal visual-auditory localization may represent a change in observational attitude rather than a fundamental reorganization of auditory perception" (p. 125).

REFERENCES

Bermant, R. I. The influence of visual perception upon auditory localization. Unpublished master's thesis, University of Kansas, 1973.

Box, G. E. P. Non-normality and tests on variances. *Biometrika*, 1953, **40**, 318-335.

Canon, L. K. Intermodality inconsistency of input and directed attention as determinants of the nature of adaptation. *Journal of Experimental Psychology*, 1970, **84**, 141-147.

Canon, L. K. Directed attention and maladaptive "adaptation" to displacement of the visual field. *Journal of Experimental Psychology*, 1971, **88**, 403-408.

Garner, W. R., Hake, H. W., & Eriksen, C. W. Operationism and the concept of perception. *Psychological Review*, 1956, **63**, 317-329.

Harris, C. S. Perceptual adaptation to inverted, reversed, and displaced vision. *Psychological Review*, 1965, **72**, 419-444.

Jackson, C. V. Visual factors in auditory localization. *Quarterly Journal of Experimental Psychology*, 1953, **5**, 52-65.

Pick, H. L., Jr., Warren, D. H., & Hay, J. C. Sensory conflict in judgments of spatial direction. *Perception & Psychophysics*, 1969, **6**, 203-205.

Rock, I., & Harris, C. S. Vision and touch. *Scientific American*, 1967, **216**, 96-104.

Stratton, G. M. Vision without inversion of the retinal image. *Psychological Review*, 1897, **4**, 341-360, 463-481.

Thomas, G. J. Experimental study of the influence of vision on sound localization. *Journal of Experimental Psychology*, 1941, **28**, 163-177.

Welch, R. B. The effect of experienced limb identity upon adaptation to simulated displacement of the visual field. *Perception & Psychophysics*, 1972, **12**, 453-456.

Willey, C. F., Inglis, E., & Pearce, C. H. Reversal of auditory localization. *Journal of Experimental Psychology*, 1937, **20**, 114-130.

Witkin, H. A., Wapner, S., & Leventhal, T. Sound localization with conflicting visual and auditory cues. *Journal of Experimental Psychology*, 1952, **43**, 58-67.

NOTE

1. Some preliminary analyses were performed to examine the subjects' performance for different locations in the stimulus array. The results indicated an absence of position effects between the central and peripheral stimulus locations. Therefore, the data were combined over all stimulus positions in calculating d's and βs for each subject.

(Received for publication December 26, 1974; revision accepted April 21, 1975.)