Sensory conflict in judgments of spatial direction

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Artificial discrepancy was created between information about azimuth coming from different sense modalities. The resolution of this discrepancy was examined for the cases of vision and proprioception, proprioception and audition, and vision and audition. Vision biases proprioceptive and auditory judgments. Proprioception biases auditory judgments and has a small effect on visual judgments. The results suggest that the combinations of sense modalities do not behave as an integrated system and the data are interpreted as indicating that different processes are involved in the resolution of discrepant directional information from different pairs of modalities.

There has been considerable recent interest in the interactions of the various sense modalities. One technique that has been especially exploited is the creation of an artificial discrepancy between the information originating from one stimulus object but entering the organism via two modalities. Attention has been focused both on the initial reaction to the discrepancy (Is the information from one modality dominant over the other?) and on the subsequent adjustment to the discrepancy (Can one modality be said to accommodate to the other?). In much of the research the two modalities have been vision and proprioception and the discrepancy has involved visual distortion of a variety of stimulus dimensions, e.g., size (Rock & Victor, 1964), inclination (Klein, 1966), and spatial direction or azimuth (Hay, Pick, & Ikeda, 1965).

The present study is an investigation of the initial reaction to a discrepancy between sense modalities in information about spatial direction. It extends to other pairs of sense modalities, our earlier work that included only vision and proprioception. The purpose of the present study was first to determine how the discrepancy of information coming from two sense modalities was resolved. For example, are there different degrees of bias or dominance that information coming from one modality has on different other modalities? Secondly, its purpose was to determine if a number of sense modalities functioned as a system. Specifically, would it be possible to predict the interaction of two modalities, knowing how each interacted with a third? Spatial direction was chosen as the contextual problem for this investigation since directional information is obtainable with relatively high precision via the three modalities of vision, proprioception, and audition.

The basic design of the present study was a straightforward replication of one previous experiment that involved a discrepancy in azimuth between vision and proprioception (Hay, Pick, & Ikeda, 1965). In the present study there were three experiments that included a discrepancy between proprioception and audition, and between vision and audition, as well as the original discrepancy between vision and proprioception. In the original study Ss were asked to view their own finger (held passively on a shelf) through a prism that optically displaced its lateral position approximately 11 deg. The Ss then were asked to point underneath the shelf to the *seen* or *felt* position of their finger. In both cases they indicated a locus between the optical position and the true position, but very close to the optical position (about 9 deg toward the optical position from the true position).

In the experiment of the present study which replicated the

original study Ss were asked to point with their right hand under a shelf: (a) at the locus of an optically displaced visual target, (b) at the locus of their own left pointer finger, vision being occluded, (c) at the locus of the *felt* position of their own finger whose position was optically displaced, and (d) at the locus of the *seen* position of their optically displaced finger. The conditions a and b above served as visual and proprioceptive controls or as "poles" for evaluating performance in Conditions c and d that introduced the discrepancy between vision and proprioception. Suppose the S was viewing his optically displaced finger and trying to point to its *felt* position as under Condition c and he pointed to the same place as he did under Condition b when he couldn't see his finger. This result would indicate no biasing of proprioceptive information by vision. If, however, he pointed to the same place as he did under Condition a when there was a (nonproprioceptive) visual target, there would be complete or 100% visual biasing or dominance of proprioception. Intermediate localization can be characterized in intermediate values of per cent visual biasing of proprioception. Similarly, responses in Condition d measure per cent proprioceptive bias of vision.³

In this experiment the discrepancy between vision and proprioception was produced by a 20-diopter wedge prism used in the conditions in which a target was viewed (a, c, d). The apparatus consisted essentially of a horizontal shelf extending at neck height away from the S whose head was supported by a chin rest. Protruding up from the shelf at a radius of 36 cm from the chin rest was an arc of pegs set 2.5 deg apart and extending 50 deg in both directions from straight ahead. Underneath the shelf was an identical arc of pegs extending down. Ss were asked to point with their right finger at the peg directly underneath a designated visual target placed on top of one of the upper pegs, or at the peg underneath their own passively placed finger. Five different target positions were used: straight ahead, 5 deg to the left and right of straight ahead, and 10 deg to the left and right of straight ahead. Two trials were given at each of these positions in unsystematic order. The control conditions a and b were conducted first, counterbalanced among the Ss, followed by Conditions c and d, again with order counterbalanced. The 4 conditions x 5 target positions x 2 trials resulted in 40 judgments that were comfortably completed in less than ½ h per S.

In the second experiment, which involves proprioception and audition, the discrepancy was created by means of a pseudophone.⁴ The interaural axis of the pseudophone was rotated to provide a lateral displacement of approximately 11 deg. The auditory targets were a series of clicks presented through a small speaker that could be mounted on the various pegs protruding from the top of the shelf. In the discrepancy condition the S held his finger on the base of the speaker and could feel it pulsing with each click. The S's response was again to point to pegs underneath the targets specified in each condition. The same target positions and ordering of conditions was used as described for the previous experiment. The S's vision was occluded throughout the experiment. The four conditions were to point under the shelf: (a) at the locus of an auditorily displaced sound, (b) at the locus of their unseen finger, (c) at the *felt* position of their finger, which was touching the speaker producing the displaced sound, and (d) at the *heard* position of the sound coming from the speaker as it was being touched.

Again Conditions a and b provide poles for evaluating performance in the discrepancy conditions, c and d. Per cent bias measures can be calculated for proprioception affecting audition and audition affecting proprioception.

In the third experiment, involving vision and audition, the discrepancy was created by having the Ss view the previously described speaker through a 20-diopter prism. [It would be possible to create this discrepancy by means of the pseudophone rather than the prism. Indeed, in one replication of the experiment, that was done. The results were almost identical with the pseudophone and prism (cf. Table 1).] This, of course, optically displaced the visual target but had no effect on the sound. The procedure again included four conditions of pointing under the shelf: (a) at the locus of a displaced visual target (a speaker emitting no sound), (b) at the locus of a sound with vision occluded, (c) at the *heard* position of a sound with speaker in view, and (d) at the *seen* position of a speaker emitting sounds. Again Conditions a and b provide poles for evaluating the discrepancy conditions, c and d. Per cent bias scores again can be calculated for vision affecting audition and audition affecting vision.

Twenty-four volunteer college students participated in each experiment. In each experiment half of the Ss were exposed to a discrepancy involving a right displacement or rotation of azimuth and half were exposed to a left displacement. It should be noted that in all three experiments the instruction for the discrepancy conditions, c and d, indicated to the Ss that they might experience a discrepancy. For example, they were told in the vision and proprioception experiment for Condition c: "You are to point underneath where you *feel* your finger to be; it may not look and feel in the same place. You are to point where it feels."

Results were analyzed in terms of per cent bias scores. Two such scores were calculated separately for each S as indicated in the description of the individual experiments; e.g., in Experiment 3, per cent bias of vision by audition, and per cent bias of audition by vision. These scores were averaged over the 24 Ss and the means and 95% confidence bounds are presented in Table 1.

The results indicate that reliable bias effects are found for all of the combinations of sense modalities. Proprioception and vision both bias auditory judgments, and the result previously obtained that vision biases proprioception to a greater degree than proprioception biases vision was replicated. Audition only minimally, if at all, exerts a biasing effect on proprioceptive direction judgments and does not at all bias visual direction judgments. Preliminary observations of the more dominant sense modality in each pair suggest that the visual bias of proprioception is greater than the effect of proprioception on audition or of vision on audition. However, analysis of variance of these data do not strongly support such an assertion [$F(2,69) = 2.84, p < .10$]. G. H. Fisher, summarized in Howard and Templeton (1966), reports experiments similar in purpose to the present ones but using different apparatus, instructions, and dependent variable. He also obtained a bias of vision over proprioception and proprioception over audition.

On the basis of the present data it does not seem possible to predict in any quantitative way the interaction of two modalities from the interaction of each with a third. Specifically, vision strongly biases proprioceptive judgments and proprioception biases auditory judgments. While it is true that vision also biases auditory judgments it does so to no greater degree, and possibly less, than it biases proprioception. This lack of transitivity also makes difficult any simple prediction of bias effect on the basis of precision of localization within a modality. That is, if susceptibility of a modality to bias were an inverse function of degree of precision of localization of that modality, a transitive ordering of bias effects would also be predicted.

Table 1
Mean per cent Bias with 95% Confidence Bounds*

Visual bias of proprioception	72 ± 10 (61 ± 19) (59 ± 37)
Proprioceptive bias of vision	16 ± 08 (40 ± 18) (35 ± 29)
Proprioceptive bias of audition	51 ± 10 (59 ± 18) (71 ± 31)
Auditory bias of proprioception	18 ± 12 (01 ± 09) (18 ± 11)
Visual bias of audition	48 ± 22 (35 ± 16) (59 ± 35) (47 ± 18)**
Auditory bias of vision	01 ± 09 (15 ± 28) (03 ± 31) (04 ± 12)**

* Figures in parentheses represent results of other complete replications of the same experiments with different Ss under slightly modified conditions. The results of these replications, in parentheses, are based on data after elimination of a few Ss whose bias scores were above 150% or below -50%. Elimination of these deviant Ss whose response under discrepant sensory information fell considerably outside the control "poles" made little difference in the mean bias scores but greatly decreased the variability. The primary scores of the above Table, those not in parentheses, are based on all 24 Ss who participated in each experiment.

** Discrepancy for this replication was produced by pseudophone rather than by prism. Double asterisk refers to last parentheses only.

The present data can be examined for clues as to how Ss resolve the discrepant information coming in the two different sense modalities. There are three obvious possibilities: (1) An individual S could at one time respond exclusively to one modality and at another time respond to the other modality, but on the average distribute his responses to give the obtained mean result. This would imply a rather high intra-S variance in the discrepancy conditions, c and d. (2) Individual Ss could respond consistently to one modality or the other but divide themselves to produce the obtained group mean. This would imply bimodal distributions of dominance scores for each pair of sense modalities. (3) Individual Ss could be consistent within themselves in reaching a compromise bias that would be close to the obtained group mean. Analysis of the intra-S variability rules out the first possibility. The discrepancy conditions produce no higher variability within each S's judgments than do the control or pole conditions. Examination of scatter plots for the bias effects of the dominant modality in each pair suggest that only in the case of the vision-audition combination is there any hint of a bimodal distribution. Here there is a suggestion of bimodality with one mode centered around 98% and another mode centered around 12%. For the other pairs of modalities the bias scores appear to be approximately normally distributed around the mean bias score.

There are at least two features of the present experimental paradigm that deserve further study. First, the response of pointing in all three experiments is more closely related to proprioception than the other sense modalities studied. Changing the response mode could alter the patterns of modality relations obtained. Second, the absolute magnitude of distortion in all three experiments was approximately equal as determined by experimental manipulation. However, a more meaningful equation of degree of distortion might have a functional basis. For example, the discrepancy selected for each pair of modalities might have been the minimum detectable discrepancy by the S. It should be noted in the present study most Ss could not report the existence of a discrepancy between proprioception and vision in the first experiment. Many Ss did experience such a discrepancy between the other pairs of sensory modalities.

Nevertheless, it can be asserted that bias effects of one modality on another do exist in judgments of visual, proprioceptive, and auditory spatial direction. The present data do not suggest that the pair combinations of modalities behave as an integrated system. Differences in the S's experience of the discrepancy, the distributions of the results, and possibly the magnitude of the effects might be interpreted to suggest different processes involved in the resolution of discrepant directional information.

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NOTES

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3. Formally "% visual bias of *proprioception* is computed as follows: $(a - c)/(a - b)$ where a is the average position of S's response when pointing at a visual target (optically displaced by the prism), b is average position of S's response when pointing at a proprioceptive target (his own finger), and c is average position of S's response when he is pointing at the "felt" position of his finger while viewing it through the prism. Similarly, proprioceptive bias of vision is computed by $(d - b)/(a - b)$ where a and b are defined as above and d is defined as the average position of S's response when he is pointing at the "seen" position of his own finger.

4. This pseudophone was a modification of one described by Kalil and Freedman (1967). It was constructed for us by S. J. Freedman and his colleagues.

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