Intermodality relations in localization in blind and sighted people¹

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Developmental data were gathered on the relative importance of vision, audition, and proprioception in determining spatial direction in a conflict situation. Age trends did not support the hypothesis that information from different modalities becomes better differentiated with age. In a follow-up study, blind children of different ages were tested under auditory-proprioreceptive conflict conditions. No age changes were found. The possibility of a visual involvement in auditory and proprioceptive localization is discussed.

In a previous paper (Pick, Warren, & Hay, 1969), we described a program of research designed to investigate the relations between different sensory modalities in determining judgments of spatial direction. By studying the nature of the compromise that Ss made between two types of information in a conflict situation, it was possible to evaluate the direction and strength of the bias of one modality on another. The general pattern of results indicated that vision strongly biases both proprioceptive and auditory localization judgments and that proprioception similarly biases auditory judgments. Proprioception slightly biases visual judgments, as does audition proprioceptive judgments. However, audition does not bias visual localization.

There is reason to expect that the relationships described above for adults might be different for children. The tasks used to evaluate the bias effects involve localization of a target on the basis of one source of information while disregarding another, discrepant source. To the extent that this is accomplished successfully, the bias is small. The larger the measured bias, the more the unwanted modality has intruded. Differentiation theories of perceptual development such as Gibson's (1969) and Werner's (1957) would presumably predict an increasing ability with age to inhibit such intrusion. Similarly, Witkin et al.'s (1962) investigations of field independence suggest that with increasing age, Ss are better able to prevent intrusions of visual information on vestibular-kinesthetic judgments. The studies reported here tested the ability of children of different ages to utilize spatial information from one modality while ignoring discrepant information from another modality.

EXPERIMENT 1

Method

A visual-proprioreceptive discrepancy was created by having S view his left forefinger through a 20-diopter wedge prism. This had the effect of displacing the visual image of the finger laterally by about 11 deg. To provide references for the conflict performance, each S performed a visual and a proprioceptive control task. The visual task consisted of pointing, with the unseen right hand, to the position of a visual target that was not a part of the body. This provided a measure of the extent of the prism displacement. For the proprioceptive control, S pointed to his own left forefinger, but with his eyes closed. Thus, in these control tasks, there was no conflict between proprioceptive and visual information. To assess the extent of visual influence on proprioceptive information, S was asked to point to the *felt* position of his left forefinger, but this time while viewing it through the displacing prism. If vision had no influence on proprioceptive localization, S would point to the same place that he did for the proprioceptive control task. To the extent that vision exerts an influence on proprioception, however, the conflict task performance would be away from the proprioceptive control in the direction of the visual control. A fourth task was used to assess the extent of proprioceptive bias of vision. The S was asked to point to the *seen* position of his target finger. To the extent that he pointed from the visual control in the direction of the proprioceptive control, proprioception could be said to bias visual localization. Percent bias scores were calculated for each S. For example, if vision influenced proprioceptive localization to the extent of moving it two-thirds of the way from the proprioceptive control toward the visual control, the result would be expressed as a 67% bias score.

A visual-auditory discrepancy was created in a similar manner. The S could see and hear a small speaker that produced two clicks per second. The sound actually came from the speaker, while the visual image of the speaker was again displaced by means of a wedge prism. Each S again performed two control tasks, pointing to the visual position of the speaker without the sound and pointing to the sound with the eyes closed. The visual influence on

auditory localization was tested by asking S to point, again with his unseen right hand, to where the speaker sounded while looking at it through the prism. Auditory bias of vision was assessed by having S point to where the speaker looked, while trying to disregard the auditory information.

An auditory-proprioreceptive discrepancy situation was created by having Ss touch and hear the small speaker. In this case, the auditory information was displaced laterally by means of a set of pseudophones. The Ss were blindfolded throughout these four tasks. The control tasks were pointing to the target finger with no sound (proprioreceptive control) and pointing to the sound without the target finger. Auditory bias of proprioception was tested by having S point to the *felt* position of the finger in the presence of discrepant auditory information, and proprioceptive bias of audition was tested by having S point to the *heard* position of the speaker while feeling his finger on the speaker.

Three age groups were tested, second and sixth graders and college students. At each age level, 72 Ss were divided into three equal groups. Each group performed the four tasks associated with one of the three modality combinations. The control tasks were always performed first, with the order counterbalanced among Ss within age groups, and the order of the subsequent conflict tasks was also counterbalanced among Ss.

Subjects were seated at a shelf with a semicircular array of pegs on top. The targets were presented on pegs at positions representing -10, -5, 0, 5, and 10 deg laterally from the Ss. Underneath the shelf was an identical array of pegs. The S made his response by pointing to one of these bottom pegs. For each task, S responded to targets twice at each of the five target positions. The 10 trials for each task were administered in random order.

Results

The individual bias scores were averaged to give a group score for each of the bias effects at each age level. Because of the nature of the ratio score calculated for each S on each bias effect, some scores had to be omitted from the group averages.³ Table 1 shows the group average scores for the six effects over the three age groups. An analysis of variance was carried out for

Table 1
Bias Effects Over Age (Group
Averages in Percent)

	Second	Sixth	Adult
V bias of P	77	89	70
P bias of V	23	13	18
V bias of A	73	60	47
A bias of V	18	11	2*
P bias of A	86	63	51**
A bias of P	-1	10	18

* Age trend significant ($p < .05$)

** Age trend significant ($p < .01$)

each of the six bias effects. The unequal groups technique described by Winer (1962) was employed. For the visual bias of proprioception, the effect of age was not significant ($F = 2.65$), nor was it for the proprioceptive bias of vision ($F = 1.16$). The apparent decrease in the visual bias of audition with age was not significant ($F = 2.33$), but the decrease in the auditory bias of vision was significant ($F = 3.09$; $df\ 2,68$; $p < .05$). The proprioceptive bias of audition decreased significantly with age ($F = 5.22$; $df\ 2,65$; $p < .01$). Although the overall age effect for auditory bias of proprioception was not statistically significant ($F = 2.63$), comparisons showed that the adults were significantly more biased by the proprioceptive information than were the second graders ($F = 5.24$; $df\ 1,65$; $p < .02$). The presence of this increasingly strong auditory bias of proprioception and the absence of decreasing trends in the visual-proprioceptive results show that the simple hypothesis of increasingly differentiable modalities with age is not supported by performance under these conflict conditions.

One explanation for the observed proprioceptive-auditory effects stems from research reported by Renshaw and his colleagues in the early 1930s. Renshaw (1930) found that an early superiority of proprioceptive localization changes around puberty to a superior visual localization. Relative to vision, proprioception decreases in importance with age as a localizing modality. Extending this notion to the present results, it seems reasonable to suggest that the auditory bias of proprioceptive localizations increases with age because of the decreasing use of and dependence on proprioceptive information. Similarly, auditory information may be less biased by proprioceptive information because of the same decrease in importance of the proprioceptive information with age.

EXPERIMENT 2

Further research, reported by Renshaw, Wherry, and Newlin (1930), indicates that for blind Ss the decrease in importance of proprioceptive information does not occur.

This presumably is because proprioception is not replaced by vision as the primary localizing modality. If this reasoning is valid, then blind Ss should show neither the decrease in proprioceptive bias of audition nor the increase in auditory bias of proprioception with age. We had the opportunity to test a population of blind children over a wide age range on the proprioceptive-auditory tasks described earlier in this paper. These children were attending the Lansing School for the Blind in Lansing, Michigan. The blind children were divided into three age groups roughly equivalent to the three groups used from the sighted population. The youngest group included 29 Ss from 6:5 to 10:1, with a mean age of 8:4. The middle group included 47 Ss ranging from 11:0 to 15:7, with a mean age of 13:7. The oldest group had 40 members, with a mean age of 17:9 and a range of 15:11 to 19:9. The four tasks connected with the assessment of proprioceptive-auditory relations were administered to each of the Ss using the same method that had been employed for the sighted Ss. Bias scores were calculated in the same way, with a proprioceptive bias of audition and an auditory bias of proprioception being calculated for each S. Several Ss were omitted from the group averages due to bias scores greater than 150 or less than -50. The group results are shown in Table 2, along with corresponding data from our sighted Ss. The blind Ss showed no change over age for either bias effect, thus supporting the predictions based on Renshaw's work.

EXPERIMENT 3

Up to this point, the discussion has considered implicitly that the proprioceptive-auditory discrepancy situation does not concern vision in any way. Warren (1970), however, provides evidence that vision plays a role in auditory, and possibly proprioceptive, localization even with the eyes closed. It may be that sighted people interpret auditory or proprioceptive information on some kind of visual map or frame of reference. Warren suggests that this visual context is built up with experience, so that

Table 2
Proprioceptive-Auditory Bias Effects for Blind
and Sighted Groups (Group Averages in Percent)

		Age Group		
		8:4 (Second)	13:7 (Sixth)	17:9 (Adult)
Blind	P bias of A	64	64	60
	A bias of P	6	6	6
Sighted	P bias of A	86	63	51
	A bias of P	-1	10	18

for sighted people the degree of its use would be perfectly correlated with the amount of visual experience. The amount of visual experience, rather than age, may be the important factor. Thus, congenitally blind Ss would have no visual frame of reference, while Ss with some residual vision or with some visual experience before acquiring blindness might still have some of the organizational qualities of vision. To investigate this possibility, the blind Ss in the present study were divided at each age level into two groups on the basis of the severity of blindness. One group consisted of Ss who were totally blind and who had been blind from birth. These Ss would have had no opportunity to build up any visual context. The second group consisted of Ss who had some light or movement perception and who had been handicapped from birth. These Ss might be expected to have some visual frame of reference for auditory and proprioceptive information. The bias results for these two groups over age are shown in Table 3, along with the results for sighted Ss at the corresponding age levels. Although the present subdivision of the blind Ss was post hoc, so that the visual experience hypothesis is tentative at best, the results for the LP blind appear to be more similar to those for sighted Ss than they are to the results of the totally blind group. Thus, there is some indication that even for the proprioceptive-auditory discrepancy situation, where vision is not immediately available, vision plays a role in determining the outcome of the bias effects.

DISCUSSION

The present study adds to the increasing

Table 3
Proprioceptive-Auditory Bias Effects for Visual Experience Groups (Group Averages in Percent).
Numbers in parentheses indicate size of sample.

		Age Group		
		8:4 (Second)	13:7 (Sixth)	17:9 (Adult)
Totally Blind	P bias of A	80 (5)	79 (7)	78 (5)
	A bias of P	7 (6)	-1 (6)	4 (6)
LP Blind	P bias of A	62 (11)	71 (21)	59 (16)
	A bias of P	5 (11)	9 (21)	13 (14)
Sighted	P bias of A	86 (20)	63 (24)	51 (24)
	A bias of P	-1 (21)	10 (23)	18 (24)

weight of evidence that the sensory modalities are not independent of each other. Furthermore, the nature of their interdependence changes with age in significant ways. Renshaw (1930) interpreted his age trends as showing that vision becomes a more important localizing modality with age, and that it does so at the expense of proprioception. More recent evidence suggests that the relation between vision and proprioception is not one of age-dependent reciprocal importance as Renshaw held, but rather one whose organization is modified with visual experience. Birch and Lefford (1963) conclude that vision acquires a greater degree of directive control over proprioception with age. Warren (in press) showed that vision at some level is strongly implicated in auditory localization for adults, while it is much less involved in children's auditory localization. Finally, the results discussed in this study suggest that the age-related changes in auditory-proprioceptive conflict performance may be due to the increasing importance of vision with age in normal Ss. We suggest that the important changes in intermodality relations are not typified by a replacement of auditory and

proprioceptive function by visual function, but rather are typified by an increasingly well-organized system involving all three modalities, with vision providing an important integrative function.

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NOTES

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3. Where the difference between control conditions was small, bias scores were more likely to be of unreasonable magnitude. This was because the same numerator can produce a much larger ratio score over a small denominator than a large denominator. Theoretically, the bias scores should range between 0% and 100%. With this in mind, it was arbitrarily decided to omit bias scores greater than 150% and smaller than -50%. In no case was it necessary to drop more than four of the 24 Ss in a group.

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