Seeing and hearing and space and time*

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A previous experiment had shown spatial location to be judged in terms of the framework provided by the modality in which stimuli were presented. In the present study, digits were either auditorally or visually presented, and in either form the three digits appeared successively to the left, in the center, and to the right of the S. The digit which occurred temporally in the middle of the sequence was never central from the spatial viewpoint. The S was asked to indicate which digit was the middle one. Ss were blind, deaf, or normal. The deaf and two control groups saw visual displays, and the blind and their controls heard auditory displays. The former groups predominantly chose the spatially middle digit and the latter groups the temporally middle. It was concluded that modality of presentation was the trigger which switched in the coding dimension of time or space.

Studies of temporal or spatial discrimination in adults and children have been made usually without reference to each other. The relationship between temporal and spatial sequences has therefore had relatively little attention. Piaget (1927, 1946) suggested such a relationship, making temporal concepts in young children dependent on the perception of movement. At the same time, he pointed out that complex concepts of time were not automatic consequences of the experience of time.

Some workers have suggested that whereas space may be best apprehended through vision, the perception of temporal duration may be more easily appreciated through auditory stimuli. This modality-specific view was advanced by Goodfellow (1934) and Savin (1967). Deprivation experiments by Hirsh, Bilger, and Deatherage (1956) indicated that temporal judgments were most disturbed by restriction of auditory input and little disturbed by restriction of vision. Cohen, Hansel, and Sylvester (1955) have shown that the estimation of temporal intervals which are related spatially are affected by these spatial components. They observed that duration appears longer if the space between two stimuli is increased.

From previous studies of spatial organization by Attneave and Benson (1969) and Hermelin and O'Connor (1971), we concluded that modality of input was critical in determining not so much the physical as the conceptual organization of space. It seemed desirable, therefore, to extend these studies to the relationship between

visual and auditory input modality and space or time. Thus, the present experiment is concerned with the study of temporal and spatial organization of stimuli as affected by either modality of input or restriction of experience in one modality and the interaction of these two factors. Contemporary theories of modality effects on memory postulate modality-specific buffers through which incoming material passes into short-term memory (Atkinson & Shiffrin, 1968; Crowder & Morton, 1969). Once material is thus stored, it is assumed to make no difference whether it was initially presented to the eyes or ears.

However, several studies have produced findings of more durable effects of modality input. Savin (1967) has suggested that in hearing, even simultaneously occurring stimuli are successively integrated, and Murdock (1969) has analyzed modality effects as a function of

temporal and spatial distributions of information. His experiment was concerned with the short-term memory for visually or auditorally presented material, and he used a technique of spatial as compared with temporal (or successive) presentation. It is possible that the absence of one sense modality may affect the organization of data from the remaining senses. We had found previously (Hermelin & O'Connor, 1971) that space was differently organized by blind than by seeing children. In the experiment reported below, we attempt to determine the effect of both sensory restriction and modality of presentation on the orientation towards spatial and temporal organization of a sequence of stimuli.

We also considered the effect of simultaneous visual and auditory presentation of an ambiguous display to determine which modality was dominant for conceptual structuring. Previous studies, by Hermelin and O'Connor (1964) and O'Connor and Hermelin (1965), with severely subnormal and autistic children had shown strong visual dominance in a simple choice situation. In this experiment we also tested the hypothesis that one characteristic modal organization could be changed to another by a previous set-inducing experience.

PROCEDURE

The basic procedure was to present three digits successively, either visually from a display box with three apertures or auditorily from three loud-speakers arranged around the S, to his left, in front of him, and to his right. In the visual sessions, Ss were shown three digits which occurred successively in such a way that the

Fig. 1. Types of response frequency of deaf, blind, and control groups.

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Fig. 2. Types of response frequency for simultaneous presentations to normal Ss.

second, i.e., the "middle one" from the temporal point of view, always occurred in the left- or right-hand positions on the display box and never in the middle. The digit which occurred in the spatial middle of the three display windows was therefore always either the first or third in succession (temporally). The same procedure was followed in the auditory presentation over the three loud-speakers. In other words, in both modality situations, if a S was asked which of the three digits was the middle one, he would be obliged to make a choice between two digits, that which occurred at the spatial and that which occurred at the temporal middle. A third possibility was that the S could choose the arithmetically middle digit.

To avoid giving any set in the first experiment, Ss were practiced in advance on three digits in which the middle digit was always both spatially and temporally central in the series. Instructions, whether spoken or written, for the subsequent test series were: "You will hear (see) three numbers. Wait till you have heard (seen) them all, then tell me (write down) the middle one." If a S asked which middle number he was to choose, he was encouraged to make a free choice. Of 80 children, only two asked this question. The temporal and spatial order of digits was randomized over trials using Digits 1-9 inclusive. The basic restriction on spatial

position was, of course, that no number presented in the middle of any temporal series of three could ever appear centrally from a spatial viewpoint. Whatever choice an S made, he was always encouraged by the word "good" or a sign to this effect.

There were two experiments. The first involved visual or auditory presentations of 32 sets of three digits to blind, deaf, and normal children. Responses were given orally by those presented with auditory stimuli and were written for the visual conditions. The hypothesis in this experiment was that modality of presentation was the critical factor which would determine the choice of a spatial or temporal "middle," rather than that type of handicap would affect the choice. It was predicted, therefore, that seeing and hearing children would demonstrate the phenomenon as well as blind and deaf children. Two normal control groups were used both for the deaf and the blind group, one operating with normal sensory input and the other with restriction of either sight or hearing. One of the groups was blindfolded and another wore earmuffs during the experiment.

The second experiment tested, first, which of two simultaneous inputs, auditory or visual, would dominate sensory organization in a percipient, and secondly, given a predominant modality in such a situation, if this could be changed by a prior set-inducing experience. To test this,

one group of normal children was tested with simultaneous visual and auditory input; another group was tested with the auditory input and, immediately thereafter, with simultaneous visual and auditory input.

SUBJECTS

Eighty children took part in the experiments. In the first experiment, 10 deaf children and two groups of 10 normal children matched for digit span and chronological age, were tested with visual material. Ten blind children of a similar chronological age and two groups of 10 normal children matched for chronological age were tested with auditory material. The children were all chosen from average groups in their school classes, so that their mental ages would be approximately equal to their chronological ages. No tests of intelligence were made. The mean chronological ages and their appropriate standard deviations were: deaf, $13:11 \pm 7$ months; normal controls, $13:6 \pm 4$ months and $13:5 \pm 5$ months; blind, $13:4 \pm 8$ months; normal controls, $13:6 \pm 2$ months and $13:8 \pm 2$ months. Simple analysis of variance showed the groups to be statistically equal in age. The digit spans for all groups exceeded the total length of presentations by at least two digits.

In a second experiment, two further groups of 10 normal children of the same chronological age were tested.

APPARATUS

Visual or auditory stimuli were digits presented to be read or heard, respectively. The three digits presented on any one trial were always successive. The digits were never successively presented from right to left or from left to right.

The visual display of digits was arranged on a panel at eye level with three windows each, 4 cm square and 12 cm apart from center to center. Digits appeared in these windows and were themselves 2.5 cm high. Auditory presentation was from three loud-speakers, 1 m from the S and to his left, in front of him, or to his right.

The three digits were presented over a 2-sec period, and the average pause between any three digits was 8 sec, with a range of 6-12 sec. The auditory digits were recorded on Channel 1 of a Uher Stereo tape recorder, and control tones were recorded on Channel 2 and the dia-pilot channel (a facility fitted to the Uher for controlling a slide projector). These control tones operated a voice switch, the output of which was coupled to two changeover relays. These relays were used to switch the output from Channel 2 to

the left, center, or right loud-speakers in a predetermined sequence governed by the tones on the tape.

The visually presented digits were operated in a similar manner, the output from Channel 1 being coupled to a second voice switch which switched on the visual displays. The duration of the digit display was set at 300 msec, which was found to be the average time taken for the naming of any one digit. The actual digits displayed were set by the operator during the pause between trials by means of three rotary switches for left, center, and right digits, respectively. Intensities were 1.2 log FL for the visual and 70 dB for the auditory displays.

RESULTS

The results of the first experiment are given in Fig. 1.

The results are self-evident, and no statistical confirmation would seem necessary. In the deaf and in both the two normal control groups, organization of visual items is obviously predominantly spatial, since the spatially central digit is chosen as the middle one in an overwhelming number of instances. In the blind and the two control groups, with auditorily presented digits, the chosen central or "middle" digit is equally obviously a temporal one. The only exceptions with the visually presented material were three deaf children who chose the arithmetic middle on most trials and two Ss in one visual control group who selected the temporal middle. Exceptions in the auditorily presented material were arithmetic in one case only, and spatial in one. One normal child in the blindfold group gave inconsistent choices.

In the second experiment, results of the simultaneous presentation of auditory and visual material to normal children led to the spatial middle being chosen in all but 3 out of 320 possible trials. Thus, the visual display dominated the organization of the material. When, however, an auditory presentation occurred before a simultaneous visual and auditory one, organization remained predominantly temporal and was determined by the auditory rather than the visual stimulus mode. Figure 2 presents the results of this experiment.

Once again statistics are not required.

Finally, the three deaf children who had given arithmetic responses were tested with visual presentations of geometric shapes. Their responses were without exception spatial, thus

confirming the results of visual presentation to other Ss. To meet a possible objection that response and input modality were confounded in this experiment, 10 adult normals were given both visual and auditory procedures in such a manner that each S responded to five signals by writing and five by speaking the answers. Only 10 trials were given in each case, half the Ss beginning with writing and half with speaking. The order of auditory and visual presentations was also balanced. Results showed that responses were clearly determined by stimulus conditions and not by type of response.

DISCUSSION AND CONCLUSIONS

Results from this experiment are so clear that conclusions can be stated very simply. In an ambiguous situation, modality of presentation determines whether stimuli will be organized spatially or temporally. Thus, an auditory presentation determines that Ss will choose the temporally central digit rather than the spatially central. A visual presentation determines that Ss will choose a spatially central digit and ignore the temporal one. The fact that blind children always choose the temporal middle and deaf children the spatial is a result of the fact that their input is confined to auditory and visual modalities, respectively. This is demonstrated by the response of the control groups. In nearly all cases, they showed results characteristic for modality of presentation. The blind and deaf children responded in a manner like that of the hearing and sighted in their functioning modality.

Current theories of information storage assume that there is a brief perceptual processing stage, during which the stimulus is directly represented. This brief trace is superseded by a stage in which items are identified and stored on the basis of meaning, naming, and similar encoding processes. On this basis, one would expect visually presented digits to be organized in an auditory-temporal fashion. Our results do not support this expectation. Rather, the selection of the "middle digits" depends on the input modality.

Essentially our results indicate that modality of input induces either a temporal or spatial set; i.e., the nature of the intuition, to use the terminology of Kant (1781), influences the selection of one or other category or concept. The term "dimensions," as used by Sutherland (1959) and Zeaman and House (1963),

might be invoked here. One could say that the input modality was the trigger which switched in the appropriate dimension for coding the stimuli. Thus, the nature of the input to a great degree determines the code used to organize it. That is, the referent of the word "middle" is in itself undefined. It is determined only by the modality of the stimulus display.

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