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Human sensory dominance*

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Human Ss matched an auditory and a visual stimulus for subjective magnitude. Then each stimulus was used as a cue in a reaction time task. On occasions when both stimuli were presented simultaneously, Ss' responding was seen to be dominated by the visual stimulus. Of further interest was the finding that on some occasions of simultaneous light-tone presentation Ss were unaware that the tone had been presented. This apparent prepotency of the visual over the auditory stimulus was seen to persist across a variety of experimental conditions, which included giving Ss verbal instructions to respond to the tone when both stimuli were presented simultaneously.

Organisms are constantly exposed to a contiguous array of stimuli rather than to the isolated action of a single stimulus. Of this array, certain stimuli are more likely to be attended to than others. Such stimuli may be called prepotent for that particular organism. It has been shown, for example, that cats will attend only to the auditory component of a compound CS made up of a soft low tone and a bright flashing light. Thus, sound stimuli appear to be prepotent over light stimuli for the cat (Jane, Masterton, & Diamond, 1965).

The four experiments described below represent a comparison of the auditory and visual modalities as to sensory prepotency for one of the most frequently used Ss in psychological research, the college freshman.

EXPERIMENT I

Experiment I involved observing the behavior that occurred when Ss were simultaneously presented with an auditory and a visual stimulus of equal subjective intensity, each of which had a characteristic response associated with it.

Method

Ten freshman psychology students at the University of Pittsburgh served as Ss. The group was composed of six males and four females. In a dimly illuminated room, each S was seated 45 cm in front of a 30-cm-sq stimulus panel containing a 5-cm speaker and a 6-W incandescent light source. Each S first matched an auditory and a visual stimulus for subjective intensity by adjusting the light with a Powerstat variable autotransformer until it was as bright as a 4,000-Hz, 65-dB SPL tone was loud. Then the matched stimuli were used as cues in a reaction time (RT) task.

Each S placed his index fingers over two telegraph keys located directly in front of him. One key was designated as the "tone key," while the other was called the "light key." The right key was the tone key for five Ss, and the left key was the tone key for the remaining five Ss. There was one left-handed S in each condition.

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S was instructed to press the tone key as soon as he heard the tone, or the light key as soon as he saw the light. A keypress terminated the stimulus. Light and tone onsets were manually controlled by E. A Standard timer measured RTs in milliseconds. After four practice trials, each S was given 30 simple RT trials where he was told ahead of time whether the light or the tone would occur. Ss were then given 30 choice RT trials where they were not told ahead of time which stimulus would be presented. Light and tone trials were presented in a random manner, with the constraint that each stimulus be used on 50% of the trials. Trials were presented at 15-sec intervals throughout the experiment.

After each choice RT trial, S was asked for a verbal report as to whether or not he had pressed the correct key. Actually, an independent measure of correctness of key choice was available; however, the question was asked to make certain that S was paying attention to his key choices. Interspersed with the 30 choice RT trials were 5 conflict trials where the tone and light were presented simultaneously. There were 50 such conflict trials altogether (10 Ss, 5 trials each).

An attempt was made to keep Ss from realizing the purpose of these conflict trials. It was felt that one way to accomplish this was to make these trials seem to be accidental. Thus, during one of the four initial familiarization trials for each S, E "accidentally" presented both stimuli simultaneously, called S's attention to it if necessary, apologized, and showed S how failure to open a switch from the previous trial could cause such an occurrence. All RT trials, simple, choice, and conflict, were preceded by E's saying "ready," so that S was prepared to respond when the RT stimulus was presented.

Results

The mean simple RTs for tone trials and light trials were 179 and 197 msec, respectively (standard errors, 7.2 and 7.9). This difference was statistically significant at the .05 level. RT values in the choice situation were 297 msec for tone trials and 299 msec for light trials (SE, 8.3 and 9.0). The mean RT of 303 msec on conflict trials did not differ significantly from the choice RTs.

Of the 50 conflict trials when both light and tone were presented simultaneously, light keypresses occurred in 49 instances. Even though the simple light RT was slower than the simple tone RT, the response to the light dominated when both stimuli were presented simultaneously. Especially noteworthy was the fact that on 16 of the 49 conflict trials when the light key was pressed, Ss were not aware that both

stimuli had in fact been presented. Ss pressed the light key, and gave the verbal report that they had been correct. On the remaining 33 conflict trials, the Ss pressed the light key, but then showed some surprise, verbally indicating that both stimuli had been presented. In such a situation, E apologized and explained that he had accidentally left a switch closed from the preceding trial, thereby causing both the light and the tone to be activated. This explanation was apparently accepted by all Ss.

The one S who pressed the tone key on one of the conflict trials gave an interesting verbal response following the trial. He reported that he was incorrect and that he should have pressed the light key. He was apparently unaware that the tone had been presented even though he had pressed the tone key. Thus, in one manner or another, the visual stimulus was prepotent over the auditory stimulus on 50 out of 50 conflict trials.

EXPERIMENT II

A second experiment was conducted as a follow-up to Experiment I. The question of interest was whether or not the apparent prepotency of the visual stimulus over the auditory stimulus could be reduced or eliminated by increasing the subjective intensity of the auditory stimulus relative to the visual stimulus by a factor of two. Experiment II also served as a control for the cross-modal matching procedure used in Experiment I, in that Ss were required to adjust the loudness of the tone rather than the brightness of the light.

Method

The Ss were 22 freshman psychology students from the University of Pittsburgh. The group was composed of 11 males and 11 females. The apparatus used and the procedure followed were identical to those of Experiment I, with one exception. The Ss in Experiment II were asked to adjust the loudness of the 4,000-Hz tone until it was twice as loud as the light (50 fc) was bright. No S had any difficulty with this cross-modal matching task. The light and tone were then used as cues in the reaction time situation.

After four familiarization trials, all Ss were given 30 simple RT trials and 30 choice RT trials. Ss were again asked for a verbal report on correctness of key choice immediately following each trial. As in Experiment I, awareness on the part of S that both stimuli had been present on a conflict trial was contended with by explaining that a switch had mistakenly been left closed from the previous trial. The location of the tone key on the right or left side was reversed for half of the Ss.

Results

Mean simple RT for the tone trials was 191 msec (SE, 8.9), while the simple light RT was 203 msec (SE, 8.6). This difference did not achieve statistical significance. The mean choice RTs for tone and light trials were 297 msec (SE, 8.4) and 284 msec (SE, 7.2), respectively.

A total of 110 conflict trials were presented in Experiment II (22 Ss, 5 trials each). Of these, light keypresses occurred 97 times, and the tone keypresses, 13 times. Awareness of the presence of both light and tone on a conflict trial was reported 86 times, with Ss being unaware on the remaining 24 trials. Ss were always aware of the presence of the light on conflict trials. The mean conflict RT was 200 msec on the 13 trials when the tone key was pressed. The corresponding value on the 97 trials when the light key was pressed was 296 msec.

EXPERIMENT III

The data from Experiments I and II suggest that visual stimuli are prepotent over auditory stimuli for human Ss, and that this prepotency holds even when the auditory stimulus has a subjective intensity twice that of the visual stimulus. Experiment III was conducted to investigate different aspects of the design used in Experiments I and II which might be contributing to this prepotency effect.

One variable that was chosen for further study was the ambient illumination level in the experimental room. Possibly, the state of the partial dark adaptation in which Ss were run was responsible for the light-prepotency effect. Another procedural change introduced in Experiment III was to omit the ready signal. Kohfeld (1969a, b) has demonstrated that it is possible for RT to be influenced by the preceding ready signal, and some unintentional bias in voice inflection or intensity of the verbal ready signal may have favored the response to light on conflict trials in Experiments I and II. Finally, the use of deception on conflict trials was discontinued in Experiment III. Apart from Ss' verbal reports, there was no objective evidence that the deception was successful, and it is possible that in some unknown way the use of deception was contributing to the observed visual prepotency.

Method

The Ss for Experiment III were 10 undergraduate psychology students from the University of Pittsburgh. The group was composed of 7 males and 3 females. The apparatus used and the procedure followed were identical to those of Experiment I, with three exceptions. First of all, the windows in the experimental room were uncovered, and the room lights were turned up to provide normal illumination. Secondly, Ss were no longer provided with a verbal "ready" signal before each trial (intertrial intervals remained the same as in Experiment I). Finally, Ss were told that interspersed with choice RT trials would be a small number of trials when both light and tone would be presented simultaneously. The instructions to Ss in Experiment III were modified to include the sentence, "On trials when both stimuli occur simultaneously, press whichever key is appropriate to the signal you recognize first." As in Experiments I and II, Ss were asked for a verbal report after each choice and conflict RT trial.

Results

Mean simple RTs were 190 and 205 msec for tone and light, respectively (SE, 6.7 and 8.1). The mean RTs for choice trials were 318 msec (SE, 11.0) for tone and 298 (SE, 9.3) for light. Light keypresses were made on 47 of the 50 conflict trials, with tone keypresses occurring on the remaining 3 trials. Mean RTs for light keypresses on conflict trials was

282 msec. The corresponding value for the three tone keypresses was 297 msec. Awareness of the presence of both stimuli on a conflict trial was reported 46 times, with unawareness occurring only 4 times. No single S was unaware on more than 1 conflict trial, and awareness of the presence of the light was reported even on the 3 conflict trials when the tone key was pressed.

EXPERIMENT IV

The results of Experiment III suggest that the apparent prepotency of the visual stimulus is not due to (a) dark adaptation, (b) the use of a verbal ready signal, or (c) deception about conflict trials. Experiment IV was conducted to determine whether or not the visual prepotency could be overcome by giving S verbal instructions to press the tone key on conflict trials.

Method

The Ss for Experiment IV were 10 undergraduate psychology students from the University of Pittsburgh. The group was made up of 5 males and 5 females. The apparatus used and the procedure followed were the same as in Experiment III, except that Ss were told, "On occasions when the light and tone occur simultaneously, press the tone key."

Results

Mean simple RTs for tone and light were 189 msec (SE, 8.4) and 195 msec (SE, 8.1), respectively. Choice RTs were 358 msec (SE, 11.0) for tone trials and 348 msec (SE, 9.3) for light trials. Each S was given 6 conflict trials instead of 5 as in the previous three experiments. Out of a total of 60 conflict trials (10 Ss, 6 trials each), light key presses occurred 36 times, while tone keypresses occurred 24 times. Mean conflict RT on light trials was 330 msec (SE, 12.2), while mean conflict RT on tone trials was 389 msec (SE, 18.4). This difference was statistically significant ($p < .01$). Three Ss in Experiment IV each exhibited unawareness on a single conflict trial of the presence of the tone.

DISCUSSION

The initial task of Ss in all four experiments was to effect a cross-modal match between the subjective magnitude of the light and that of the tone. In Experiments I, III, and IV, Ss were asked to create a condition of subjective equality between the two stimuli. In Experiment II, the tone was to be set at twice the intensity of the light. The reliability and validity of cross-modality matching as a psychophysical procedure is well established (Stevens, 1966). No S in the present series of experiments had difficulty in performing such an operation.

A consistent finding in all four experiments was the obvious prepotency of the visual stimulus over the auditory stimulus on conflict trials. Out of a total of 270 conflict trials, Ss responded to the light 230 times. This is especially interesting in that there was a trend across all four experiments for the simple tone RT to be faster than the simple light RT (overall mean simple RT across experiments was 185 msec for tone and 197 msec for light). These data are in agreement with the general finding that RT to light is slower than RT to tone (Woodworth & Schlosberg, 1965, p. 16).

Out of a total of 40 responses on conflict trials made to the tone stimulus, 13 occurred in Experiment II, when the tone had a subjective magnitude twice that of the light, and 24 occurred in Experiment IV, when Ss were instructed to respond to the tone on conflict trials. Since over twice as many Ss were run in Experiment II as in Experiment IV, it is obvious that the verbal instructions to press the tone key on conflict trials accounted for the vast majority of tone keypresses. Even in Experiment IV, however, more responses on conflict trials were made to the light (36) than to the tone (24). It is noteworthy that the mean RT for the 13 conflict trial tone keypresses in Experiment III was only 200 msec as compared with a mean of 296 msec for light keypresses. Several Ss in Experiment III spontaneously volunteered the information that the loudness of the tone was such that it became aversive when it was adjusted to twice the subjective intensity of the light. Perhaps this aversive component that was not present in the other three experiments accounted for this unusually short RT.

Observation of the behavior of Ss in Experiment IV further suggests the presence of a strong visual prepotency effect. On approximately 40% of the conflict trials on which the tone key was pressed, Ss were first seen to actively inhibit an initial movement toward the light key. The mean tonal RT on conflict trials of 389 msec seen in Experiment IV was significantly longer than the RT to light or tone seen in any other condition that was investigated. The need to first suppress a tendency to respond to the light on conflict trials undoubtedly accounted for this slow RT.

The major finding of the present series of experiments is the consistent tendency for the visual stimulus to dominate behavior, whether or not S was (a) light or dark adapted, (b) deceived or informed about the conflict trials, (c) to equate the light and tone for subjective intensity or make the tone twice as intense as the light, (d) given a verbal ready signal or not, or (e) specifically instructed to respond to the tone on conflict trials. A secondary finding of some interest was the occurrence of conflict trials on which S was unaware of the presence of the tone. A total of 47 such trials was seen in the four experiments. The sequence of procedural differences introduced from Experiment I to Experiment IV was successful in reducing, but not in eliminating, instances of unawareness.

As deception was not a part of the procedure in Experiments III and IV, the seven Ss in these experiments who reported unawareness were

questioned immediately after such an occurrence in an attempt to further establish the validity of the phenomenon. Upon questioning, five Ss (four from Experiment III, one from Experiment IV) exhibited surprise and considerable interest in the fact that they had completely failed to perceive the presence of the tone. The two remaining Ss exhibited what might be called "delayed awareness," in that when E had interrupted the sequence of trials to pursue the question of awareness, these two Ss seemed to attend to the last vestige of a rapidly fading memory trace, and gave such verbal reports as, "Now that you call my attention to it, the tone was on, wasn't it?" At the conclusion of testing, all Ss were informed as to the purpose of the experiments, and an attempt was made to justify the mild deception that had been used in Experiments I and II.

It is well documented that Ss cannot respond as effectively to two simultaneously presented stimuli as to the same two stimuli presented in succession (Broadbent, 1958; Mowbray, 1954; Poulton, 1953). Broadbent (1958) has proposed that the central information processing mechanism (attention) can handle information from only one channel (modality) at a time, and that attention must be switched from one channel to another sequentially in dealing with simultaneous inputs. The present data are in accord with such a channel-switching model if one assumes that our Ss were sampling from the visual channel first, thereby causing the light keypress to be initiated before the tone keypress. Unfortunately, the four experiments described above do not provide an unequivocal explanation for the apparent priority of the visual channel.

One possible explanation for the present data may be related to the short duration of the stimuli. While a reflexive orienting response occurs both to brief auditory and visual stimuli, there is some evidence (Ades, 1944) that in both cases the orienting response ultimately involves the neural connections of the superior colliculus with the motor centers of the ventral tegmentum, medulla, and spinal cord. Thus, the visual channel may be sampled first by virtue of its more direct connections with the superior colliculus.

While the underlying mechanism remains unclear, the above data point to the existence of visual prepotency in normal humans, at least for stimuli of very brief duration.

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