Bisensory signal detection[1]

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In an experiment comparing unimodal with bimodal signal detection, groups of Ss performed a four-alternative spatial forced-choice visual and a "yes-no" auditory task either singly or simultaneously. The results were a significant decrement in bisensory visual discriminability and a comparable decrement in bisensory auditory performance, with little evidence for other interactions between tasks.

This experiment was performed to determine whether detection performance on either a visual or an auditory detection task depended on whether S performed only one or both tasks when signals occurred simultaneously in both modalities.

A number of experiments have reported reduced performance due to simultaneous bisensory detection. Among recent results, Gregg & Brogden (1952) found that instructions to respond to both a tone and a light resulted in significantly lower acoustic sensitivity than when Ss were merely instructed to fixate the light. Similar results were obtained by Thompson, Voss, & Brogden (1958). Webster & Haslerud (1964) showed that counting clicks significantly decreased detection of simultaneous peripheral light flashes, as did counting foveal flashes. Lindsay, Cuddy, & Tulving (1965) obtained a significant reduction in amount of transmitted information per modality under conditions of simultaneous presentation in an absolute judgements task. However, of the two vigilance studies which recorded separately responses to simultaneous bisensory signal presentation (Baker, Ware, & Sipowicz, 1962; Osborn, Sheldon, & Baker, 1963), neither found decrements due to bisensory detection.

Of the experiments demonstrating reduced performance, none has shown conclusively that sensitivity changes rather than response criterion shifts produced the decrements.

Method

Subjects. The Ss were 30 male and 30 female undergraduates, participating to satisfy a requirement in an introductory psychology class. The Ss were not selected for visual or auditory acuity, and all performed with unaided vision.

Apparatus. The S sat in a straight-backed wooden chair in one of two identical 5 ft. by 8 ft. rooms, facing at a distance of approximately 3-1/2 ft., a 4 in. diameter disk of 1/4 in. white opaque plastic, mounted flush in a flat-white plywood surface at eye level. Four General Electric NE 45 neon bulbs were located 1/4 in. behind the disk, forming a 1-3/4 in. sided square, centered on the center of the disk, with the bulbs located on the vertical and horizontal axes. Slightly below S's head and 2-1/2 ft. to the left was located a 7 in. speaker, through which a white noise generator, along with an overhead ventilation fan, produced masking noise of 34 dB SPL continuously throughout the session. The auditory signal, a tone of 560 cps, 28 dB SPL measured in a quiet room, was presented through the same speaker as the white noise. Stimuli durations were controlled by Hunter timers and relay circuitry, and intertrial intervals by a Western Union tape transmitter. Individual S microphones permitted scoring of S's verbal responses.

Procedure. The Ss were randomly assigned to one of three groups, each restricted to 10 males and 10 females. Group L_a was instructed to perform the visual detection task, Group L_cT_c was instructed to perform both visual and auditory detection tasks, and Group T_a was instructed to perform the auditory task. The groups differed only in their instructions; stimuli and sequences were identical for all groups. The presence of visual or auditory signals was not mentioned to Ss not detecting them.

At intertrial intervals of 10, 15, and 20 sec., randomized in blocks of three, three of the lights came on, followed after a 67 msec. delay by the fourth, with a total presentation time of 475 msec. The delayed light was randomly preselected with the restrictions that in the 100 trials that made up a session, each light was delayed 25 times, and no light was delayed more than four times in succession. On 50 randomly predetermined trials, the tone was presented during the 67 msec. light delay, with the restriction that the tone was neither present nor absent more than four trials in succession.

A tone demonstration was presented to Ss performing the auditory detection task following the instructions. The tone was sounded for 5 or 6 sec. at an intensity 10 to 20 dB above the presentation intensity, and then, at the same intensity and without the lights, for the 67 msec. duration, repeated until S reported that he heard it, usually the first time.

Results and Discussion

Because the d' measure is presumably unaffected by the type of experimental situation and is thus somewhat comparable for the visual and auditory data, Fig. 1 presents mean d' values, obtained from the tables in Swets (1964), for each of the four conditions. There are, however, two reservations which should be mentioned. The experiment provided no way to check the assumptions of normal, equal variance distributions necessary to use of d' (Swets, Tanner, & Birdsall, 1961) for the visual task, and the auditory d' values were obtained from group mean "hit" and "false alarm" rates due to the failure of some Ss to give any "false alarm" responses.

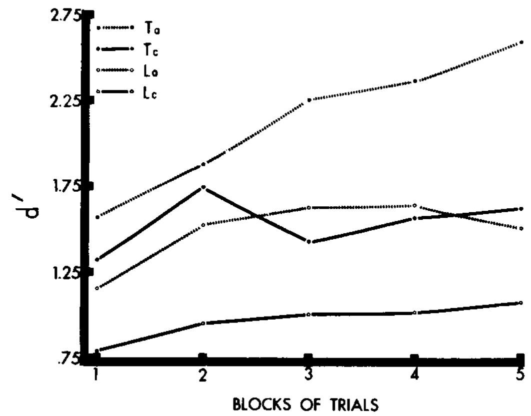

Fig. 1: Mean d' values plotted in blocks of 20 trials for a four-alternative forced-choice visual detection task and a "yes-no" auditory detection task performed singly and simultaneously.

For the comparison between L_a and L_c conditions, the transformation from percent correct, P(C), to d' makes little difference since overall session L_a performance was significantly superior to L_c performance by both measures (d': $t=2.91$, P(C): $t=2.82$, $df=38$, both p's $< .01$). Lack of individual S values prevented statistical comparisons between the two auditory tasks on the d' measure. Comparison of P(C) values indicated that the superior performance of the T_a Ss did not differ significantly from that of the T_c Ss ($t=1.39$, $df=38$, $p< .20$). Examination of Fig. 1 suggests, nevertheless, that performance decrements under the combined task conditions were quite comparable for both tasks. The difference in mean d' values between the T_a and T_c conditions for the session was .58 and between the L_a and L_c conditions, .56. Since there was little evidence for intersensory effects, it seems clear that bisensory detection produced lower sensitivity for at least the visual task.

A number of theories of attention have implications for possible interactions between the visual and auditory tasks under the combined condition. Most theories of attention (e.g., Berlyne, 1960; Broadbent, 1957, 1958; Schmidt & Kristofferson, 1963) start by assuming that the human has limited capacity to receive and process sensory information. As a result, at any given moment some sensory inputs are processed and other simultaneously occurring inputs are not. Which stimulus inputs are processed can vary as a function of time or stimulus characteristics. Although further details differ among theories, all would predict bisensory detection decrements, since processing of the stimulus input from one modality implies a lack of processing of the stimulus input from the other modality. Thus, theories of the type under discussion must predict a dependent relationship between detections in the two modalities; a relationship such that a correct detection in one modality is accompanied by a reduced probability of a correct detection in the other modality. Comparisons of the conditional proportions of correct in each modality given correct or incorrect in the other modality revealed no significant differences, but the tendency was to be either correct or incorrect in both modalities on the same trial, differences opposite in direction from those predicted from a "limited channel" hypothesis.

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Notes

1. This experiment is from a dissertation submitted to the Graduate School of Indiana University in partial fulfillment of the requirements of the Ph.D. degree. The author is grateful to I. Gormezano, who served as chairman of the dissertation committee and provided support from NSF Grant GB-2843. I thank Marius Smith, who suggested the visual task used in this experiment.

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