THE EFFECTS OF BIMODAL STIMULUS PRESENTATION ON TRACKING PERFORMANCE

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The Effects of Bimodal Stimulus Presentation on Tracking Performance

Most previous research comparing unimodal stimulus presentation with bimodal presentation of correlated stimuli have shown evidence for intersensory facilitation; better performance is produced when stimuli are presented in two modalities as opposed to only one. This result has been found with reaction-time experiments (Todd, 1912; Swink, 1966; Bernstein, Clark, and Edelstein, 1969a), vigilance experiments (Buchner and McGrath, 1961), and detection studies (Brown and Hopkins, 1967; Loveless, Brebner, and Hamilton, 1970). Handel and Buffardi (1969) have also shown that simultaneous auditory and visual stimulus presentation produces a faster rate of pattern identification than does individual modality presentation. The present experiment was designed to explore the effects of bimodal, correlated stimulation on a complex motor task — tracking a repeating series of step function inputs.

The rationale for this investigation was that methods developed for analyzing tracking performance would allow specific statements concerning the locus of performance changes resulting from bimodal stimulation. That is, if bimodal stimulus presentation affects tracking performance, it would be possible through an analysis of oscillographic records to locate where the additional redundant input makes its contribution.

Method

Subjects. -- Thirty-six right-handed, male college students volunteered to serve as Ss for the experiment. These students were all between the ages of 18 and 25 and had normal vision and audition. They were paid for their services.

Apparatus. -- The apparatus was the Kansas State University Versatile Electronic Tracking Apparatus (VETA). Since a detailed technical description of the apparatus is available elsewhere (Trumbo, Eslinger, Noble, and Cross, 1963), only a general description will be presented here.

The VETA was used to present a repeating pattern of visual inputs on a pursuit tracking display. The input function, or target, was punched on mylar tape, read out by a Digitronics Model 2500 tape reader, converted to analog voltages by means of a digital-to-analog converter, and displayed on a cathode ray tube (CRT) as a vertical line which moved along the horizontal axis of the CRT. The position of a similar vertical line, the cursor, was continuously adjustable by means of an arm control attached to S's chair in a position for easy manipulation by S's right arm. This arm control consisted of a horizontal arm rest, pivoted at the elbow on a vertical shaft, and an adjustable hand grip. A potentiometer attached to the lower end of the rotating shaft converted the arm control position into a continuously variable voltage which, in turn, drove the cursor on the CRT. A movement of 5.6 degrees of the arm control caused the cursor to move 1 cm. Both the target line and the control line were 16 mm. long and they overlapped by 2 mm.; the cursor appeared below the target.

Since both the input function and the control positions were represented as voltages within the system, the absolute difference between these two voltages was integrated over each trial by an operational amplifier manifold. This integrated error was read out on a digital voltmeter at the end of each trial. In addition, the input function and control positions were continously recorded on an oscillograph during selected trials for purposes of analytical scoring.

An auditory input function was also punched on mylar tape and read out by a second Digitronics tape reader which was pulsed by the same timer used for advancing the visual input function. The auditory input consisted of either white noise generated by a Grason-Stadler model 455C noise generator or four pure tones generated by four audio oscillators.

Two *S*s were run simultaneously in 2 identical experimental booths. Each *S* was seated approximately 71 cm. from the CRT. The loudspeaker used to present the auditory input was about 50 cm. directly behind *S*'s head.

Inputs and conditions. -- The visual input consisted of a step function in which the target moved from position to position in discrete jumps and remained at each position for 0.8 sec. The target moved through each of 4 different positions then through the same four positions in a different order, defining an 8 element pattern. This pattern was repeated 6 times per trial so that each trial lasted 38.4 sec. The pattern in terms of voltages was -3, +7, +2, -6, +7, -3, -6, +2 where -7 would be the extreme left position and + 7 the extreme right. Zero volts was at the center of the CRT. The equivalent of a one volt displacement on the display was 5.7 mm. Condition V consisted of *S*s who tracked this visual pattern without any simultaneous auditory input.

The different auditory inputs used in conjunction with the visual input produced 2 further conditions. In Cond. VN the visual pattern of inputs was presented along with 40 msec. bursts of 50 db. white noise. The onset of the noise bursts occurred simultaneously with the changes in target position on the CRT. In Cond. VT the visual pattern was accompanied by a synchronous pattern of tones. Four different tones were used to correspond to the 4 positions in the visual pattern. Each tone was 40 msec. in duration with loudness subjectively equated to that of the white noise. The frequencies of the tones were 300 hz., 690 hz., 1590 hz., and 3650 hz. The tones were arranged such that the highest tone was presented with the extreme right position in the visual pattern (+7), the next lowest tone with position +2, the third lowest with position -3, and the lowest tone with the extreme left position (-6).

Procedure. -- The *S*s were randomly assigned, 12 each, to the 3 experimental conditions. For all conditions *S*s were instructed to track the target on the CRT by keeping their cursor superimposed on the target as much as possible. They were told that there would be an 8 element pattern repeated 6 times in each of 30 trials and the most accurate means of tracking this pattern would be to move simultaneously with the target. It was explicitly stated that the *S* should learn the pattern in order to perform well. Each trial was preceded by a 5 sec. warning light and followed by a 15 sec. rest interval. All 30 trials were presented in one experimental session. In the VT condition *S*s were informed that 4 tonal bursts would be presented successively and that they would correspond to various target positions. The *S*s in Cond. VN were instructed that a brief burst of white noise would occur when the target changes position. All *S*s were informed of their integrated error score at the end of each trial.

Performance measures. -- Integrated error was the global performance measure (see Trumbo, Noble, Cross, and Ulrich, 1965). In addition, several indexes of temporal and spatial performance were obtained from the oscillagraphic records of the second repetition of the pattern on each of trials 2, 4, 6, 10, 20, and 30. The indexes of temporal performance were determined by comparing the time that *S* initiated his primary movement relative to the target displacement; a movement initiated before target displacement is called a lead and a movement started after target displacement is called a lag. All temporal measurements were made to the nearest 50 msec. Spatial performance was determined for those movements which were associated with any lead or a lag of less than 150 msec. For these movements, spatial performance was called an overshoot if *S* moved his control too far before stopping his primary movement and an undershoot if *S* did not move far enough before stopping. Movement accuracy was measured to the nearest 1 mm.

Results

Integrated Error

Figure 1 shows integrated error as a function of 10 3-trial blocks for each of the 3 conditions. These 3-trial block data were used in an analysis of variance which showed tracking conditions, F (2,33) = 8.019, and blocks, F (9,297) = 154.011, to be the only significant effects, both at $p < .01$. Inspection of the data shown in Fig. 1 reveals that all groups improve over blocks but that Cond. VT is consistently superior to Cond. VN which, in turn, is consistently superior to Cond. V. However, Newman-Keuls tests on the group means show the VT and VN conditions not to differ from one another but both differed significantly ($p < .05$) from Cond. V. It should be noted that the effects of auditory input (Conditions VT and VN) on integrated error are apparent as early as the first block of 3 trials. Integrated error curves for only those trials used in analytical scoring were also constructed and found to be essentially a duplication of Fig. 1.

Insert Figure 1 about here

Analytic Scores

Temporal performance. -- Leads and lags served as the basis for the indexes of temporal performance. From these basic measurements the following indexes were determined: the number of long leads (leads greater than 150 msec.); the number of long lags (lags greater than 150 msec.); beneficial anticipations (defined as a lead or lag within 150 msec. of target displacement —

short lags are considered anticipatory because 150 msec. is less than visual reaction time); the average magnitude of all leads and of all lags; and the average absolute magnitude of all leads and lags combined.

The number of long lags and the average magnitude of lags best reflect the factors underlying the integrated error data; Cond. V is always inferior to Conditions VT and VN which are about equal. Both the number and magnitude of lags decrease over trials for all groups. An analysis on the average magnitude of lags indicate a significant difference between conditions, $\underline{F}\ (2,33) = 3.988$ and a significant trial effect, $\underline{F}\ (5,165) = 28.249$. Newman-Keuls tests on the condition main effects replicated the integrated error findings. That is, with respect to the average magnitude of lags, the two auditory groups proved to be significantly superior ($\underline{p} < .05$) to the nonauditory group (Cond. V). An interesting observation, however, is that the VN group tended to be better at timing than the VT group early in the task. This observation is most clearly depicted in Fig. 2 which plots the number of beneficial anticipations as a function of trials. It can readily be seen that the VN group is superior to the V and VT groups over the first 10 trials. After trial 10, no differences between groups are apparent. Figure 2 also reveals that benificial anticipations remain fairly constant over trials. This results from the fact that the number of long leads increased over the 30 trials for all groups (from 1.5 to 3.1) while the

Insert Figure 2 about here

number of long lags decreased. With respect to long leads, Cond. VN tended to have fewer (5 vs. 9) in trials 2, 4, 6, and 10 than Cond. VT. This temporal superiority of the VN group early in practice was also reflected in the absolute lead-lag data.

Spatial performance. -- Overshoots and undershoots for those primary movements associated with a lag of less than 150 msec. or any lead served as the basis for the following indexes of spatial performance: the number of large overshoots (overshoots greater than 3 mm.); the number of large undershoots (undershoots greater than 3 mm.); the percentage of spatially accurate movements (defined as the percentage of overshoots and undershoots within 3 mm. of the target); the average magnitude of all overshoots and of all undershoots; and the average absolute magnitude of all overshoots and undershoots combined. The results of all spatial measures are singularly reflected in the composite overshoot-undershoot data which is shown in Fig. 3. An analysis of variance on this composite data indicated a main effect for groups, F (2,33) = 4.352. Newman-Keuls tests show both the VT and V groups to be significantly better ($p < .05$) than the VN group. However, no differences were found between Conditions VT and V with respect to the average absolute magnitude of overshoots and undershoots. It can be seen in Fig. 3 that auditory input for both the VN and VT groups clearly is associated with large spatial errors early in the session

Insert Figure 3 about here

relative to the V group. It can further be seen that the VN group improves only slightly over the entire session while the VT group shows an abrupt improvement surpassing the performance of Cond. V which remains fairly constant.

Discussion

It would seem from this data that an additional redundant input can facilitate certain aspects of performance in a tracking task. This conclusion arises from the finding that *S*s who were given tones (Cond. VT) in addition to the visual pattern consistently performed as well as or better than *S*s who did not receive any additional input (Cond. V) on all performance measures examined. However, the data suggests that the major contribution of the tones lies only in the timing aspect of the task since Cond. VT did not differ significantly from Cond. V on any of the spatial indexes but did differ with respect to average magnitude of lags and integrated error. Despite the lack of statistical significance between these 2 groups in spatial accuracy, Fig. 3 clearly points out that *S*s having the additional tonal input become consistently more accurate as practice continues than *S*s without such input. It might, therefore, be premature to conclude that tones do not assist in positioning.

The apparent superiority of the VT and VN groups with respect to temporal accuracy infers that redundant, correlated auditory input, in general, can be readily utilized to enhance timing in a tracking task. However, to generalize this inference to all aspects of the task would be a gross mistake.

The rationale for this notion lies in the fact that the VN group was spatially less accurate than either the VT or V group. This unexpected result appears to indicate that redundant, correlated auditory input can either facilitate or inhibit certain aspects of tracking performance depending on the type of additional input employed. It would, therefore, appear that the data are inconsistent with Bernstein, Clark, and Edelstein's (1969b) energy integration model which proposes that stimulus intensities add across modalities causing the joint auditory and visual event to be effectively stronger than the visual event alone. Clearly, if adding stimulus intensities were all that was involved, little or no difference between Conditions VT and VN on any of the performance measures should have occurred since both intensity and duration of the auditory inputs were equated.

A more plausible explanation has been proposed by Handel and Buffardi who have suggested that the auditory and visual modalities compliment each other when they are combined. That is, they propose that each modality presents "information" not present in the other modality. Even though the results presented here clearly show that two modalities may not only compliment each other, but can also be antagonistic, this is not to say that they are not consistent with Handel and Buffardi's explanation. For example, it is quite possible that the ambient noise actually provided a type of negative "information", possibly in the form of a distraction — noise might distract one from concentrating on positioning by accenting the timing aspect of the task whereas tones accent both timing and positioning. This explanation seems quite reasonable in light of the observation that noise tended to aid temporal performance more than tones initially. That is, since only the timing aspect of the task was accented in the VN Cond., one would certainly expect that accenting another aspect of the task (positioning) in addition could do nothing but hinder temporal accuracy. In order to assess this account of intersensory facilitation and inhibition, further research involving the properties of various types of inputs would seem mandatory. In addition, the fact that the global performance measure in this study, integrated error, was so inconsistent with many analytic scores should serve as a reminder that research in this area demands probing beyond gross measures of skill.

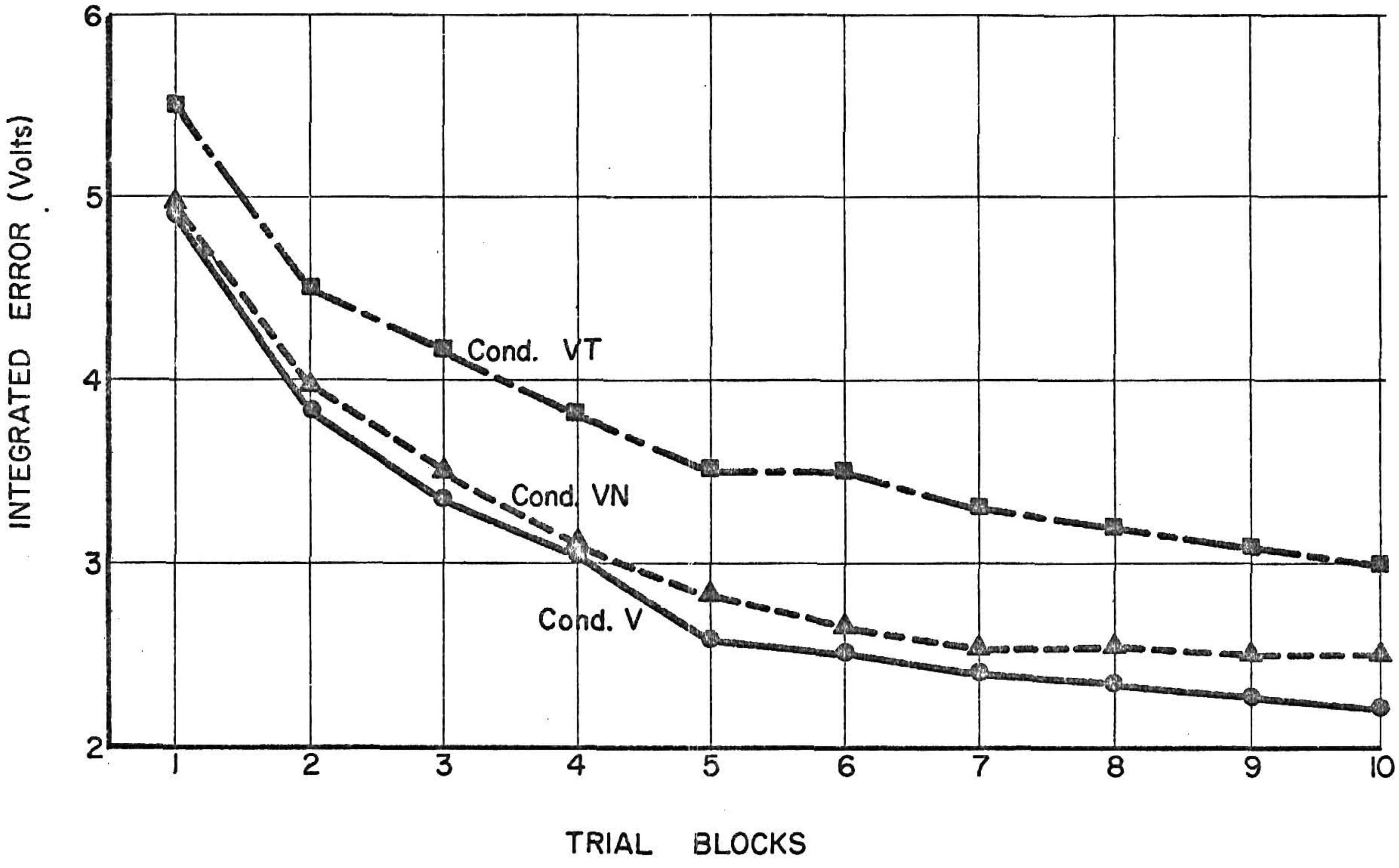

Figure 1. Integrated error as a function of conditions and three-trial blocks.

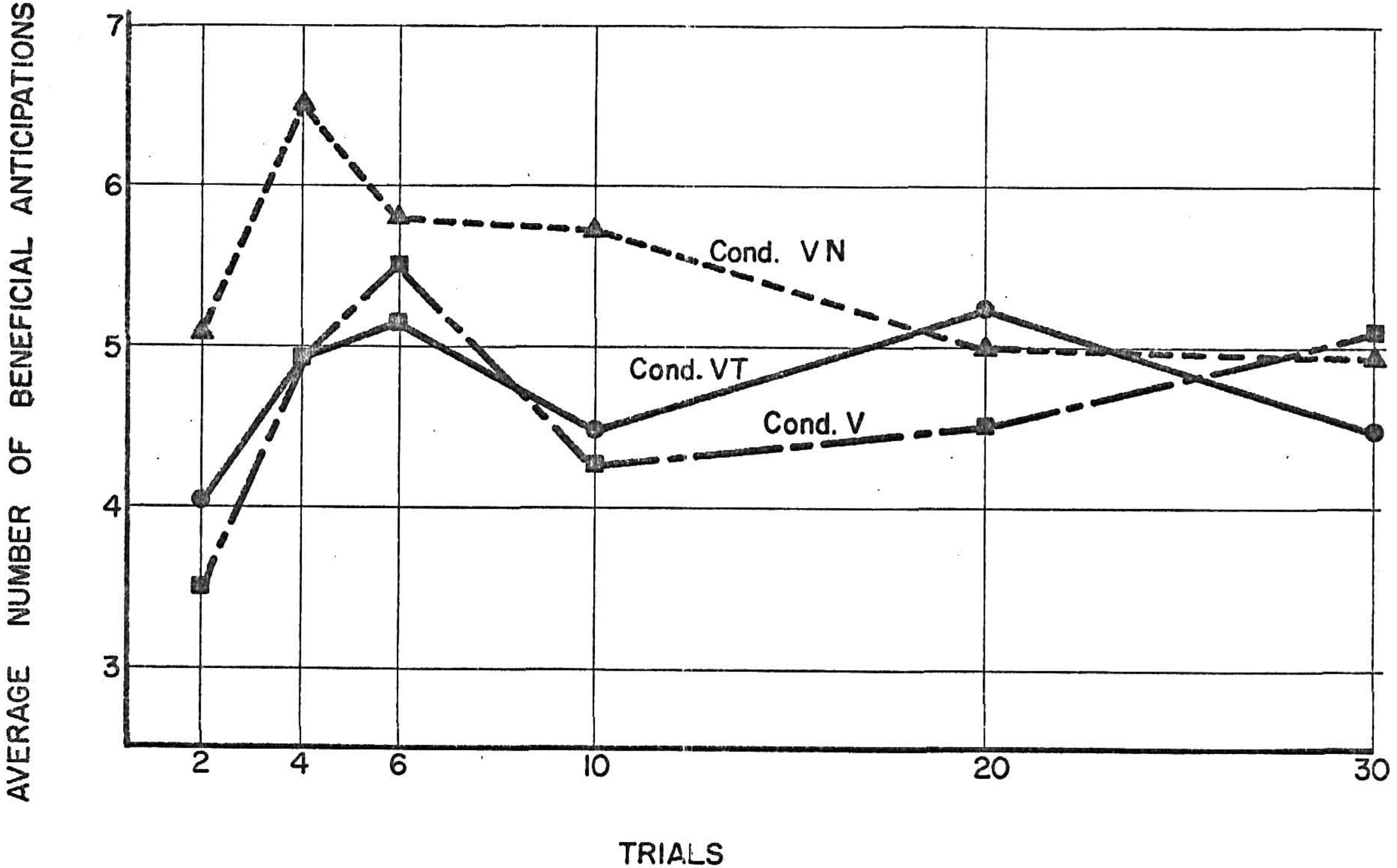

Figure 2. Average number of beneficial anticipations as a function of conditions and trials.

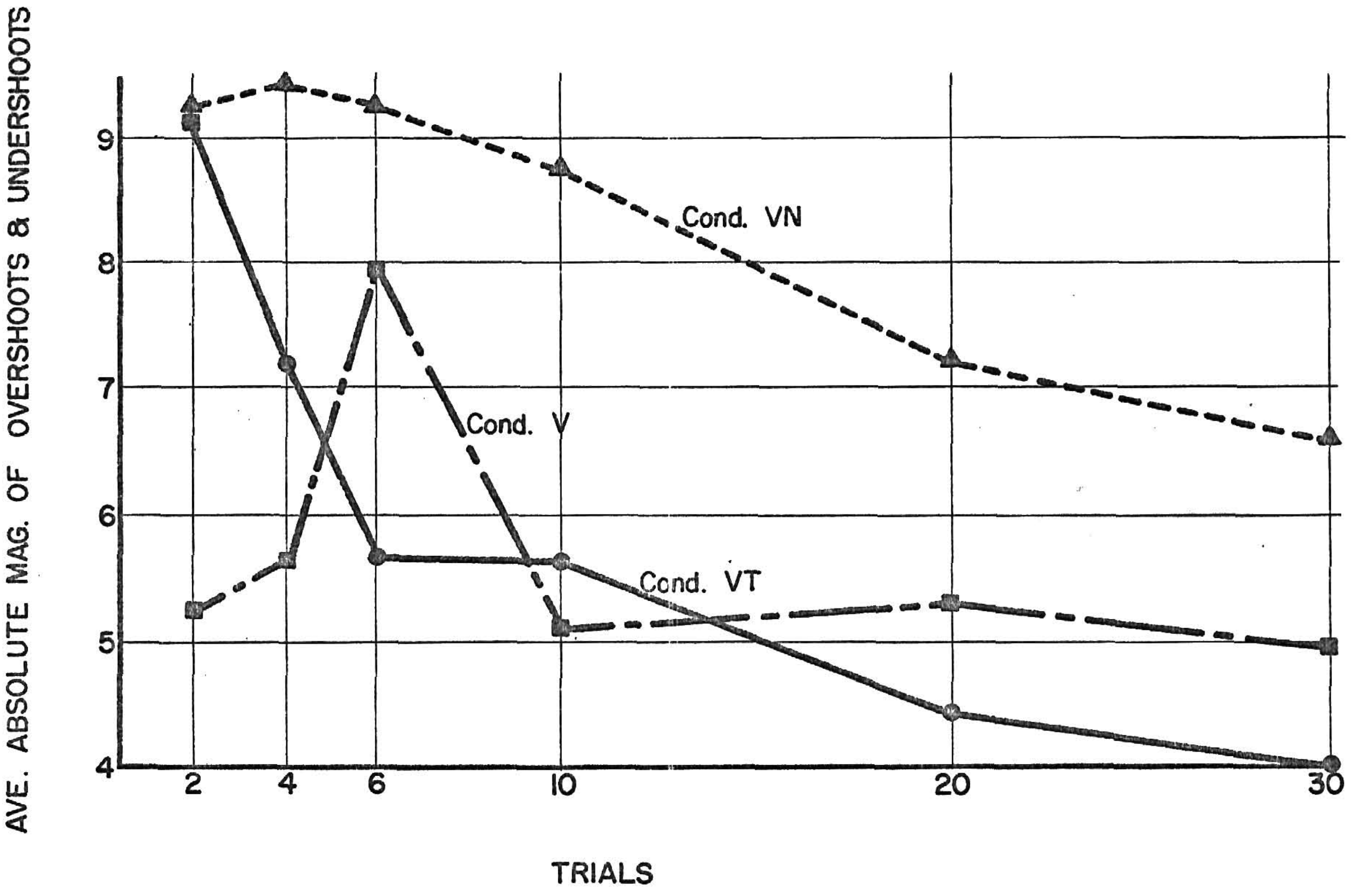

Figure 3. Average absolute magnitude of overshoots and undershoots combined as a function of conditions and trials.

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AN ABSTRACT OF A MASTER'S THESIS

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A tracking task was employed to compare the effects of unimodal stimulus presentation with those of 2 types of bimodal correlated stimulus presentations. Thirty-six *S*s were randomly assigned, 12 each, to 3 experimental conditions. The task for all *S*s was to track a visual step function input displayed on a cathode ray tube. In Cond. VN *S*s were exposed to a short burst of 50 db. white noise every time the visual target changed positions. *S*s in Cond. VT received a 40 msec. tone simultaneous with the target position change. 4 different tones were used in Cond. VT and each corresponded to a particular position in the visual pattern. In Cond. V no auditory input was employed. The data were analyzed with respect to both a global performance measure and several temporal and spatial indexes. The results indicated that a redundant auditory input can either facilitate or inhibit certain aspects of tracking performance depending on the type of additional input employed. A plausible explanation for the findings was proposed and supported by observations within the data.