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EFFECTS OF SOUND ON POSTURAL CONTROL[1]

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The close association between the cochlea and the vestibular system has led to assumptions that sounds of different frequency can affect posture To test this assumption, two experiments were done to determine the effects of four tones of 260, 590, 1500, and 2500 Hz on coordinate postural control The intensity level of each tone was presented both asymmetrically and symmetrically to the two ears of *S*. In the asymmetrical study, the intensity of the right ear was held at 75 db ± 2 5 db and the left ear level was held at 95 db ± 2 5 db The analysis of variance indicated that the frequencies used in the experiment did not have a significant effect on postural regulation as measured by error in postural tracking on a coordinate force platform The results on learning of postural balance indicated that the coordinate force platform, as equipped with yoked visual feedback, can provide a most effective technique in the training of different modes of postural tracking and coordination

The fact that the cochlear and vestibular system are closely interrelated as fluidic systems has led to assumptions and observations that sound stimulation may affect postural control. Ades (1953) found subjective postural effects from noise stimulation to one ear in deaf patients with partially intact vestibular systems. Fregley and Graybeil (1963), Harris (1968), Harris and von Gierke (1967), and Harris and Sommers (1968) have reported that asymmetrical noise and tone stimulation applied to the two ears can induce imbalance in postural control in rail-walking tests. Moore and Pezzoli (1966) have reported that they could condition postural sway to tones in normal *S*s.

The possibility of *E* suggestion in simple rail-walking and sway tests suggests that the claims for interaction between cochlear and vestibular stimulation should be tested under precise conditions in which *S* is required to perform well-controlled tracking performances which are not subject to direct suggestions as to how to perform. It is well known that body sway can be easily induced in blindfolded persons by suggestion and hypnosis. The question at issue is: Can asymmetrical or symmetrical tones and noises applied to the two ears affect posture under conditions in which the possibilities of suggestion have been minimized?

METHOD

The *S*'s task in this experiment consisted of controlling balance on a coordinate force platform (Smith & Henry, 1967) in relation to movement of a visual cursor that was controlled by the movements of the platform (see Figure 1) Right-left movements on the platform caused right-left motion of the visual cursor and front-back movements caused up-down movements of this cursor spot on a projection screen A second stationary target spot also was projected on the feedback display and *S* was instructed to keep his moving indicator on this center spot While attempting to control postural balance by centering the visual target on the feedback display, *Ss* were presented tones of different or equal intensity in the right and left ears The tones were transmitted to the ears by means of protected earphones which were connected with variable frequency generators During presentation of the tones, the accuracy of *Ss* in postural tracking was measured by means of a real-time hybrid computer system

The *S*'s postural behavior movements were transduced by the coordinate postural platform As just noted, this platform was designed to separately sense movements in the front-back and right-left axes of

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the body. The platform consists of two heavy steel plates arranged at right angles and fitted with strain-gauge sensors, which record changes in force as *S* moves in coordinate directions on the platform.

As indicated in Figure 1, *S* viewed a cursor spot projected on a translucent glass screen from an oscilloscope behind it. The stationary target dot and *S*'s cursor spot were obtained from a type 564 storage oscilloscope with a type 3A72 dual trace amplifier A visual record of *S*'s posture performance, the wave pattern and calibration blocks generated for the target dot by the computer, and *S*'s tracking error were recorded on a Beckman type R 8-channel oscillograph The computer used to generate the wave pattern of the target dot which *S* viewed was a 160 A Control Data computer equipped with analog-digital and digital-analog converters. The computer also measured the error between the generated wave pattern and *S*'s subsequent tracking movements, and stored these measurements according to a predetermined statistical format.

In the asymmetrical stimulation study, the sound stimuli for the separate ears were produced by two separate frequency generators, and after amplification were transmitted to separate earphones. The right ear received a sound of 75 db. while the left received a sound of 95 db. The auditory stimuli were a series of four tones at 260, 690, 1500, and 2500 Hz and a no-tone condition (i e., the sound present in the room). The intensity levels were controlled at the two wave generators and were maintained at the proper intensities to an accuracy of ±2 5 Hz

The *S*s were fully instructed regarding the procedure that the trial length would be 60 sec., that the calibration period would be repeated before each trial, and that they would be presented one of four

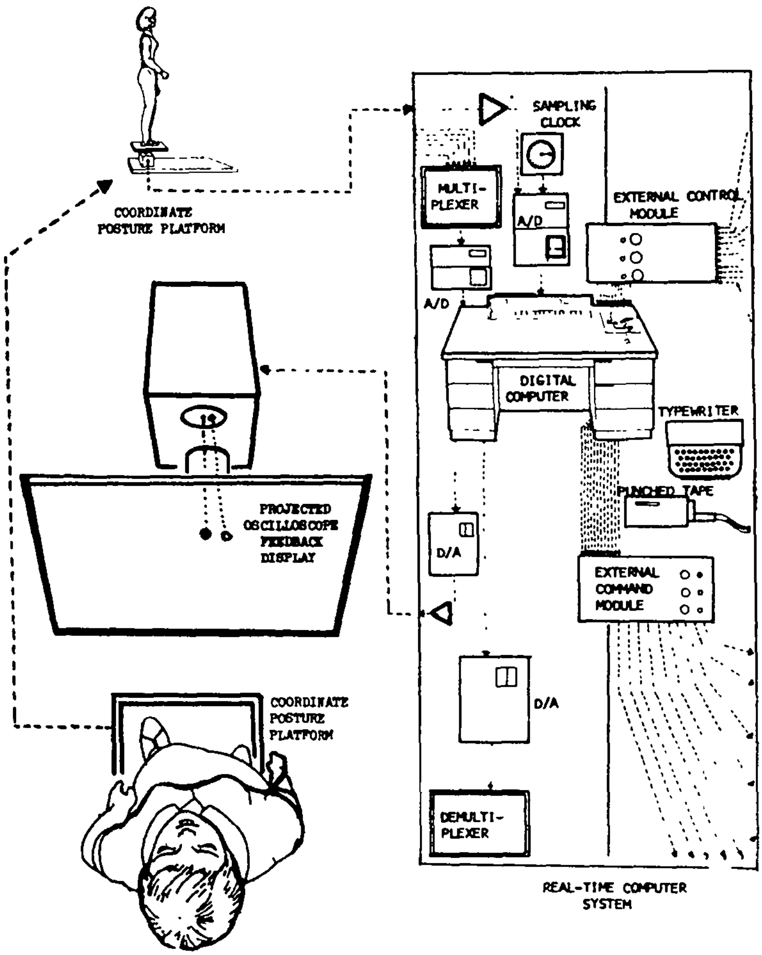

FIG 1. Diagram of the components of the coordinate postural platform, the feedback display, the hybrid computer system for controlling parts of the experiment, and the binaural auditory apparatus

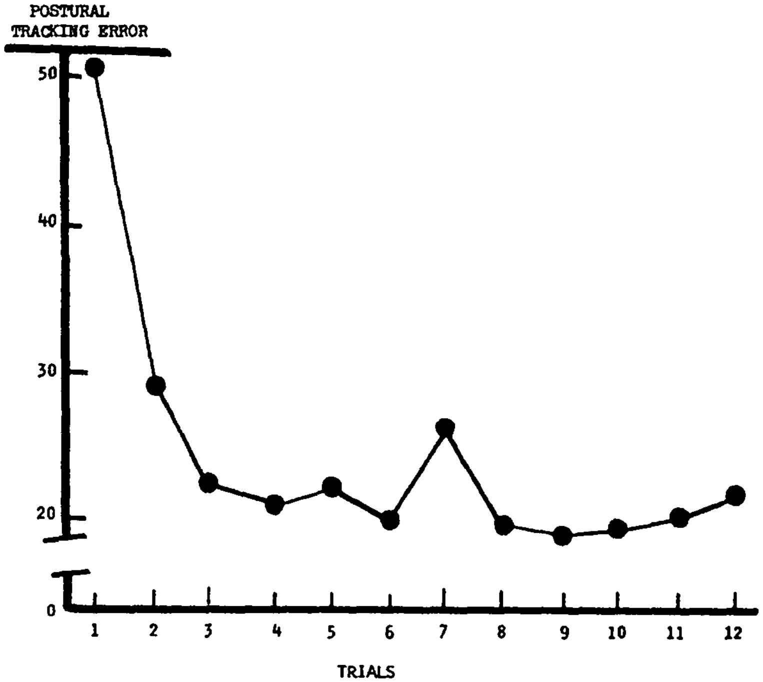

FIG 2 Learning curves over the 12 trials of tested performance in postural tracking.

tone conditions to each ear simultaneously but with two unequal intensity levels (75 db to the right ear and 95 db to the left ear) The performance instructions were to try to keep the feedback indicator dot directly beneath and in line vertically with the stationary target dot The four frequency conditions and the no-sound condition were presented randomly to Ss Presentation of experimental conditions also was counterbalanced to keep the effects of order of frequency conditions from influencing the error measures The computer controlled the length of the trial and other experimental factors and variables The E manipulated the two sound generators for the tone presentation in their predetermined randomized order for each S. The tones were always off during a calibration period preceding the trial Each S was given a test trial condition to familiarize him with the experimental set-up before he was actually tested The error in lateral movements of the force platform was recorded on an oscillograph and measured by the computer system.

Twelve Ss, 10 males and two females, from various backgrounds were obtained for the experiment They ranged in age from 21 to 29 yr None had a chronic history of dizziness, fainting spells, severe head injuries, serious foot or leg injuries, or recent illness of any type. They varied in weight from 105–210 lb. and in height from 5 ft 3 in to 6 ft 4 in All Ss had normal hearing The data of one S had to be discarded because of malfunctioning of the equipment

The experiment also tested the effects of binaurally symmetrical sound stimulation on postural tracking. The tones used in the study just described also were used for symmetrical stimulation of the two ears. The same methods of postural tracking also were used in this symmetrical study Twelve Ss were tested, with each S performing six 1-min test trials at each test tone Presentation of the four frequencies of tone were randomized by S

The procedure of adapting S to the situation consisted of an initial explanation of the apparatus and its use The S was told how the target cursor would appear on the screen as the computer calibrated the system and that he was to step off the force platform while the system was being calibrated At a signal ending the calibration he was supposed to step back on the force platform and control the movement of the visual cursor.

RESULTS

The results consist of measures of postural tracking error under the five main sound conditions of the experiment—that is, with the 260, 590, 1500, and 2500 Hz binaurally asymmetrical and symmetrical tones and with the no-tone condition For the five asymmetrical tone conditions, the mean postural tracking error varied between 21.9 (for the

TABLE 1

SUMMARY OF ANALYSIS OF VARIANCE ON THE EFFECT OF TONES PRESENTED AT ASYMMETRIC EXPOSURE TO THE VESTIBULAR SYSTEM AND ITS SUBSEQUENT EFFECT ON LATERAL BODY SWAY

Source	*SS*	*df*	*MS*	*F*
Ss (A)	44191 86060	10	4419 18606	
Frequency (B)	55 70606	4	13 92652	.01291
Period (C)	11800.59848	11	1072.78168	12 08646*
A × B	4602.09394	40	115 05235	1.38836
A × C	9763 48486	110	88 75895	1.07107
B × C	2962.62122	44	67.33230	.81251
A × B × C	36462.37878	440	82.86904	

* $p = .01$.

no-tone condition and the 1500 Hz tone) to 22.6 for the 260 and 2500 Hz tones. The error level for the 590 Hz tone was 22. The differences between these means, as indicated by an analysis of the sources of variance, were not statistically significant.

A definite learning effect occurred over trials in the asymmetrical stimulation experiment. The learning function is indicated in Figure 2. Since the order of conditions within trials was counterbalanced, this learning effect represented a general learning change in the situation which is not attributable to the sound stimuli used. The curve suggests that rapid learning occurred in postural tracking in normal *Ss*. Results of the three-way analysis of variance indicated that the variations in the means for trials of practice were statistically significant (see Table 1).

Individual differences among the 11 *Ss* showed no consistent evidence for a differentiative effect of the sound differences in postural tracking. Only one *S* (S_2) showed what might be considered a marked variation in response to the tones. In this case, the individual gave a high error level of 43.0 to the 260 Hz tone and error levels of about 30 to the 1500 and 2500 Hz tones.

The means for tracking error for the conditions of symmetrical stimulation also showed reliable differences did not occur between means. For the frequencies of 260, 590, 1500, and 2500 Hz, respectively, these means were 26.74, 26.02, 24.20, and 26.75. The mean for the control or no-tone condition was 25.97.

SUMMARY

Accuracy in postural control was measured under four conditions of binaurally asymmetrical and symmetrical tone conditions of 75 and 95 db. with frequencies of 260, 290, 1500, and 2500 Hz and under a no-tone condition. Contrary to previously reported findings, no evidence was found that the unequal and equal stimulation of the two ears affected error in postural tracking. A prior report that asymmetrical stimulation of the two ears with an intensity difference of 20 db. (95 versus 75 db. as used in this study) at a frequency of 1500 Hz (Harris & Sommers, 1968) was not substantiated. Neither the finding that binaurally symmetrical stimulation effects accuracy of postural control nor Ades' (1953) observation that a tone of 590 Hz could have a differentiative effect on posture and the vestibular system were substantiated.

The experiment needs to be extended to study binaurally asymmetrical stimulation of greater intensity differences than those thus far used, with frequency differences between the two ears and with differential interrupted sounds of low frequencies. That is to say, the experiment may in time provide a design for measuring the nature of the fluidic mechanical and neural interactions between the vestibular and auditory systems of the inner ear.

In the course of the experiment, data were obtained on the use of feedback methods to train balance control by postural tracking with the coordinate force platform. Data indicated that *Ss* learned the postural tracking quickly. These studies are to be extended to study the effects of tactual stimulation and electrical aural stimulation on learning postural balance.

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ERRATUM

In the article, "Comparison of Sources of Personal Satisfaction and of Work Motivation," by Paul F. Wernimont, Paul Toren, and Henry Kapell in the February 1970 issue, Figure 1 on page 99 should appear as follows:

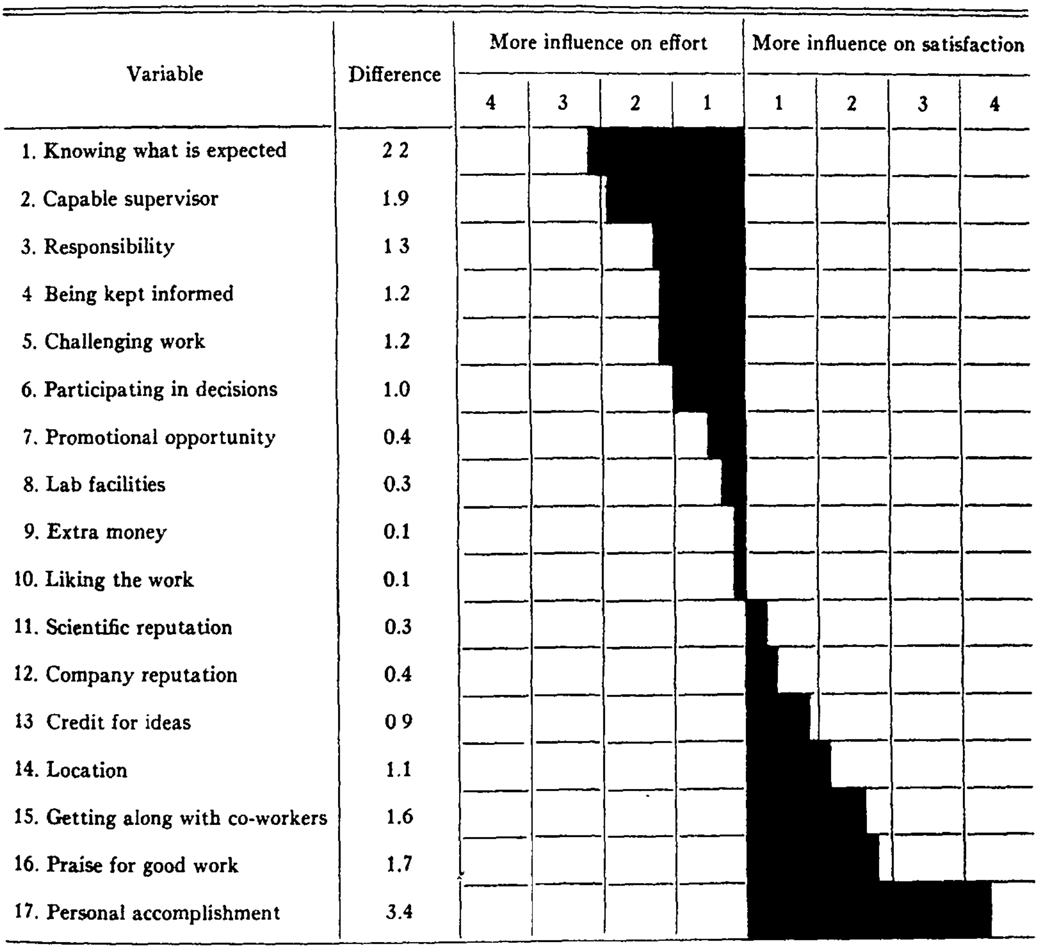

FIG. 1. Differences in median rank values, between "motivation" and "satisfaction" rankings, for total group.