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EFFECTS OF SEVERAL MENTAL TASKS ON AUDITORY FATIGUE[1]

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Eight male Ss were exposed for three minutes to a 4000 cps fatigue tone at 40 dB SL. Each S was tested under four task-conditions: mental arithmetic (MA), written long division (LD), threshold determination on a 500 cps tone (TD), and reverie (REV). Temporary threshold shifts (TTS) were computed by comparing pre- and post-fatigue thresholds. MA produced significantly more TTS than any other condition, and LD resulted in greater shifts than REV. Amount of auditory fatigue can vary with the type of mental activity performed by the S.

Recent studies have demonstrated differential effects of instructions regarding mental activity on responses to sensory stimulation. Thus, for example, the effectiveness of a vestibular stimulus in eliciting a nystagmic eye response is greater when subjects are engaged in solving mental arithmetic problems than when they are in "reverie" (Collins, 1962; 1963). Similarly, Wernick and Tobias (1963) found that the temporary threshold shift (TTS) resulting from both low-level and high-level auditory fatigue was increased when, during exposure to the fatiguing stimulus, subjects performed mental arithmetic tasks (silent, continuous division) as opposed to relaxing in reverie states.

Three subsequent reports (Ward & Sweet, 1963; Bell & Stern, 1964; Riach & Sheposh, 1964) failed to substantiate the Wernick and Tobias (1963) data. However, in the former two of these reports, different "mental tasks" were employed.

Since not all tasks appear equally potent in producing a given sensory effect (Collins, 1962; 1964), Capps and Collins (1965) replicated exactly the Wernick and Tobias (1963) procedure for low-level fatigue and confirmed the finding that the mental arithmetic (MA) task during the fatigue period resulted in statistically greater TTS than the reverie (REV) condition. The authors suggested that the task (addition of columns of figures) employed by Ward and Sweet (1963) and those (light tracking and pencil-and-paper long division) used by Bell and Stern (1964) might not have been equivalent to MA.

The Riach and Sheposh (1964) study was reported as a non-confirmatory replication of Wernick and Tobias (1963) conditions. However, Capps and Collins (1965) noted that the large TTS obtained by Riach and Sheposh for the REV condition under low-level fatigue (about 9 dB) was far out of the range of values (2.3 - 4.1 dB) reported by other investigators for the same condition (Wernick and Tobias, 1963; Bell and Stern, 1964; Capps and Collins, 1965).

The present study was designed: (1) to provide further evidence concerning the effects on TTS of mental arithmetic (MA) and reverie (REV) during periods of low-level auditory fatigue; (2) to compare with MA and REV the effect on TTS of a different "mental task" (written long division); and (3) to examine the influence on TTS of attending to other auditory stimuli during the fatigue period.

[1] Instrumentation assistance rendered by Peter Bergsneider is gratefully acknowledged.

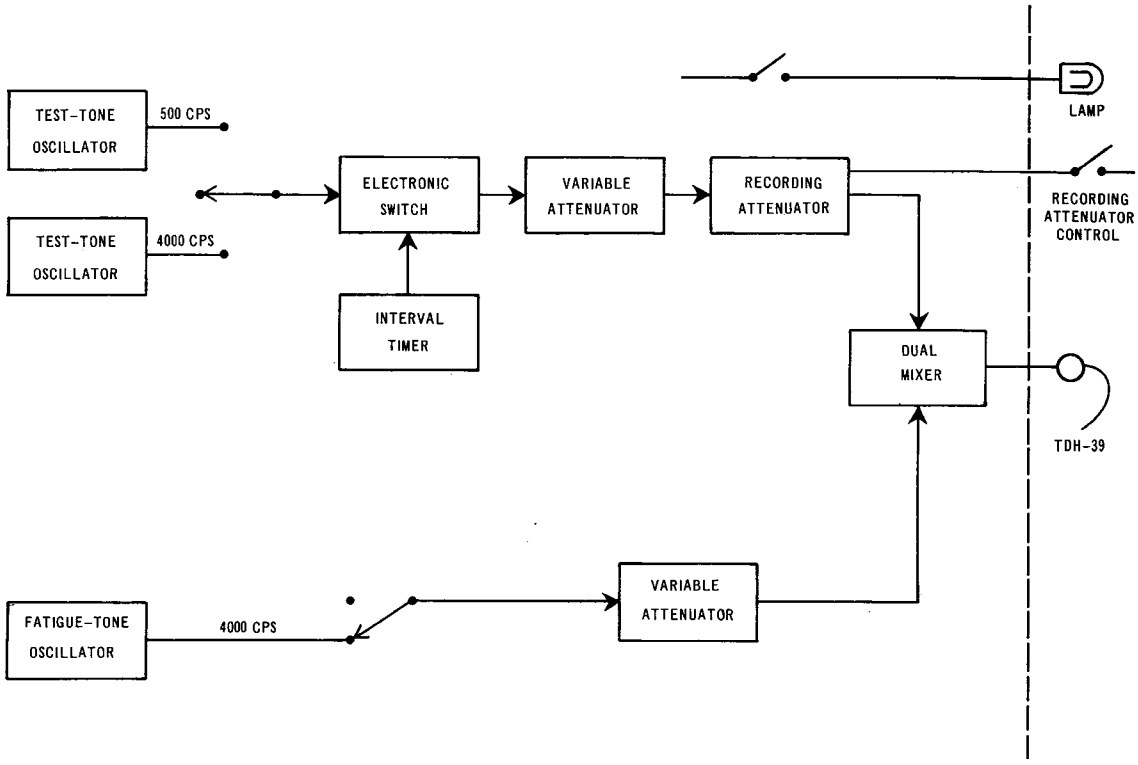

Figure 1. Block diagram of the apparatus.

APPARATUS

Figure 1 shows a block diagram of the instrumentation. The 4000 cps fatigue tone was generated by a Hewlett-Packard model 200 CD oscillator and led through a Hewlett-Packard model 350 B variable attenuator. The 4000 cps and 500 cps test tones were generated respectively, by Hewlett-Packard model 201 C and model 200 CD oscillators. Both test tones were led through a Grason-Stadler model 839S electronic switch, a Hewlett-Packard model 350 B variable attenuator, and a Grason-Stadler model E 326A recording attenuator (attenuation rate: 4 dB per sec). The fatigue channel and the test tone channel were mixed and sent to one Telephonics TDH-39 earphone with an MX-41/AR cushion (a dummy earphone and cushion occluded the opposite ear). The instrumentation allowed the experimenter to present: (1) fatigue tone alone; (2) fatigue tone and 500 cps test tone together; (3) 4000 cps test tone alone; or (4) no tone. The signal light in the subject room was also under the control of the experimenter.

SUBJECTS

The Ss were eight paid, experimentally naive, male volunteers ranging in age from 18-29 years. All had normal hearing.

PROCEDURE

All Ss were exposed to the fatiguing stimulus at 40 dB SL under each of the four following conditions: (1) continuous mental division (MA); (2) written long division (LD); (3) threshold determination on 500 cps pulsed tone (TD); (4) reverie (REV). Four combinations of the conditions were selected to obviate order effects and two subjects were tested under each combination. The conditions were separated by 60-75 min to assure complete recovery from the low-level fatigue tone. The four orders of presentation were: (1) MA, REV, LD, TD; (2) REV, LD, TD, MA; (3) LD, TD, MA, REV; and (4) TD, MA, REV, LD.

Several minutes of practice threshold determinations preceded the first condition for each S. After a brief rest period, instructions

for the test condition were given. Each condition then began with a two min threshold determination for the 4000 cps pulsed tone, and was followed by a three min period of silence and rest. At the end of the rest period, the fatigue tone and the light in the subject room were turned on; the S then performed as previously instructed until the light and tone were turned off. At this time, a three min post-fatigue threshold was taken on the 4000 cps pulsed test tone.

The following instructions were given for the four conditions:

(1) Mental arithmetic (MA) – "In a moment I'll ask you to take your threshold again and after a few minutes I'll tell you to stop. Then relax. After a while the light in your room will go on and you'll hear a tone in your earphones. When the light goes on turn this card over. There are two numbers on it. Divide the larger number by the smaller number. Take that answer and divide it by the smaller number from the card. Keep dividing your answers by the smaller number from the card, not writing anything down at all. Do it all in your head. In a few minutes the light in your room will go off again. The instant the light goes off, write down your last answer on the bottom of the card. Don't worry if it's a fraction or a decimal. Immediately start taking your threshold. Work as fast and as accurately as you can because your performance will be graded. If you get mixed up and forget an answer, you may start over again, but be sure to stop wherever you are when the light goes off, because the tone will start very quickly, and I want you to be ready for it. Remember . . . take your threshold . . . when the light goes on, you turn over the card and start dividing . . . and when the light goes out, you immediately write down your last answer and start taking your threshold. Do you have any questions?"

(2) Threshold determination (TD) – "In a moment I'll ask you to take your threshold again and after a few minutes I'll tell you to stop. Then relax. After a while the light in your room will go on and you'll hear two tones in your earphones. The higher tone will be continuous while the lower tone will be pulsed. When the light goes on, I want you to start taking a threshold on the lower, pulsed tone in the same way as you did before. Continue to take your threshold until the light goes off. When the light goes off the first pulsed tone will reappear and you will begin to take a threshold on it. Remember . . . take your threshold . . . when the light goes on take a threshold on the lower tone. When the light goes off start taking your threshold on the next pulsed tone. Do you have any questions?"

(3) Long Division (LD) – "In a moment I'll ask you to take your threshold again and after a few minutes I'll tell you to stop. Then relax. After a while the light in your room will go on and you'll hear a tone in your earphones. There are division problems on this paper. As soon as the light goes on, turn the paper over and begin to work the problems. All of the answers come out even. In a few minutes the light in your room will go off again. The instant the light goes off stop wherever you are and immediately start taking your threshold. Work on the problems as fast and as accurately as you can because your performance will be graded, but be sure to stop wherever you are when the light goes off, because the tone will start very quickly, and I want you to be ready for it. Remember . . . take your threshold . . . and when the light goes on, you turn over the paper and start dividing . . . and when the light goes off, you immediately start taking your threshold. Do you have any questions?"

(4) Reverie (REV) – "In a moment I'll ask you to take your threshold again, and after a few minutes I'll tell you to stop. Then relax. After a little while, the light in your room will go on and you'll hear a tone in your earphones. Just continue to relax and try not to follow any train of thought. In a few minutes the light will go off again. The instant the light goes off, start taking your threshold. Remember . . . take your threshold . . . when the light goes on, just relax completely and try not to follow any train of thought . . . and as soon as the light goes out, start taking your threshold. Do you have any questions?"

RESULTS

Means and standard deviations of the TTS data at the 10-second post-fatigue point are presented in Table 1. The greatest mean shift occurred for MA and the smallest for REV. For seven of the eight Ss the shift under MA was greater than that under any of the other conditions. The single exception was an equally great shift for both MA and LD.

A time-course comparison of recovery from auditory fatigue under the MA and REV conditions appears in Figure 2. In addition to greater initial TTS differences, the recovery time appears longer for MA than for REV.

Further comparisons are plotted in Figure 3. Again the MA data show greater evidences of fatigue and an apparently longer recovery time than do those of the LD and TD conditions. The latter two appear to differ little from the REV data with the exception of the 10-sec point.

Analysis of variance of the 10-sec TTS data indicated significant differences among the conditions ($F_{3,21} = 10.01$, $p < .001$). Orthogonal comparisons showed that the MA TTS scores were significantly higher than those of the other three conditions ($F_{1,21} = 25.09$, $p < .001$), that LD scores were significantly higher than those of REV ($F_{1,21} = 4.93$, $p < .05$), and that no statistically reliable difference occurred when TD scores were compared with those of LD and REV ($F_{1,21} = .005$, $p > .05$).

DISCUSSION

The striking differences between the TTS data for the MA and REV conditions clearly support the studies of Wernick and Tobias (1963) and Capps and Collins (1965). The data indicate that performance of mental arithmetic during a low-level auditory fatigue period results in statistically greater TTS and an apparently longer recovery time than does a state of reverie.

The data also point to differences among attention-demanding tasks in their contribution to auditory fatigue. Thus, the MA task resulted in greater TTS than did either LD or, perhaps most surprisingly, TD. In both cases, the difference persisted in favor of MA for 60 sec or more. The LD task produced statistically greater TTS than REV at the 10-sec point, but differences among those tasks became negligible within the next five sec.

The REV data obtained in this study lend further support to the proposed explanation (Capps & Collins, 1965) that the failure of Riach and Sheposh (1964) to obtain MA-REV differences in TTS was due primarily to an ineffective REV condition. Differences obtained with the three attention-demanding tasks used here also support the position that the tasks employed by Ward and Sweet (1963) and Bell and Stern (1964) may not have been so effective in producing whatever central changes occur as a result of MA.

TABLE 1

Temporary threshold shift (TTS) means and standard deviations for data obtained 10 seconds after exposure to a 4000 cps fatiguing tone. During the fatigue period, subjects were either in reverie (REV) or engaged in mental arithmetic (MA), long division (LD), or threshold determination (TD) tasks. (N = 8)

	TTS (dB)	
Task	M	SD
MA	9.6	5.0
LD	6.6	3.1
TD	5.4	1.7
REV	4.3	2.3

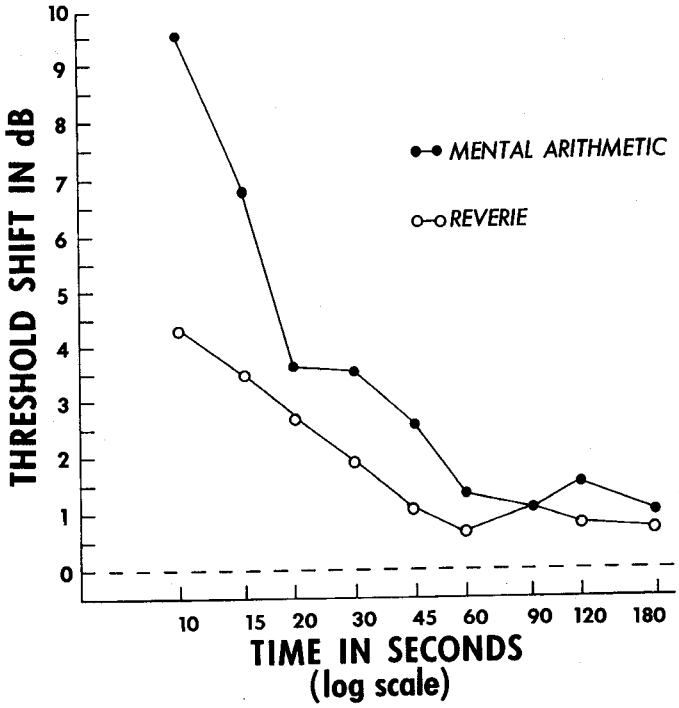

Figure 2. Recovery from auditory fatigue: comparison of mental arithmetic and reverie conditions. Each point is a mean for 8 Ss.

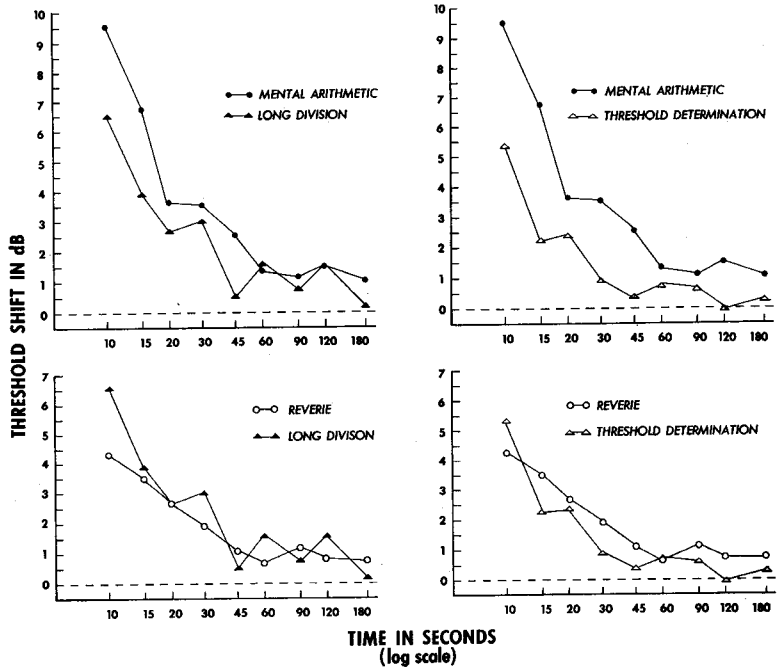

Figure 3. Time-course comparisons of the temporary threshold shifts to a 4000 cps fatiguing tone. Each point is a mean for 8 Ss.

The mean LD-REV data reported in this study are very similar to those noted by Bell and Stern (1964) for their first trials, although variability in the present study was less. That the LD-REV differences in the Bell and Stern (1964) study were not maintained with repeated exposure to the conditions might result from rapid habituation to the test and/or test situation. That such habituation can occur (although perhaps not so rapidly) has been noted elsewhere with regard to other phenomena (Collins, 1963, 1964; Galambos, 1956). In addition, Bell and Stern (1964) used female subjects and there is the possibility that a female's approach to a given type of mental task may differ from that of a male.

Two other points seem worthy of mention. If too much time (more than 10 sec) is allowed to elapse from the end of the fatigue period to the start of the post-exposure threshold determination, some tasks may show no difference in TTS from the REV condition. The LD task in the present study is a case in point. Second, it is of interest that the TD trials proved relatively ineffective in contributing to auditory fatigue. Although the TD task may simply not require the same central components or amount of attention as MA, there is a possibility that considerable selectivity may exist, such that attention to a tone of the same, or nearly the same, frequency may be required during the fatigue period if the tone is to exert an influence on TTS.

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