Effects of signal to noise variability over repeated sessions in an auditory vigilance task¹

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Subjects listened to a sequence of Gaussian noise pulses of 0.5-sec duration, occurring at 2.5-sec intervals. Performance was compared under two conditions: One group detected the occurrence of a 1.8-dB increment in noise pulses; a second group detected the occurrence of increments of 1.3, 1.8, or 2.3 dB. All Ss performed for three 90-min sessions on different days. The usual trends were noted for hits and false alarms. TSD indices, d' and β , were also derived. For both groups, it was found that d' increased slightly over sessions and decreased almost negligibly during sessions, and criterion indices, β , generally increased slightly both within and over sessions. Performance was generally comparable under the fixed- and mixed-signal conditions.

A number of variables related to signal occurrence have been identified as important for assessing performance in the vigilance situation—performance that typically requires the detection of randomly occurring events (signals) in a situation characterized by the monotonous occurrence of similar nonsignal events. Past research has concentrated on manipulating such variables as signal rate, event rate, nonsignal event regularity, the ratio of signal to nonsignal events—i.e., those variables that emphasize the temporal aspects of signal occurrence.

Few experiments, on the other hand, have investigated the effects of differences in signal intensity. Most vigilance experiments have employed signals of invariant signal intensity and invariant signal-to-noise ratio within sessions, although some (e.g., Binford & Loeb, 1963) have used different values in different sessions. The effect of employing several S/N levels was investigated by Gettys (1966) in a nonvigilance detection experiment; he reported that when information regarding signal amplitude was given, detectability was increased slightly, although criterion for response was not significantly changed. Recently, Hatfield and Loeb (1968) required Ss to monitor several intensity levels of auditory or visual stimuli for single sessions, and Ss performed essentially as they did with a single intermediate level.

Vigilance performance with mixed

signals is important if we want to extrapolate from the laboratory to practical situations, since signal intensity fluctuates against a background of irregular noise.

There are also theoretical reasons why one might expect different results with multiple-signal levels. First, any variation in the task might alter apparent learning effect in vigilance experiments where Ss must learn how nonsignals differ from signals. With a multiple-signal level, such learning might be difficult. The research to be described involved (a) the measurement of vigilance performance under conditions in which the intensity of the signal could not be identified with one particular value, and (b) the determination of effects of such conditions on dependent variables usually observed to change over repeated sessions.

METHOD

Subjects

Thirty-two college students served as Ss. The Ss were paid at the rate of \$1.50 per hour. An incentive of \$25.00 was offered for the "best" performance.

Experimental Conditions

Two groups of 16 Ss (8 males and 8 females in each group) were employed. The Ss of one group were required to detect signals (intensity increments) that occurred at a single level of intensity throughout a vigilance session. For Ss in a second group, the signal occurred at each of three levels of intensity increment during a session.

Schedule

Each S was employed for three sessions on separate days, each of which lasted for 90 min. Preceding the first session, threshold measurements for white-noise pulses were obtained (method of limits). Also, Ss were familiarized with the signal and nonsignal pulses and instructed in using the response key. A 15-min training session followed, during which all Ss were exposed to five signals at each of the three intensity levels employed for the three-level condition, with feedback provided regarding misses, hits, and false alarms.

Signal Parameters

During the three experimental sessions,

all Ss were exposed to a periodic sequence of pulses of Gaussian noise. The pulses had a duration of 0.5 sec and occurred at 2.5-sec intervals. Amplitude of the nonsignal pulses was 60 dB above threshold (SL), as determined from threshold measures mentioned above; amplitude of signal pulses was 61.8 dB (SL) for the single-level condition and 61.3, 61.8, or 62.3 dB (SL) for the three-level condition. Intervals between signal pulses were exponentially distributed, with the restriction that (a) the distribution had a mean of 1 min, and (b) the interval between signals was never less than 10 sec nor greater than 110 sec. The occurrence of signals was balanced in the three-level condition within consecutive 15-min blocks of time in each 90-min session so that five signals at each of the three levels of intensity were presented.

Apparatus

The Ss were run individually in an air-conditioned, sound-shielded room (IAC, Model 402A). Noise was generated by means of a Grason-Stadler Model 455C noise generator and fed through an attenuator network to a pair of Grason-Stadler Model HD30 earphones. A General Radio 1450HB decade attenuator was used to set the level of nonsignal pulses at 60 dB (SL), and a relay circuit shorted a 1.8-dB fixed attenuator to provide signals for one group of Ss; additional relay circuits shorted other fixed attenuators to provide signals of 61.3, 61.8, and 62.3 dB (SL) to the other group of Ss. Signals were programmed by means of a Gerbrands filmstrip programmer, holes punched in the film as specified by the distribution described above. S made his response by pressing a pushbutton switch on a table in front of him. The switch was connected to timing and counting circuitry in an adjacent room where an E monitored the programming and recording apparatus.

RESULTS

The data of the present experiment has been analyzed principally in terms of responses related to the signal increment (1.8 dB SL) employed for both groups. Since only one-third of the signals presented to the multiple intensity (MI) level group were of 1.8 dB, the percentages

Fig. 1. Changes in hits over sessions and over successive 15-min blocks for multiple- and single-intensity groups.

computed for this group are based on one-third as many data as those computed for the single-intensity (SI) level group. The percentages of hits for all signal levels in the MI group were essentially identical to those of the SI group.

An analysis of variance of hits (repeated measures on sessions and blocks of time; Winer, 1962, p. 319) indicates a significant sessions effect ($p < .05$) and a significant effect over blocks of time ($p < .01$). The main between-groups effect, multiple intensity vs single intensity, did not approach significance, although the means for the SI group were consistently above those of the MI groups. (With a larger number of Ss and similar variances,

differences between the SI group and the comparable level for the MI group would not be statistically significant.) None of the interactions approached significance.

The major trends in hits are graphically shown in Fig. 1 as a function of successive sessions and blocks of time within sessions. Although the mean percentage of hits in the SI condition is greater than for the comparable level (II-61.8 dB) in the MI condition, these means are considerably less separated than the different signal levels of the MI condition. (The differences between comparable levels in the two conditions are not statistically significant.)

Since false alarms cannot be associated with a given signal level for the MI group,

Fig. 2 plots percentages of FAs based on all data for the MI and SI groups. Figures 3 and 4 plot mean d' and $\log \beta$ s at comparable levels—middle intensity—for both groups on the assumption that FAs in the MI groups can be assigned to each signal level.

Figure 1 also shows the trend in hits as a function of blocks of time within sessions. Apparently, the significant variance attributable to blocks (noted above) reflects a decreasing trend for detections. An analysis by orthogonal polynomials indicates that the linear component accounts for 95% of the blocks sum of squares and is significant ($p < .01$), while no other component is significant. Since the interaction of MI vs SI with Blocks was insignificant, it can be concluded that the trends are the same for both groups.

An analysis of variance (Winer, 1962, p. 319) of false alarms was computed, and results resembling those obtained with the analysis of hits were obtained. The sessions effect and blocks effect were highly significant ($p < .01$). The between-groups variable (multiple level vs single level) only approached significance at the 10% level. There was a significant Blocks by Sessions interaction ($p < .01$).

Figure 2 shows that the number of FA over sessions decreases in later sessions. The linear component accounts for 95.2% of this trend, and the trend is the same for both the MI and the SI groups.

Figure 2 also shows that the significant variation in FA over blocks is a matter of a decreasing trend. The trend is largely accounted for by linear component (76.7% of the SS_C), but there is also a significant quadratic component ($p < .05$). The nature of the significant interaction of Sessions and Blocks is not apparent from the figures, but examination of the data suggests that it is due to a lessened tendency for FA to decrease over blocks in the final session.

Sensitivity indices, d' , and criterion indices, β (Tanner et al, 1961), based on the proportion of hits and false alarms for each S for each block of time, were determined using the Freeman tables (Freeman, 1964). The d' data were analyzed, and trends in d' over sessions and blocks are plotted in Fig. 3. The only clearly significant effect is that of sessions ($.01 < p < .05$). The effect is largely a matter of an increase in d' over sessions, an appearance supported by analysis of variance by orthogonal polynomials that indicates that 51.6% of the sessions sum of squares is accounted for by a significant linear trend ($.01 < p < .05$).

The trends in d' over blocks of time indicate a tendency to decrease. It is noted that sum of squares for blocks was not significant, and only about 15.5% of the SS

Fig. 2. Changes in false alarms over sessions and over successive 15-min blocks for multiple-intensity and single-intensity groups.

Fig. 3. Changes in d' over sessions and over successive 15-min blocks for multiple-intensity and single-intensity groups.

for blocks can be accounted for by a linear component.

Criterion measures, β , were highly skewed, and they were normalized by a logarithmic transformation before analysis. Mean $\log \beta$ s for sessions and blocks, respectively, are given in Fig. 4. Both sessions and blocks proved to be significant sources of variation ($p < .01$). Although the MI group had uniformly higher mean criteria (larger mean $\log \beta$ s), the main effect MI vs SI is not significant. There was also a significant interaction of Groups (MI vs SI), Sessions, and Blocks ($p < .01$).

The significant sessions effect is largely a matter of an increasing trend in β , with most of the trend occurring between the first and second session. In support of this conclusion, the mean for Session 1 differs from the means of Sessions 2 and 3, taken jointly, at the $.01 < p < .05$ level, and the difference between the means for Sessions 2 and 3 is negligible and nonsignificant.

The significant blocks effect is a matter of an increasing trend in β , the increase occurring largely between the first and second blocks. There are significant linear and quadratic components ($p < .05$).

The significant three-way interaction noted above is apparently due to a difference in trend over blocks for the two groups in the third session. For the MI group, there is a small increase in $\log \beta$ in Session 3, but for the SI group, β actually decreases somewhat. (This is not apparent in the figures, as drawn.)

DISCUSSION

The temporal trends observed in this experiment generally resemble those previously found (e.g., Loeb & Binford, 1968). The principal finding in this experiment would appear to be that, within the range of stimulus parameters employed, comparable indices of performance are obtained under single-intensity and multiple-intensity conditions.

There was, as noted, a differential trend in $\log \beta$ for the two groups in the third session, perhaps indicative of a faster stabilization in criterion for the SI group. It will be noted that while the mean hit rate was nonsignificantly, but consistently, higher under the SI condition, β , the criterion, was nonsignificantly, but consistently, lower; thus, comparable d'

Fig. 4. Changes in $\log \beta$ over sessions and over successive 15-min blocks for multiple-intensity and single-intensity groups.

values resulted, despite the differential H obtained under the two conditions. Also, the data show learning effects under the MI condition as strong as those shown by Ss in the SI condition—hits increase from the second to the third session for both groups and each shows a concomitant increase in d' . Although any generalizations are limited by the use of only three sessions in the present study, it appears that an inability to identify a signal level with one particular value does not hinder learning about the signals' stimulus characteristics. Trends within sessions were generally comparable as well.

In spite of the similarities between the groups observed in the present experiment, it would appear desirable to run further experiments in which a wider range of signal levels or a nonsymmetrical distribution of signal levels is employed. It seems possible that with a monitoring task involving a number of highly discriminable signals and other signals discriminable from noise only with great difficulty, and with an S not informed regarding the range of signal strengths, the S might never realize that the weak signals were present and so would never detect them.

REFERENCES

- BINFORD, J. R., & LOEB, M. Some factors influencing the effective auditory intensive difference limen. *Journal of the Acoustical Society of America*, 1963, 35, 884-891.
- FREEMAN, P. R. Table of d' and β . Applied Psychology Unit, Cambridge, England, Report 529/64, 1964.
- GETTYS, C. F. McK. The theory of signal detectability extended to the case of amplitude known statistically. Unpublished doctoral dissertation, University of Louisville, 1966.
- HATFIELD, J. L., & LOEB, M. Sense mode and coupling in a vigilance task. *Perception & Psychophysics*, 1968, 4, 29-36.
- LOEB, M., & BINFORD, J. R. Variation in performance on auditory and visual monitoring tasks as a function of signal and stimulus frequencies. *Perception & Psychophysics*, 1968, 4, 361-367.
- TANNER, W. P., SWETS, J. A., & BIRDSALL, T. G. Decision processes in perception. *Psychological Review*, 1961, 68, 301-340.
- WINER, B. J. *Statistical principles in experimental design*. New York: McGraw-Hill, 1962.

NOTES

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