# RECOVERY OF MOTOR PERFORMANCE FOLLOWING STARTLE

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## I. Introduction.

Sudden, high-intensity sounds, such as those produced by sonic booms, can be quite startling. In view of the increasing interest in possible detrimental effects of sonic booms, it would appear important to consider what is presently known concerning the general effects of startle on behavior. Although there have been numerous studies of autonomic or electromyographic response to startle,[1 2 4 9 14 16] as well as the well-known work of Landis and Hunt[8] on the muscular reflex to startle, relatively few studies have been concerned with the effects of startle on performance. Thus, while it is generally believed that startle has a disruptive effect upon performance, little data are available concerning the actual extent of disruption resulting from startle, the rate of recovery, or the characteristics of subjects (*S*s) who differ in their susceptibility to startle.

Woodhead[20 21] employed sudden bursts of broad-band sound (100 – 110 db) and studied the effects of such stimuli on a decision task in which moving symbols were matched against stationary ones. Performance was found to be significantly impaired following stimulation, but recovered to pre-stimulus levels within 17 to 31 seconds. Woodhead, however, was more concerned with the use of sudden, intense noise as a "distractor" and attempted to reduce the startle qualities of the stimuli through pre-experimental adaptation. Consequently there is some question as to whether these recovery rates would apply to completely unexpected, startling sounds.

Several other studies have examined the speed with which individuals can react to startle, with particular emphasis on identifying possible differences between fast and slow reactors. Sternbach[17] used a pistol shot and identified a group of slow reactors (mean response time of 1,695 msecs.) and a group of fast reactors (mean response time of 200 msecs.). The slow reactors were found to be significantly more responsive to the startle stimulus on a number of autonomic variables. While the study was not specifically concerned with determining the over-all mean response time to startle, it was estimated from the data given to be approximately 950 msecs. Thackray[18] obtained a mean response time of 893 msecs. to a 120 db auditory stimulus on its initial presentation, and also obtained evidence to support Sternbach's finding of a relationship between reaction time to startle and autonomic response. In addition, Thackray found that startle tended to exaggerate the differences which exist between individuals in their "normal" speed of response, such that *S*s classified as slow reactors under nonstartle conditions tended to respond more slowly to startle stimuli, while fast reactors responded more rapidly. This latter finding, however, was significant only for the second of the two startle stimuli employed.

The present study was designed to provide additional data on the extent and duration of performance disruption following startle, as well as to examine further the physiological and behavioral correlates of *S*s who differ in the extent of disruption. A tracking task requiring continuous perceptual-motor coordination was chosen as the principal or primary task. Reaction times to both startle and nonstartle auditory stimuli were also obtained as a secondary task. This latter task was included for purposes of comparison with the previous studies of Sternbach[17] and Thackray[18] and to determine the relationship, if any, between reaction time to startle and performance impairment on the tracking task. The startle stimulus was presented twice with sufficient time between presentations to minimize adaptation effects. A final aspect of the study was the examination of possible relationships between the recovery rate of perceptual-motor performance following startle and the rate of autonomic recovery.

## II. Method.

*Subjects.* Thirty paid male college students between the ages of 18 and 25 were employed. All were right-handed, had no known hearing loss, and had no prior experience with tracking tasks.

*Apparatus.* The basic task apparatus consisted of a console containing an oscilloscope which constituted the display for a two-dimensional compensatory tracking task. The spot on the oscilloscope was driven in a random manner by means of a cam-function generator which constantly varied the voltages to the horizontal and vertical deflection plates of the oscilloscope. The *S*'s task was to attempt to keep the spot continuously at the center of the oscilloscope by means of a small control stick located at his right hand. Minimal muscular effort was required to move the stick, and an excursion of approximately 1 inch in any direction from center was sufficient to move the spot to the edge of the scope. Voltages defining the position of the target on the oscilloscope (i.e., the algebraic sum of the function generator and control stick voltages) were fed to a PACE TR–20 analog computer and the output voltages (absolute horizontal and vertical error) were separately integrated by Beckman Type 9873B resetting integrator couplers. The entire tracking task was essentially a slightly modified version of one previously described by Pearson.[11]

High-intensity noise served as the startle stimulus and was produced by amplifying the output of a Grason-Stadler, Model 455B noise generator. Stimuli for measures of "nonstartle" reaction time were produced by a General Radio, Model 1310 oscillator. All auditory stimuli were presented through Sony Model DR–3A headphones which had been previously calibrated using an artificial ear. Stimulus levels were periodically monitored by means of a Ballantine Labs, Model 300–E voltmeter. Duration of all stimuli was 1½ seconds, and a Friden Model SP–2 tape reader was used for stimulus sequencing. Each stimulus activated a Hunter Klockounter which was stopped when *S* pressed a button located on top of the control stick.

A Beckman Type R Dynograph recorded the physiological variables as well as the integrated tracking error. Beckman biopotential electrodes were attached to the lateral walls of the *S*'s chest and the leads connected to a Beckman Type 9857 cardiotachometer coupler. Skin resistance was obtained from two Fels zinc-zinc sulphate electrodes leading to a Fels Model 22A Dermohmmeter. One electrode was attached to the palmar surface of the left hand and the other to the ventral surface of the left wrist. Current density was 22.3 microamps/cm.$^2$. The output of the Dermohmmeter led to another channel of the recorder. Beckman miniature biopotential electrodes were attached immediately above and below the right eye and direct coupled to the recorder. This yielded a gross indication of eye closure as well as blinks. The electroencephalogram was obtained from bipolar placements on the left occipital and left midcentral regions. Standard Grass electrodes with Grass electrode cream were employed.

All equipment, with the exception of that equipment used by *S* in actually performing the tasks, was located outside the *S*'s room. Figure 1 shows a *S* instrumented for physiological recording and performing the tracking task.

*Procedure.* Upon arrival each *S* received an audiometric examination, was given a general description of the tasks he was to perform, and was told that the purpose of the experiment was to investigate physiological changes during the learning and performance of perceptual-motor tasks. The various electrodes were attached and *S* was given detailed instructions concerning the tasks. He was told that the first or training phase would consist of a series of 2-minute trials with a 35-second rest period between each. His principal task was to try to keep the moving spot on the oscilloscope as close to center as possible during the trials. He was further told that while tracking he would occasionally hear a tone through his headphones, and that he should respond to each tone by pressing the button located on top of the control stick. He was informed that a small red warning light would come on 5 seconds prior to the beginning of each trial. The *S* then rested quietly for approximately 8 minutes while the physiological equipment was adjusted and recordings made of "eyes open" and "eyes closed" electroencephalographic activity.

Fifteen 1,000 Hz, 75 db reaction time stimuli were presented during the 15–trail training period. Although the temporal position of each of these stimuli within trials was randomly de-

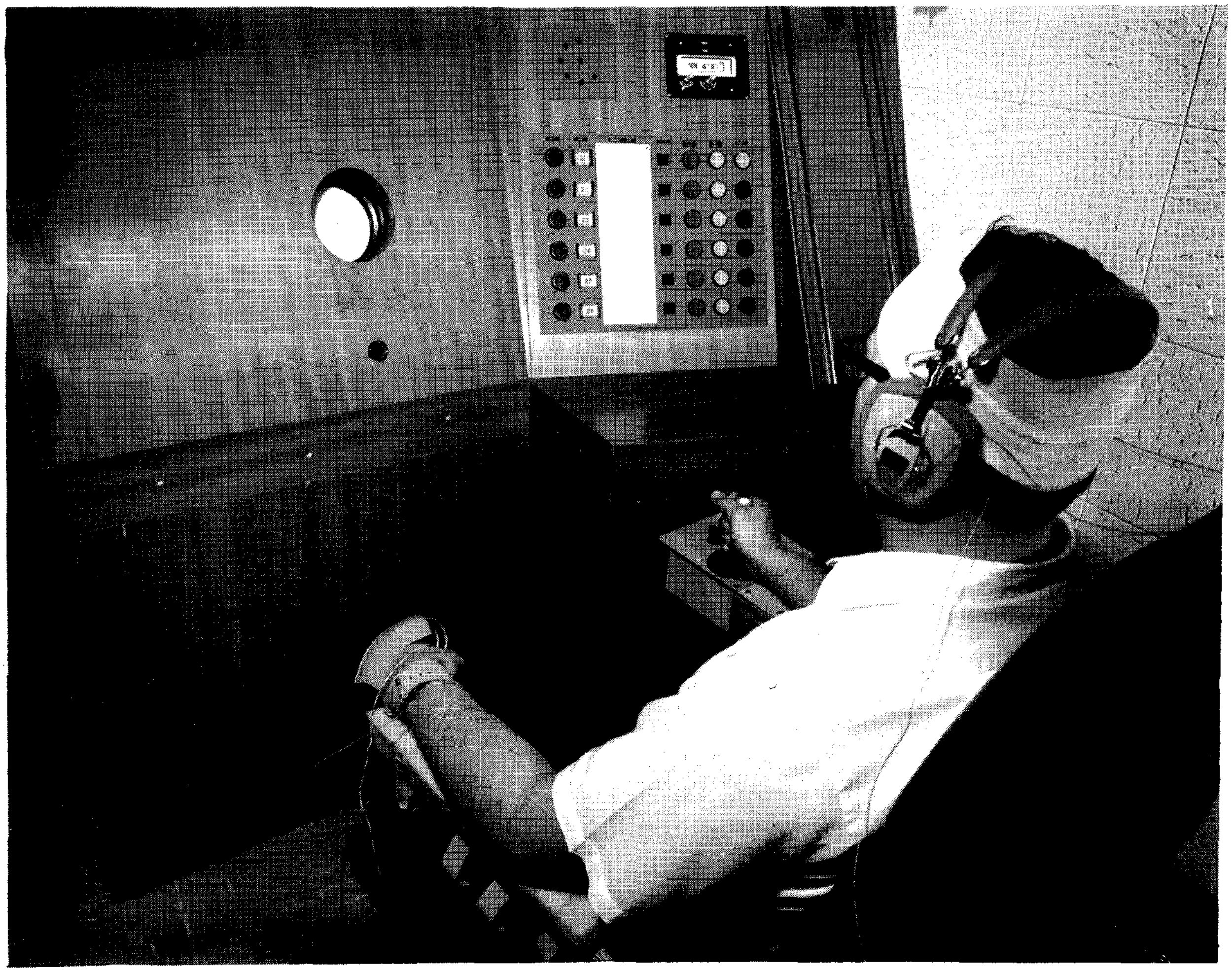

FIGURE 1. Subject instrumented for physiological recording and performing tasks. The displays to the right on the console were not used in this experiment.

termined, all *S*s received them in the same positions.

Following completion of training, *S* was allowed a 10-minute rest period. He was then informed that the next or test phase of the experiment would be similar to the training phase just completed, except that he would have to perform both tasks without rest periods for 35 to 40 minutes. He was also told to respond to all auditory stimuli presented through the headphones and that not all stimuli would be the same. (No indication was given that any of the stimuli would be loud or startling.) It was emphasized that *S* should try to maintain tracking at all times even when making the button response to auditory stimuli. The test phase actually lasted only 30 minutes. Two minutes after the phase began, the first 115 db startle stimulus was presented. The same stimulus was again presented 15 minutes later. (These two high-intensity, "startle" stimuli will be subsequently referred to as $S_1$ and $S_2$, respectively.) Fifteen of the 1,000 Hz, 75 db stimuli were again presented at random intervals during this phase, although as with the training phase, all *S*s received them in the same temporal position. None of the 75 db stimuli was presented during the 90-second periods immediately prior to or following $S_1$ or $S_2$. Upon completion of this phase *S*s were administered a post-experiment questionnaire. Audiograms were also taken at this time to insure that no hearing loss had occurred.

*Scoring of the test and training phase data.* Although the tracking task was essentially continuous in terms of the stimulus and response, the measure of performance (integrator resets) was a discrete measure. In order to plot the recovery of tracking proficiency following startle, the number of integrator resets had to be obtained for successive periods of time. From some initial pilot data, it appeared that a 1-minute period following startle would be adequate in terms of encompassing the duration of performance disruption. The same pilot data also suggested that 5-second scoring intervals would be reasonable for plotting the recovery of tracking as well as the physiological data. Consequently, the 1-minute periods following $S_1$ and $S_2$ were each divided into twelve 5-second intervals. The number of resets in each interval of the horizontal and vertical integrators was then determined for each *S*. Skin resistance was measured at the end of each interval and the values converted to conductance. In addition, the minimum resistance occurring within the 10-second period following startle was also obtained for each *S* and converted to conductance. This latter measure constituted a more precise determination of the magnitude of conductance change to startle and was used for purposes of inter-individual comparison. To determine the course of heart rate recovery following stimulation, the maximum heart rate (single fastest beat as measured from the cardiotachometer recording) was obtained within each interval.

The mean number of horizontal and vertical integrator resets per 5-second interval was obtained for the 2-minute period immediately preceding each startle stimulus. This was done for the purpose of obtaining a stable estimate of pre-startle tracking performance against which to compare the change following stimulation. For heart rate, the maximum rate was obtained for the 5-second interval immediately preceding $S_1$ and $S_2$. Skin resistance was measured at the moment of stimulation and converted to conductance.

For the training period, only the performance data were scored. In order to make the tracking data comparable to the test phase data, the number of horizontal and vertical resets obtained during each 2-minute trial was expressed in terms of means per 5-second interval. Each *S*'s distribution of reaction times to the 15 presentations of the 1,000 Hz stimulus was obtained and a median computed. Since no warning signal was employed with the reaction time stimuli, the individual distributions were often quite skewed, and thus the median yielded a better measure of central tendency than the mean. Medians were also used for the reaction time data of the test phase.

The electroencephalographic and eye closure recordings were used only to monitor possible changes in levels of wakefulness during the 30-minute test period. No detailed analyses were made of these data.

## III. Results.

*Training data.* In plotting the data for the horizontal and vertical tracking error during training, it was found that the two curves essentially paralleled each other and were highly correlated across trials ($r=.93$; $p<.01$). Consequently, there appeared little to be gained by considering them separately, and they were combined in both the training and subsequent test phase of the experiment.

The combined error data over the 15 training trials are shown in Figure 2. The scores are plotted in three-trial blocks with each block representing the mean number of integrator resets per 5-second interval. It is apparent from the figure that an asymptotic level of performance was reached at or before the end of training.

For the reaction time data, each *S*'s median response time to the 15 stimuli was obtained and these values averaged across *S*s. This yielded a mean value of 516 msecs.

*Response to startle.* Figure 3 displays mean number of integrator resets for the tracking data during successive 5-second intervals of the first minute following $S_1$. Also displayed are mean maximum heart rate and mean conductance level for each 5-second interval. In addition, mean pre-stimulus values are given for each variable. Relative to the pre-stimulus level, tracking error increased by 65 percent during the first 5-second interval. This declined to a 16 percent increase by the second interval. Both increases were significant with *t*-values of 5.35 ($p<.01$) and 3.34 ($p<.01$) respectively. Error continued to decline up to the fourth interval, with an apparent rise in tracking error beginning at the fifth interval and then a fall below the pre-stimulus level by the seventh and for most of the remainder of the minute. Of intervals three through

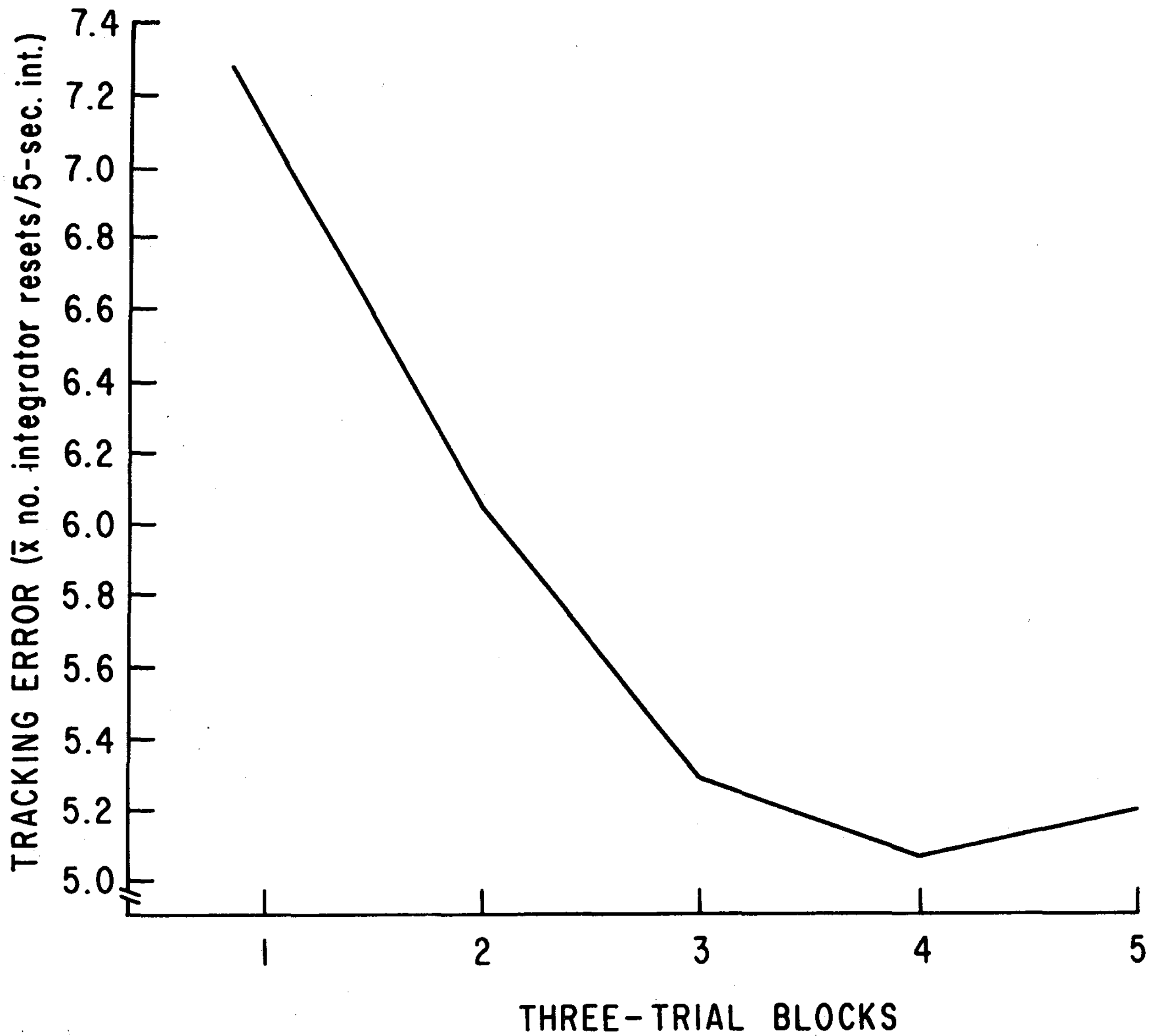


FIGURE 2. Mean tracking error during the 15-trial training period.

12, only the eighth ($t=3.43$; $p<.01$) was significantly different from the pre-stimulus level.

Maximum heart rate in beats per minute (b.p.m.) increased significantly from a pre-stimulus value of 80.2 to 95.7 ($t=7.57$; $p<.01$) during the first interval, declined below the pre-stimulus value during the third and fourth intervals, rose to about the pre-stimulus level during the fifth, sixth, and seventh intervals, and then steadily declined during the remainder of the minute. With the exception of the first interval, only intervals 11 and 12 differed significantly ($p<.05$) from the pre-stimulus value, although the $t$-values for intervals three (1.68) and four (1.81) approached significance ($p<.10$).

Conductance level increased to a maximum during the first interval and then began a generally consistent decline throughout the remainder of the minute. Comparisons of each interval with the value at the time of stimulation yielded $t$-values which were significant ($p<.05$) for all intervals.

Of the two physiological measures, heart rate was the only one which revealed any possible covariation with the curve of performance recovery. This appeared to extend up to at least the sixth interval. Beyond this the fluctuations in tracking performance were not generally paralleled by any corresponding heart rate changes. Because of the apparent relationship

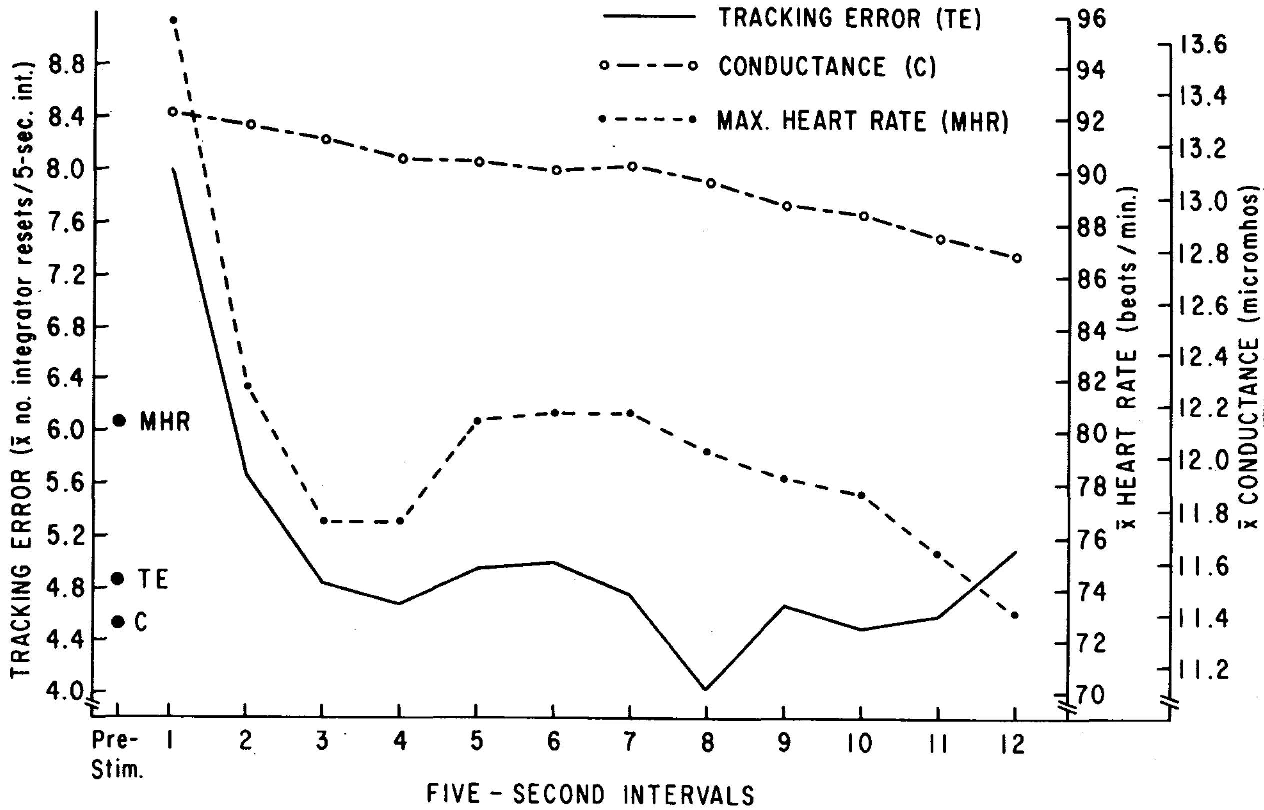


FIGURE 3. Mean tracking error, maximum heart rate, and conductance level during successive 5-second intervals following $S_1$. Also shown are pre-startle values for each variable.

between the initial heart rate and performance changes, the rise in tracking error (interval four to interval six) was compared with the heart rate increase during these same intervals. However, neither the error increase ($t=1.01$; $p>.05$) nor the heart rate increase ($t=1.81$; $p>.05$) was significant.

Figure 4 displays the same variables shown in Figure 2 except that the data are those for $S_2$. Tracking error during the first 5-second interval increased by only 29 percent over the pre-stimulus level. This increase, however, was significant ($t=2.67$; $p<.05$). By the second interval, error had decreased below the pre-stimulus level and remained below during the rest of the 1-minute period. Comparisons of each interval with the pre-stimulus value yielded $t$-values which were significant ($p<.05$) for intervals three, five, six, seven, eight, and 11.

Maximum heart rate increased significantly from a pre-stimulus level of 80.8 b.p.m. to 93.6 b.p.m. during the first interval following startle ($t=7.65$; $p<.01$). It then followed a recovery pattern similar to that obtained for $S_1$. Of intervals two through 12, however, only the third interval was significantly different from the pre-stimulus value ($t=2.63$; $p<.05$).

Conductance level also showed a pattern which approximated that obtained for the earlier startle stimulus, and $t$-tests revealed all intervals to differ significantly ($p<.01$) from the level at the time of stimulation.

Once again, it is interesting to note the apparent relationship between heart rate and tracking error immediately following stimulation. After the initial decline, however, the secondary increase in both heart rate and tracking error occurred 5 seconds earlier than the corresponding rise which appeared to follow $S_1$. A comparison of the heart rate increase between intervals three and four yielded a significant $t$-value ($t=2.90$; $p<.01$), but the increase in tracking error which occurred during these intervals was not significant ($t=1.77$; $p>.05$).

While the immediate effect of startle on tracking was a temporary impairment, startle appeared

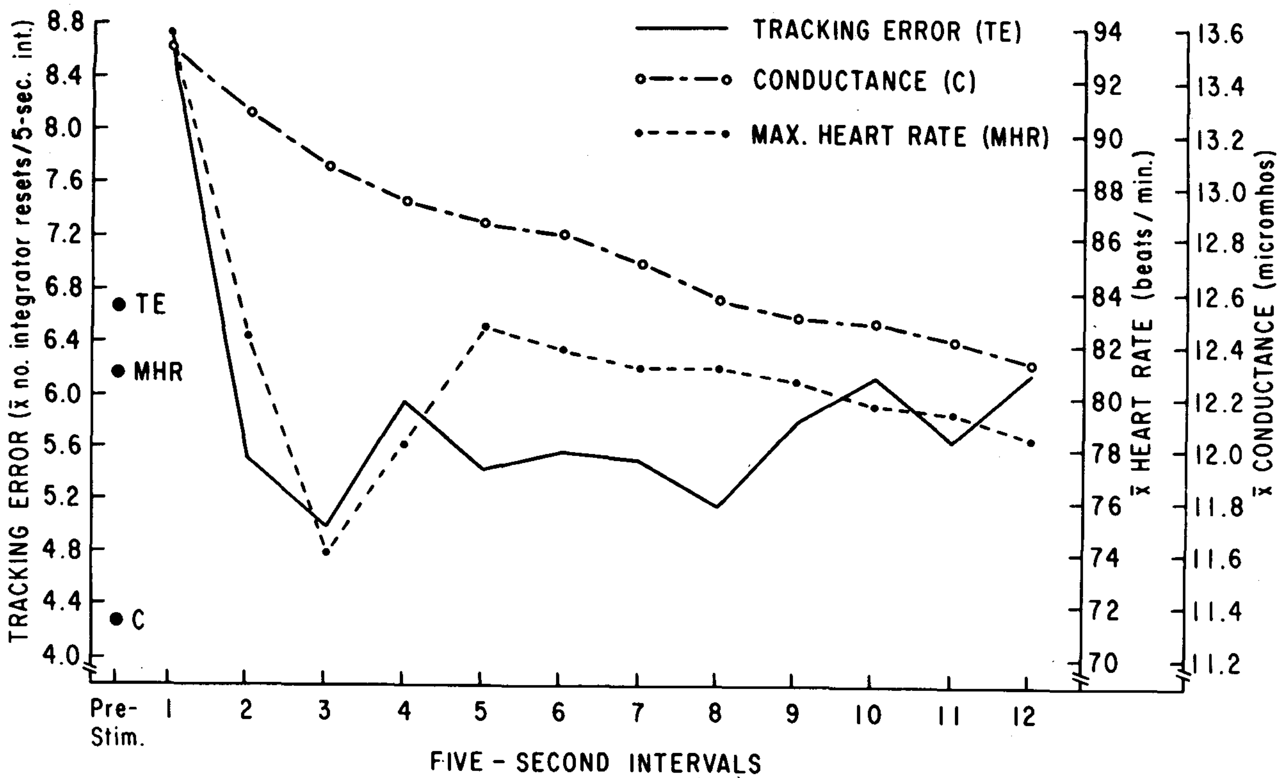


FIGURE 4. Mean tracking error, maximum heart rate, and conductance level during successive 5-second intervals following $S_2$. Also shown are pre-startle values for each variable.

to have a facilitative effect on reaction time. Thus, mean reaction times to $S_1$ and $S_2$ were 402 msecs. and 401 msecs., respectively, while the mean of each *S*'s median reaction time to the 15 nonstartle tones was 462 msecs. Separate comparisons of this latter value with mean reaction times to the two startle stimuli yielded $t$-values of 3.39 ($p<.01$) for $S_1$ and 4.75 ($p<.01$) for $S_2$. The correlations of nonstartle reaction time with response time to $S_1$ and $S_2$ were 0.33 ($p>.05$) and 0.54 ($p<.01$) respectively. There was no evidence of any relationship between either the nonstartle or startle reaction time measures and tracking performance as measured either prior to $S_1$ or $S_2$ or during the first 5-second interval following startle. The obtained product-moment correlations ranged from 0.00 to 0.14.

Although it was not intended to investigate adaptation effects to startle, and the startle stimuli were presented only twice with 15 minutes between presentations to deliberately minimize any possible adaptation, a comparison of Figures 3 and 4 might suggest that the second startle stimulus was somewhat less disruptive in its effects on tracking behavior than the first. Thus, relative to the pre-stimulus levels, tracking error rose only 29 percent during the initial 5-second interval following $S_2$, but increased 65 percent during the same interval following $S_1$. Further, tracking error following $S_2$ was found to be significantly less than the pre-stimulus level for most of the remaining minute; this was not the case with $S_1$. These differences between $S_1$ and $S_2$, however, appeared to be due primarily to differences in the level of pre-stimulus tracking error. A comparison of the mean levels revealed the level prior to $S_2$ to be significantly greater than the level prior to $S_1$ ($t$=4.71; $p<.01$). This increase is interesting in view of the fact that there were no significant differences between the pre-stimulus levels for maximum heart rate ($t$=0.29; $p>.05$) or conductance ($t$=0.12; $p>.05$) which might have indicated a declining arousal level. Because of the difference in pre-stimulus tracking performance, it was difficult to compare the two startle stimuli in terms of either their immediate effects on performance or possible differences in the recovery patterns. There were several indications, however, which would suggest that $S_1$ and $S_2$ did not differ appreciably in their immediate startle effect. For example, a comparison of the absolute level of tracking error (integrator resets) during the initial 5-second interval following $S_1$ with absolute level of error during the same interval following $S_2$ yielded no evidence of a difference ($t=0.77$; $p>.05$), nor, as indicated earlier, was there any apparent difference between reaction times to $S_1$ and $S_2$. Also, neither the maximum heart rates during the first 5-second interval nor the maximum conductance levels following startle were different for $S_1$ and $S_2$. The obtained $t$-values were 1.49 ($p>.05$) and 0.76 ($p>.05$) for heart rate and conductance level respectively. It should be noted, though, that while there was little evidence from the physiological or performance data to suggest any substantial difference between the startle stimuli, there did appear to be a subjective difference between them. A five-point rating scale with endpoints consisting of "not startled at all" (scale value of 5) to "extremely startled" (scale value of 1) was administered following the experiment. The mean rating for $S_1$ was 4.5 and for $S_2$ 3.6. A sign test[15] indicated this difference to be significant ($p<.001$).

*Individual differences.* To enable comparison of the characteristics of those *S*s whose tracking performance was poorest following startle with those whose performance was best, the distributions of absolute error scores (integrator resets) were obtained for the first 5-second interval following $S_1$ and $S_2$. A correlation of 0.60 ($p<.01$) between these two distributions revealed a moderate degree of consistency among *S*s in their performance following startle. Since primary concern was only with examination of the characteristics of extreme reactors, two groups were formed. Those *S*s whose scores were in the top third of both distributions were designated as high error (HE) *S*s and those in the bottom third of both distributions as low error (LE) *S*s. Eight HE and six LE *S*s were obtained in this manner. For $S_1$ the obtained mean error scores were 12.87 for the HE group and 4.08 for the LE group. For $S_2$ the comparable values were 13.56 and 4.00 for the HE and LE groups respectively.

In comparing the two groups with respect to possible differences prior to startle, neither the pre-startle values for conductance level nor for maximum heart rate approached significance. There were, however, significant differences between the groups with regard to tracking error prior to startle. The pre-startle means for $S_1$ were 6.56 and 3.67 for the HE and LE groups respectively. For $S_2$ mean values for the two groups were 8.09 and 4.90. These differences between the groups were significant for both pre-startle periods ($S_1$ ($t=2.96$; $p<.05$); $S_2$ ($t=2.51$; $p<.05$)).

In terms of response to the startle stimuli, there were no significant differences between the HE and LE groups in mean conductance change to either $S_1$ or $S_2$. This was not the case with heart rate response, however. For $S_1$ the heart rate response (maximum heart rate during the 5-second interval following stimulation minus maximum heart rate in the 5-second interval preceding stimulation) was 20.4 b.p.m. for the HE group and 8.3 b.p.m. for the LE group. This difference was significant ($t=2.54$; $p<.05$). A similar trend was found for $S_2$, but the difference between the mean HE change of 17.2 b.p.m. and mean LE change of 9.7 b.p.m. was not significant ($t=1.95$; $p>.05$).

With regard to the subjective ratings obtained from the post-experiment questionnaire, the HE group rated $S_1$ more startling than did the LE group ($U=3$; $p=.004$). Although the trends were the same, the two groups did not differ significantly with respect to their ratings of $S_2$ ($U=13$; $p=.18$).

## IV. Discussion.

The results of the present study revealed the recovery of tracking performance following startle to be quite rapid. Upon initial presentation of the startle stimulus, maximum disruption was found to occur during the first 5 seconds after stimulation, with significant, but considerably less disruption during the second 5-second interval. Interpretation of the effects of the second startle on tracking was difficult because of the elevated level of tracking error prior to the stimulus. Neither presentation of the startle, however, yielded any indication of adverse effects after the initial 5- to 10-second post-stimulus interval. Beyond this, startle appeared to have an alerting effect in which performance was generally improved relative to pre-stimulus levels.

Recently, Vlasak[19] has reported a study which also dealt with recovery of motor performance following startle. He employed a simple task in which the *S* attempted by means of a stylus, to trace an irregular line. Startle resulting from a "klaxon" horn was reported to produce only momentary disruption of performance lasting approximately 1 to 2 seconds. It should be noted, though, that Vlasak chose to examine performance only during the first few seconds following startle. Thus, the possibility of subsequent disruption of lesser magnitude was ignored. In addition, he used what would appear to be a much simpler "tracking task," and one which might reveal more rapid recovery from startle. Nevertheless, the tracking data of the present study were re-examined to determine whether the increase in error during the initial 5-second interval following startle could be attributed primarily to an increase occurring during the first 1 or 2 seconds. The total number of integrations within each successive second of this interval was obtained and expressed as a percentage of the total. For the initial interval following $S_1$, the percentages were 28, 28, 17, 15, and 12 for 1, 2, 3, 4, and 5 seconds, respectively. Comparable percentages for $S_2$ were 30, 26, 17, 13, and 14. These data indicate that over 50 percent of the error during the initial 5-second interval occurred during the first 2 seconds, and thus tend to support Vlasak's findings. Since the total startle reflex may last from 0.3 to 1.5 seconds,[8] this suggests that at least some of the performance disruption which takes place within the 5-second interval following startle may be attributable to direct mechanical effects of the startle reflex on motor control. However, the fact that the present study showed performance to be significantly impaired during the second 5-second interval following startle as well, at least for the first presentation of the stimulus, would also suggest that not all of the increase in error can be attributed entirely to a disruption of motor control resulting from the mechanical effects of the startle reflex*.

In addition to tracking, Vlasak also studied the effects of startle on continuous mental subtraction and on simple and choice reaction time. Subtraction was found to be significantly impaired for 15 seconds following stimulation. For the reaction time tasks, there were insufficient data given to determine the precise duration of impairment, although both were impaired temporarily following startle. As noted earlier, Woodhead[20, 21] found decrements on a decision task following sudden noise stimulation which lasted from 17 to 31 seconds. It would appear from the results of the present study and from the few others which also have investigated performance recovery, that the major performance decrement following startle probably occurs within the first few seconds. However, a lesser but significant decrement may last for periods of from 10 to 30 seconds after startle. There is some indication that following startle, recovery of performance on motor tasks may be somewhat more rapid than recovery of performance on tasks which are more cognitive in nature, although this must be considered a tentative conclusion at present.

Reaction times to the startle stimuli themselves were found to be facilitated relative to the nonstartle reaction times. This was an unexpected finding, since two previous studies[17, 18] obtained lengthened reaction times to startle. One possibility might be that the thumb flexion required as a response in this study was facilitated by the startle reflex itself, although the mean reaction times to $S_1$ and $S_2$ (402 and 401 msecs., respectively) were considerably longer than the times (145 to 195 msecs.) reported by Landis and Hunt[8] for the muscular startle reflex to reach the hand. This would suggest that the obtained reaction times, while possibly facilitated by startle, were not simply reflex responses. Purohit[12, 13] has recently argued that reaction time to startle may be either inhibited or facilitated depending on the extent to which the voluntary response employed is compatible with the reflex startle response. This would appear to offer a reasonable explanation for the discrepancy between the reaction time data of the present study and the findings of both Sternbach[17] and Thackray,[18] since these earlier studies employed arm or hand responses which likely were partially inhibited by the total startle pattern.

With regard to individual differences, there was a direct relationship between tracking proficiency before and after startle, i.e., the group which revealed the greatest error immediately following startle also had significantly higher

*Since reaction times were also obtained in the present study, it could be argued that the response of pressing the button to the startle stimulus may have contributed to tracking impairment during the first second following startle. Although this may have had some effect upon tracking, it is likely that the effect was quite small, since pilot data indicated that the actual button response itself resulted in no apparent increase in tracking error.

error before startle and vice versa. These findings are consistent with those of several previous studies. Thus, Vlasak[19] found a similar relationship between performance disruption following startle and level of prior proficiency, with less proficient *S*s being considerably more disrupted by startle. This held for three out of the four tasks studied. These included mental subtraction, choice reaction time, and simple tracing. As noted earlier, Thackray[18] also found evidence to suggest that, with the particular reaction time task employed, startle tended to exaggerate preexisting differences between individuals in their "nonstartle" response time, i.e., the slow became slower and the fast responded with even shorter latencies to startle. Taken together with the present findings, these results suggest the general hypothesis that the extent of disruption following startle is dependent upon the level of task proficiency prior to startle with greatest disruption occurring among those who are least proficient prior to startle.

Although there was some indication of greater subjective and physiological response to startle by the HE *S*s, the differences were not pronounced and appeared somewhat inconsistent. Thus, while the differences between the groups in heart rate response and subjective judgment were significant for $S_1$, they were not for $S_2$. Also, the two groups did not differ in their conductance change to either $S_1$ or $S_2$. Nevertheless, with the exception of this lack of difference between the groups in conductance change, the trends of these differences were in general agreement with the previous findings of Sternbach[17] and Thackray.[18] Both earlier studies found a tendency for slowness of response to startle (greater impairment) to be associated with greater autonomic response. Also, like the present study, neither of these previous ones found any relationship between the extent of performance disruption to startle and pre-startle levels of physiological activity.

Evidence of an apparent covariation between the recovery curves for heart rate and tracking was found for both $S_1$ and $S_2$. For both stimuli the significant increase in heart rate and tracking error immediately after startle was followed by parallel decreases in heart rate and error. The subsequent secondary heart rate acceleration was accompanied again by an increase in error, although this was a considerably weaker effect as shown by the general lack of statistical significance. Nevertheless, there are reasons to believe that the secondary rise in tracking error was real. Not only did it appear following both stimuli, but it was also present in the data of pilot *S*s run prior to the experiment. Why the apparent coupling between these two variables continued for the initial 20- to 25-second period following stimulation, and then appeared to dissipate is an interesting question. Certainly there is evidence to suggest that cardiac-behavioral coupling can and does occur.[3 5 6 10] Lacey[6 7] has reviewed the evidence for a mechanism whereby cardiac change can either facilitate or inhibit sensory input via baroreceptor feedback to the central nervous system, and the present data may reflect the operation of such a mechanism.

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