Performance disruption by startle-eliciting acoustic stimuli*

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Six rats were trained to press a lever on a variable interval schedule of food reinforcement. When response rates were stable, a response-independent startle-eliciting acoustic stimulus was presented at intervals of approximately 6 min, and its disruptive effects were assessed. It was found that stimulus presentations yielded large decrements in response rate that persisted for several minutes. As daily test sessions proceeded, the decrements lessened, but even after 6 days of testing, startle stimuli continued to disrupt responding.

Investigation of the mammalian startle reaction to intense sound has typically proceeded in one of three ways: (1) studies focused on the muscular and/or autonomic components of the response (Berg & Beebe-Center, 1941; Freeman & Pathman, 1942; Sternbach, 1960); (2) studies of the adequate stimulus for eliciting the response (Fleshler, 1965; Hoffman & Wible, 1970); and (3) studies of the effects of various antecedent conditions on startle evocation (Brady & Nauta, 1953; Brown, Kalish, & Farber, 1951). In contrast to these more or less direct approaches which examined the response proper, the work reported here focused on the behavioral aftereffects of startle evocation. In particular, it sought to assess the potentially disruptive consequences of presenting startle-eliciting acoustic stimuli to rats while they performed a food-reinforced leverpress response.

At the outset, there was little information upon which one might predict the nature of such consequences. Previous investigations of the startle response per se (Landis & Hunt, 1939; Hoffman & Stitt, 1969) and of the reinforcement afforded when rats are permitted either to escape or to avoid intense sounds (Harrison & Tracy, 1955; Barnes & Kish, 1957) suggested that sounds that evoke startle are aversive and, hence, that their presentation might disrupt ongoing leverpress performance. But whether the disruptions would be sizable or small, whether they would persist for seconds or minutes, and whether the effects would decrease or increase with repeated startle evocation seemed impossible to predict. Indeed, there appeared to be equally good behavioral arguments for anticipating any set of these

alternatives. For example, it seemed possible that if startle-evoking sounds were aversive and if these were presented independently of ongoing behavior, a condition of learned helplessness might develop (Maier, Seligman, & Solomon, 1969). Under such circumstances, the disruptive effects of startle evocation should progressively increase. On the other hand, since the overt startle reaction is known to habituate with repeated evocation (Davis, 1970; Moyer, 1963; Hoffman & Stitt, 1969), one might predict that any associated performance disruptions ought also to exhibit decreases. Clearly, the question demanded an empirical analysis in which the details of startle-induced performance changes were carefully documented. Presumably, in this fashion one could reduce the ambiguity surrounding the issue and possibly provide a useful methodology for future work in the area.

SUBJECTS

Six experimentally naive male Sprague-Dawley rats were used. They were approximately 120 days old at the time initial training began.

APPARATUS

All training and testing occurred in an Industrial Acoustics Company sound-attenuating room, Model 1200-A. The basic design of the device for the assessment of startle has been described fully elsewhere

(Hoffman & Fleshler, 1964). The device used in the present experiment was built along similar lines, except that the animal's chamber was enlarged to 20 x 13 x 15 cm and its side walls and floors were constructed of stainless steel rods to permit better acoustic penetration. The animal's chamber was supported by a relatively stiff fiberglass suspension system such that vibrations of the chamber were transmitted to a magnet located in a stationary coil. With this arrangement, when the rat made a sudden movement (as during startle), an electrical current was generated in the coil. This current was amplified, rectified, and passed to a recording milliammeter. A Gerbrands rat lever and a foodcup were located next to each other at one end of the animal's chamber. The lever was silenced by omitting its microswitch and substituting a mercury switch. Food pellets (45 mg) were delivered by a Davis feeder that was silenced by substituting a synchronous motor for its rotary solenoid. The purpose in silencing these units was to preclude extraneous click-like sounds which are known to influence the rat's tendency to startle (Hoffman & Searle, 1965, 1968).

Startle-eliciting stimuli were generated by feeding the output of a General Radio random-noise generator through a Grason-Stadler electronic switch which was operated by a Grason-Stadler interval timer. This circuitry permitted control over the duration and rise-decay time of the startle signals. A final stage of amplification was produced by passing the signals through one channel of a Crown 300-W power amplifier. The signals were delivered to the Ss through a 20.3-cm midrange speaker mounted 5 cm from the S's chamber. Throughout training and testing, continuous background noise was provided by a separate system consisting of a Grason-Stadler random-noise generator, the output of which was fed through the other channel of the Crown amplifier to a second 20.3-cm midrange speaker mounted 76 cm from the S's chamber.

Table 1
Baseline Leverpress Rate and Startle Amplitude Throughout Testing*

	Sessions		
	1 and 2	3 and 4	5 and 6
Mean Rate of Leverpresses (Responses Per Min)	19.9	16.2	19.8
Mean Amplitude of Startle (mm of Pen Deflection)	32.9	25.9	23.2

*The top line shows the mean number of leverpresses during the several 1-min intervals that ended with presentation of a startle-eliciting acoustic stimulus. The bottom line shows the mean amplitude of the startle reactions in millimeters deflection of the recording milliammeter.

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When measured in the S's chamber, the background noise intensity was 70 dB (re .0002 dynes/cm²). Earlier studies have shown that the amplitude of the rats' startle reactions to other more intense signals is increased when testing occurs in this acoustical background (Hoffman & Fleshler, 1963; Hoffman & Searle, 1965). Standard electromechanical equipment was used to program reinforcement, to document leverpresses, and to control the intervals between presentations of startle stimuli.

PROCEDURE

At the start of the investigation, all Ss were placed on reduced rations until they reached 80% of their ad lib body weight. Thereafter, they were maintained at this body weight until all procedures were completed. After being trained to leverpress, each S went through a sequence of exposures to various schedules of reinforcement in order to develop stable response rates. First, Ss were exposed to 5 days of continuous reinforcement, the average session being 45 min in duration. For the 50 min of the next session, a small-valued fixed-ratio schedule of reinforcement (FR 5) was employed in order to develop efficient response topographies. The next phase of training consisted of 7 days of exposure to a variable-interval (VI) schedule with a mean interreinforcement interval of 5 sec, the average daily session being 1 h. This was followed by 7 days of exposure to a VI 30-sec schedule, the average session being 1 h. The final phase of training was composed of 18 daily sessions, 1 h each, of exposure to a VI 60-sec schedule. This schedule consisted of a random sequence of 25 different intervals generated by a special progression (Fleshler & Hoffman, 1962). With VI schedules derived from this progression, the probability of reinforcement tends to remain constant as a function of time since reinforcement. As a result, the schedule optimizes the conditions necessary for the establishment of stable response rates within the limitations imposed by electromechanical programming equipment.

Tests for the disruptive effects of startle-eliciting stimuli were begun on the day following the completion of the final phase of training. Test sessions had the same format as the final phase of training, and they employed the same VI 60-sec schedule of food reinforcement. They differed only in that a response-independent startle-eliciting acoustic stimulus was occasionally presented in the course of the leverpress performance. The startle-eliciting stimulus consisted of a 20-msec burst of broad-band random

Fig. 1. Mean percentage of prestartle leverpress responses during successive poststartle minutes. The arrow indicates the presentation of the startle-eliciting stimulus.

noise (rise-decay time was 0.1 msec) at an intensity of 130 dB (re .0002 dynes/cm²) when measured in the S's chamber. In a given test session, the first stimulus occurred after 5 min of startle-free leverpressing, and subsequent stimuli were presented every 6±1 min thereafter. The session ended 5 min after presentation of the sixth startle stimulus. Each S was exposed to one test session per day for 6 consecutive days.

RESULTS

At the end of training, the mean rate of baseline leverpressing was approximately 20 responses/min, and this rate remained fairly stable throughout the six sessions of testing. The top row of Table 1 shows the mean number of leverpresses across blocks of two sessions during the several 1-min periods that ended with presentation of a startle stimulus.

A repeated measures analysis of variance of these data failed to yield a statistically significant effect ($F = 2.63$, $df = 2/10$, $p > .05$). Hence it can be concluded that the perturbations in rate seen in Table 1 are not reliable. The bottom line of Table 1 shows the average amplitude of startle in millimeters of pen deflection of the recording millimeter for the same blocks of trials. Again, a repeated measures analysis of variance failed to yield a significant result ($F = 3.54$, $df = 2/10$, $p > .05$), leading

to the conclusion that though the startle reaction appears to be habituating, the effect is not reliable. Consistent with the failure to detect statistically significant habituation is that, throughout the course of the experiment, no animal ever failed to exhibit a measurable startle reaction to presentation of the intense acoustic stimulus.

The behavioral aftereffects of the startle-eliciting stimuli are summarized in Fig. 1. It shows response rates in each of the first 3 poststartle minutes expressed as percentages of the response rate in the final minute prior to presentation of the startle stimuli. In preparing this figure, mean rate of leverpress responses in the 1 min preceding and in each of the 3 min following each startle stimulus were tabulated for each S across the 12 startle stimuli that occurred in each block of two test sessions. These rates were then converted to percentages of the rates during the prestartle minute on a S-by-S basis. Finally, the obtained percentages were averaged across Ss to derive the several points in Fig. 1.

The dominant effect of presenting startle-eliciting stimuli was a sizable reduction in response rate that persisted for several minutes and which habituated quite slowly. A repeated measures analysis of variance was used to assess the statistical reliability of these findings. It revealed significant differences among the rates

during the 3 poststartle minutes ($F = 4.25$, $df = 2/10$, $p < .05$) and among blocks of days ($F = 7.36$, $df = 2/10$, $p < .05$) and no significant interaction between these two factors ($F = 0.49$, $df = 4/20$, $p > .05$).

DISCUSSION

The major conclusion generated by these findings is that the behavioral effects of presenting an intense acoustic stimulus persist well beyond the 200 msec or so occupied by the startle reaction it evokes. In the present circumstances, the aftereffects of a single stimulus were sizable (as revealed by the large rate reductions during the first poststartle minute). They persisted for several minutes (as indicated by the incomplete recovery within trials), and they habituated rather slowly (as revealed by the poststartle rate reductions that were still visible on Days 5 and 6).

While these findings do not indicate the factors responsible for either the disruptive effects of the startle stimuli or the recovery from those effects, the overall configuration of the data is consistent with the hypothesis that a byproduct of startle evocation is an emotional type of reaction that either directly or indirectly inhibits leverpressing and which may take several minutes to dissipate completely. If this reaction habituates with repeated startle evocation, one would expect: (1) that a single startle stimulus would produce disruptive effects that might persist for minutes rather than seconds, and (2) that the effects might decline as trials progressed. Both of these phenomena were visible in the present data.

As noted earlier, the bulk of the

available information about the reactions engendered by intense acoustic signals suggest that such signals are aversive. For this reason, their effects might be expected to include an emotional reaction. What has been unclear until now is whether or not these effects also included sizable and persistent disruptions of ongoing behavior. The present findings provide unambiguous evidence that they do.

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