Preception in the Rat: Autonomic Response to Shock as Function of Length of Warning Interval

Abstract. *The* autonomic response (galvanic skin response) to a noxious stimulus (shock) is reduced when the stimulus is preceded by a warning signal. The greatest reduction, 53 percent, was obtained with a warning interval of 1 second. Warning also reduces variance of the response over trials, a decrease of over 90 percent for the optimum 1-second interval.

It has been shown with human subjects that the galvanic skin response (GSR) to a painful electric shock is smaller and less variable when the shock is preceded by a brief warning signal than when presented unexpectedly [1]. It is known that the mammalian nervous system contains elaborate mechanisms for preliminary analysis and modulation of sensory input prior to arrival at the highest neural destination, mechanisms which presumably subserve the functions of sensory adaptation, selective attention, and the like. It may be, therefore, that a warning signal which presages a brief noxious stimulus can produce an afferent "set" which serves to attenuate selectively the sensory representation of the noxious stimulus when it occurs. Since the relative amplitude of the galvanic skin response is known to covary with other indicants of subjective stimulus intensity [2], such a hypothesis would account for the results mentioned above and would also explain why many subjects volunteered that the shock felt less strong when preceded by the warning tone.

This hypothetical effect of the warning signal upon the "admittance" of the afferent system for the expected stimulus was called the "preception response." When the expected stimulus is noxious and unavoidable, the warning appears to generate a *negative* preception response which attenuates the afferent result of the stimulus. When, as in an ordinary sensory threshold experiment, the expected stimulus is non-noxious or weak, or both, the warning signal may perhaps elicit a *positive* preception response, which then selectively amplifies the signal initiated by the expected stimulus. The fact that sensory thresholds are lower for short warning intervals and higher for variable intervals [3] would seem to square with such an interpretation.

These considerations suggest that the negative preception phenomenon should vary as a function of the length of the warning interval. Suppose an animal is given a series of brief shocks at varying inter-trial intervals and that half of these, at random, are preceded by a warning signal lasting exactly *t* seconds and terminating with the onset of the shock. If the galvanic skin responses to the shock on the tone-shock (TS) trials are smaller on the average than those produced by the shock-alone (S) trials, this relative difference is a measure of the negative preception produced by the t-second warning. Longer intervals (for example $t = 10$ sec) should yield less preception since the time of occurrence of the shock cannot be predicted as accurately as it can when the interval is short. On the other hand, too short an interval would not allow time for the preception response to occur. (Thus, the shock alone can be thought of as providing its own warning signal with $t = 0$.) Therefore, one might expect decreased negative preception with long and very short intervals and a maximum at some interval of intermediate length.

The 20 animals used in this experiment were rats of the Wistar strain, all about 90 days old. Each animal was lightly anesthetized with ether and then bound to a special restraining platform [4] for GSR recording. Small zinc GSR electrodes were attached to the plantar surfaces of the two hind feet with thin strips of tape, after the footpads had been daubed with a zinc-sulfate paste [5]. Two shock electrodes, made of lead, were taped about 1 inch apart near the proximal end of the tail. The animal was then placed in a sound-insulated
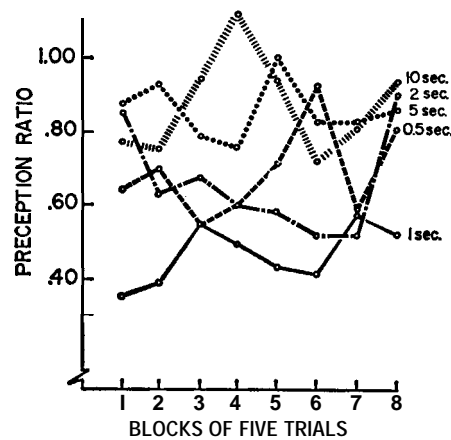

Fig. 1. Preception ratio is GSR to shocks preceded by warning tone divided by GSR to interspersed shocks given without warning. Curves show attenuation of response to the more predictable shocks found in five groups of animals run on different constant warning intervals.
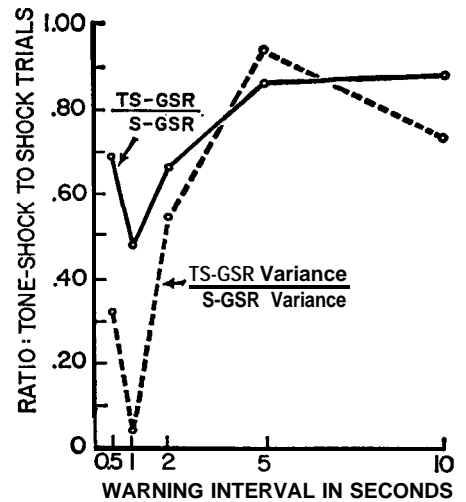

Fig. 2. Solid curve shows ratio of GSR amplitude on tone-shock (TS) trials to amplitude on shock-alone (S) trials as a function of the duration of the tone or warning interval. Broken curve shows similar ratio of the variances (across trials) or GSR amplitudes.

box containing a compressed air inlet which provided both ventilation and a "white" masking sound. Skin conductance was measured directly [6] by connecting a 3-volt mercury battery in series with the GSR electrodes and a small resistor (100 to 500 ohms); the signal across this resistor, which varied linearly with skin conductance, was fed to a Sanborn 150-1500 chopper pre-amplifier and its associated chart recorder. With this arrangement, apparent skin conductance varied from about 2 to 11 μmho and current from about 6 to 33 μa. The shock stimulus was the discharge of a 1-μf capacitor charged to 300 volts. The warning signal was a 1000 cy/sec tone delivered through a speaker situated about 6 inches over the animal's head.

Each animal was given 40 shocks (S-trials) randomly intermixed with 40 tone-shocks (TS-trials). The inter-trial interval varied unpredictably from 15 to 60 seconds with a mean of 35 seconds. Four animals were run on each of the five warning intervals, 0.5, 1, 2, 5, and 10 seconds.

Since, on the TS-trials, the galvanic skin response to the warning signal frequently merges into the response to the shock itself, it is necessary to devise a means of determining what portion of the total response following shock is actually elicited by the shock. First, the GSR latency was measured for each shock-alone trial, that is, the time from the onset of shock until the subsequent

response had reached 10 percent of its total amplitude (such "10 percent latencies" can be measured considerably more accurately than can the time to the absolute start of the response). These S-trial latencies were then averaged for each five successive trials. The shock-GSR for any TS-trial was then found by laying off one latency period from the start of the shock (by use of the mean for the five S-trials nearest that TS-trial) and measuring the amplitude from that point to the peak of the shock-GSR. This value was taken as being 0.9 of the total galvanic skin response actually elicited by the shock on that TS-trial. Since most of these animals showed a moderate negative p-type correlation between GSR amplitude and latency, this scoring procedure tends to err in the direction of reducing the expected differences. The preception hypothesis predicts that the galvanic skin responses on the TS-trials shall be smaller than those on the S-trials, hence their latencies should be somewhat longer also; the scoring procedure used here would therefore tend to overestimate GSR amplitudes for the TS-trials.

Mean GSR amplitudes were computed for successive blocks of five S-trials and five TS-trials. For each such block of five pairs of trials, a preception score was obtained by dividing the mean TS-GSR by the mean S-GSR; this ratio represents the shock response on the TS-trials as a fraction of the response shown on the interpolated S-trials. These values are plotted for each warning interval group in Fig. 1. The TS-GSR was always smaller than the S-GSR except for one point on the 10-second curve and another on the S-second curve. Thus, the expected negative preception effect is apparent. Moreover, the effect appears to be strongest for the 1-second warning interval and least for the two longest intervals. The overall mean preception ratios for the five interval groups are plotted in Fig. 2. For the 1-second group, the TS-GSR averaged only 47 percent of the S-GSR amplitude but was about 65 percent for the 0.5 and 2-second intervals and over 85 percent for the 5- and IO-second intervals.

The preception hypothesis also predicts that the responses to the more predictable shocks should be less variable from trial to trial than those produced by the shocks given alone. Therefore, the warning interval which is optimum for preception should yield the smallest ratio of TS-GSR variance to S-GSR variance (these variances being computed over the eight blocks of five trials each). This variance ratio is also plotted in Fig. 2 and shows the expected result. For the optimum 1-second interval, the variance of the TS-trials is only about 4 percent of the variance on the S-trials: for the 0.5 and 2-second intervals, the values are 32 and 53 percent, rising to 94 and 74 percent for the 5- and lo-second groups, respectively.

An immediate practical implication of these findings concerns the widespread use of shock or other brief noxious stimuli in behavioral studies of stress, emotional learning, and the like. The data make clear that the effective intensity of a stimulus having a constant physical intensity may vary greatly from trial to trial unless the time of occurrence of the stimulus is made predictable for the subject. Whether the optimum warning interval is the same for the human and other species as for the rat remains to be determined (7).

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References and Notes

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2. Measurement problems complicate the comparison of galvanic skin responses from different individuals, but the general truth of this interpretation rests upon an abundance of evidence-for example, see H. G. McCurdy, *Psychol. Rev.* 57, 322 (1960).
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