by Dickmann and Noyes (*3*) in their studies on unoperated animals.

The demonstrated absence of ova from the operated horn on the 5th day reflects an unfavorable uterine environment, induced by the presence of the foreign body. Intraluminal factors may act upon the blastocysts, so that they disintegrate; or alterations in normal uterine tone and motility may allow the ova to escape into the vagina before the time of implantation.

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30 November 1962

Proprioceptive Discrimination of a Covert Operant without Its Observation by the Subject

Abstract. *When the subject occasionally emitted an invisibly small thumb twitch (detected electromyographically), he received a tone as a signal to press a key. After several conditioning sessions, the tone was progressively diminished to zero. The subject nevertheless continued to press the key whenever he emitted a thumb twitch, and he reported that he still heard the tone.*

A response so small as to be visually imperceptible to subject and experimenter alike may, on the basis of electromyographic detection, be successfully conditioned by standard operant procedures (*1*). We now show that the faint proprioceptive feedback from such a response can become a discriminative stimulus for other behavior.

Our specific objective was to train the subject, although he might remain otherwise unresponsive to an occasional minute twitch in his left thumb (*m. abductor pollicis brevis*), nevertheless to "report" its occurrence within 2 seconds by pressing a key with his right index finger. Should this prove unfeasible we hoped at least to demonstrate preparatory activity in a muscle associated with key pressing (*m. extensor carpi radialis brevis*), since this would indicate that one covert response, the thumb twitch, had become a discriminative stimulus for a second, the incipient movement of the index finger. The latter we call "sub key press."

The first five subjects, all of them young adults, exhibited sub key presses. Three others, who underwent more prolonged training, came to execute the overt key press.

In the first session we determined operant level for both thumb twitch and sub key press. These unconditioned rates of occurrence for the two responses would, of course, produce some instances where the sub key press would follow the thumb twitch within 2 seconds by chance. Accordingly, evidence for the formation of a discrimination required that our experimental procedures bring about an unmistakable increase in the proportion of such joint occurrences.

In Fig. 1 the third column of cumulative records, labeled "Hits," displays this type of event for each session. The first column, "False Alarms," shows sub key presses *not* preceded by a thumb twitch within 2 seconds, and the second column, "Misses," shows thumb twitches *not* followed by a sub key press within 2 seconds. The total number of sub key presses is thus the sum of "False Alarms" and "Hits," and the total number of thumb twitches is the sum of "Misses" and "Hits." Each of the responses reveals an operant level rate of approximately 600 per hour, or about one every 6 seconds. These overall rates did not change appreciably throughout the experiment.

In a second session we compounded the proprioceptive stimuli produced by the thumb twitch with a readily discriminable exteroceptive stimulus. This was a moderately loud 1000-cycle tone of about ½ second duration, superimposed on the constant, random masking noise. We instructed the subject to press the key with his right index finger whenever he heard this tone, and then to note the advance in his score as shown on an illuminated digital display. His total score, he was told, would directly determine his pay for the session. (At the end of each session he was paid 2 cents for each reinforcement which he had scored.)

We triggered the tone as quickly as the experimenter's reaction time permitted whenever we saw on an oscilloscope a deflection which represented the thumb twitch. This deflection consisted of a discrete sinusoidal wave with

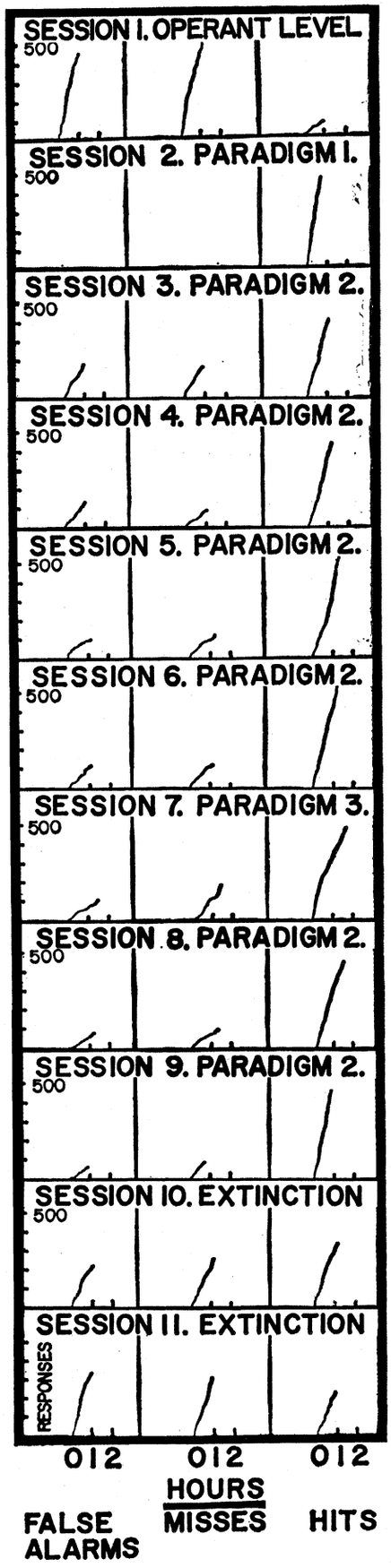

Fig. 1. Cumulative response curves for a single subject.

an amplitude of less than 25 microvolts (root mean square). The effects of a proprioceptive stimulus from this response would, presumably, overlap the tone in time. The session was terminated when 500 reinforcements had been administered. For this situation there were, of course, no "False Alarms" or "Misses." The procedure is shown as the first paradigm in Fig. 2.

In sessions 3 to 6 we did not present the tone at once after observing the thumb twitch, but watched a second trace on the dual-beam oscilloscope for a deflection of the same type which represented the sub key press. If this occurred within 2 seconds, a "Hit" was recorded and the tone was presented immediately. If it did not occur, the tone was presented at the end of 2 seconds and a "Miss" was recorded.

Although, as stated earlier, the overall rates of the two responses remained much the same throughout the experiment, under paradigm 2 there was a striking increase in the number of "Hits," with a corresponding decrease in the frequency of "False Alarms" and "Misses." Most of this change is shown in the curves for the third session, with only slight additional effects obtained in three further sessions under this procedure.

Session 7 began under paradigm 2, except that each time the thumb twitch and sub key press occurred the tone was reduced in intensity, so that after 20 presentations it was completely gone, thus effecting a transition to paradigm 3. As the tone became faint, the subject complained over the intercom that it was "getting hard to hear," but was told simply to continue to respond to those tones that he did hear. In this session the cumulative record for "Hits" is for the thumb twitch followed within 2 seconds by the *overt* key press and not, as in all other sessions, by the sub key press.

Our purpose in fading out the tone was, of course, to remove the exteroceptive component from the original compound stimulus for key pressing, and thus to ascertain whether proprioceptive feedback alone could now evoke the overt response. The cumulative records under this condition are scarcely distinguishable from those for preceding days when the tone was present. The reduction in the rate of "Hits" which occurs about half way through the session and the corresponding rise in the rate for "Misses" were not present in the records for the other

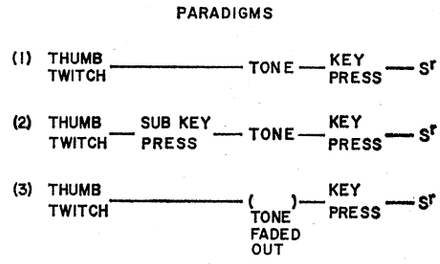

Fig. 2. Paradigms employed at various stages of experiment. S^r, reinforcing stimulus.

two subjects who progressed to this stage.

Following this session in which the tone was not presented, paradigm 2 was reinstituted for two more sessions, and the experiment was then concluded with two sessions of extinction, where neither tone nor reinforcement was presented. The extinction curves indicate an incomplete return to the original operant level rates for the three types of event. Further extinction would have been conducted, but the subject was not willing to continue.

It remains to account for the subject's continued key pressing to the tone after this was no longer exteroceptively presented. His report, when he was questioned at the end of the experiment, was that he "still heard it." This is in keeping with the literature on experimentally produced "images," "conditioned sensations," and "hallucinations" (*2*). Using a procedure very similar to ours, Stevens recently conditioned a patient to press a key when paroxysmal epileptiform activity occurred in his electroencephalogram (EEG) (*3*). She first allowed the patient to hear the abnormal activity by means of an "audio EEG" produced by feeding one channel through a speaker. When the audio signal was later removed, he continued to press the key and reported that for the first time in his life he now occasionally experienced a warning sensation prior to his petit mal attacks. Whether this sensation was of an auditory nature Stevens does not specify. (Since abnormal activity in the EEG lasting 5 seconds or more was accompanied in this subject by eye opening and rhythmic blinking, it was perhaps the onset of these discriminable movements, rather than the change in the EEG per se, which served as the basis of the sensation.)

When paradigm 2 was resumed in sessions 8 and 9, our subject responded to his thumb twitch with a key press which came faster than the experimenter's reaction time in noting the oscilloscope deflection and presenting the exteroceptive tone. The subject claimed that he sometimes heard the tone twice in rapid succession. Apparently the two kinds of discriminative stimulus, "subjective tone" and "objective tone," were not appreciably different.

Under the extinction procedure, although "Hits" continued at a high rate, the subject overtly pressed the key (and later reported that he had "actually" heard the tone) not more than four or five times during each of the 1-hour sessions. Whether the initiation of reinforcement for sub key presses would at this stage reinstate "hearing the tone" has not been determined (*4*).

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Indophenol Blue as a Chromogenic Agent for Identification of Halogenated Aromatic Hydrocarbons

Abstract. *The metachromatic dye indophenol blue* [N-(p-*dimethylaminophenyl*)-*1,4-naphthoquinoneimine*] *is adaptable for qualitative and quantitative measurements of halogenated aromatic hydrocarbons in paper chromatographic procedures and spot tests.*

The chromogenic procedures used to define chlorinated aromatic pesticides on paper chromatograms are tedious and often noxious. Silver precipitation techniques (*1*), or the reduction of ferric sulfate (*2*) have been employed. Neither technique produces chromospectric differentiations of isomers or analogs superimposed on similar R_F loci.

A search was made of the quinoneimine dyes for a more suitable chromogene, since these agents often form