standard observer as defined by the Commission International de l'Éclairage (C.I.E.). This procedure produces better agreement between the observers than computation based on energy calibration of the stimuli because it cancels out the effects of individual differences in absorption by the ocular media.

The curves are in reasonable agreement with the absorption difference spectra found for human parafoveal cones by Marks and MacNichol and Brown and Wald, and with the retinal densitometry measurements of Rushton (*2, 5*). However, it should be emphasized that this is a preliminary study on only two trained observers and that detailed comparisons are premature.

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31 August 1965

Differential Classical Conditioning: Verbalization of Stimulus Contingencies

Abstract. *The verbal activity of female subjects undergoing differential classical conditioning was investigated through their verbal reports between conditioning trials and interviews with them after conditioning. Conditional differentiation in galvanic skin responses occurred only in the group of subjects who accurately verbalized the stimulus contingencies.*

The cognitive activity of human subjects undergoing classical conditioning has been investigated in numerous experiments concerned with subjects' knowledge of stimulus contingencies and procedural shifts (*1*). Most frequently, the approach has been to instruct subjects about the stimulus contingencies prior to acquisition or extinction trials, with the result that acquisition or extinction is markedly facilitated (*2*). It is not clear, however, how applicable these results are to interpreting findings of more conventional classical conditioning experiments in which preparatory instructions are omitted.

Without preparatory instructions, subjects may develop recognition of stimulus contingencies during conditioning. This process has been studied by obtaining subjects' verbal reports either between conditioning trials or during an interview after conditioning. Results based upon interviews following conditioning have been inconsistent (*3*), perhaps because of some instances in which interviews were conducted and analyzed unsystematically. The three available studies (*4*) using intertrial verbal reports also used conditional responses potentially under voluntary control. The early, exploratory studies by Hamel and by Schilder were followed by a more systematic study by Hilgard, Campbell, and Sears, in which intertrial verbal reports were elicited during differential eyeblink conditioning. Hilgard *et al.* noted a slight indication that subjects showing the most marked eyeblink differentiation also were most accurate in describing the stimulus contingencies. Though Grant (*5*) suggested that "a systematic study of verbalization and resulting behavior during conditioning should do much to clear up the problem of controlling verbal processes with human subjects," no further studies using intertrial verbal reports in classical conditioning have been reported.

We probed cognitive activity during differential conditioning of the galvanic skin response (GSR) both by intertrial reports and by an interview after conditioning. Systematically analyzed verbal data were used to specify the subject's degree of accuracy in verbalizing the differential stimulus contingencies. We compared rates of differential conditioning of the GSR in subjects who differed in accuracy of verbalization. We assessed synchrony between conditional GSR differentiation and the first accurate report of the stimulus contingencies.

The subjects were 26 women of ages 20 to 55. The GSR was recorded monopolarly from the palmar surface of the second phalange of the right index finger. Basal resistance was measured in ohms, and GSR was measured in microohms.

The unconditional stimulus consisted of an electric shock (0.25 second long, 100 pulses per second) applied to the left forefinger and adjusted to the subject's tolerance. The two conditional stimuli were 8-second tones of 700 and 3500 cy/sec. The tone intensities were above threshold for all subjects; subjective intensities had been equated earlier in another group of subjects by psychophysical procedures.

The initial instructions were that, when the experimenter said "report," the subject was to state aloud what she had observed, thought, or felt about events occurring in the experiment since her last report. No references were made to the tones or to the stimulus contingencies. There were 36 trials in three phases: 8 for adaptation, 20 for acquisition, and 8 for extinction. In each phase an equal number of the two tones was presented in unsystematic order, with the same tone never presented more than twice successively. During acquisition, half the subjects had the 3500-cy/sec tone paired with shock, and half the 700-cy/sec tone. The tone duration was 8 seconds and shock presentation was coincident with tone offset. The signal to report followed the offset of each tone by 10 to 15 seconds. The mean interval between tone onset in one trial and tone onset in the next was 49.8 seconds (standard deviation = 16.5 sec).

After the 36 trials, an experimenter who had not been present during conditioning interviewed the subjects, using a standard series of increasingly informative questions. The first question was, "What did you think about it all?", and one of the last was, "Did you have the idea that one type of tone signaled that a shock was coming?"

Three raters, working individually, analyzed separately the content of intertrial verbal reports and of interviews. The content-analyses of both focused upon the subject's communication of information relevant to the experiment and placed it on a continuum ranging from "no reference to relevant stimuli" to "accurate conceptualization of stimulus relationships." On the basis of the content-analyses, each subject was placed in an "Accurate" or an "Inaccurate" group. The Accurate group consisted of subjects

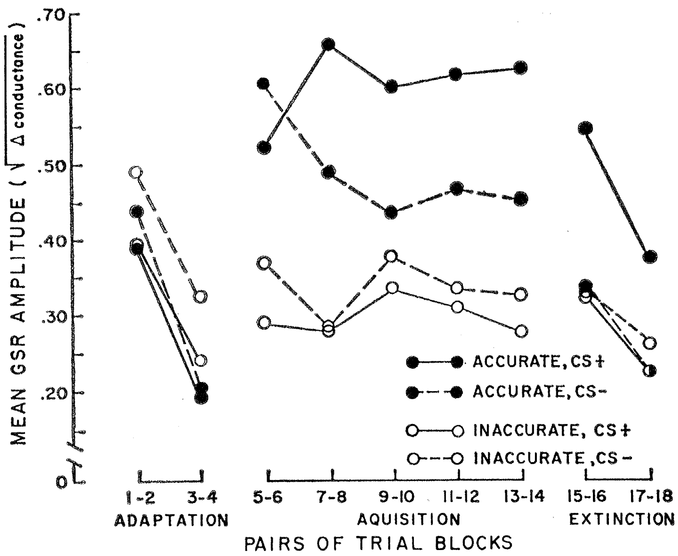

Fig. 1. First-interval conditional GSR differentiation over trial blocks for an Accurate group, which correctly verbalized the stimulus contingencies during an interview following conditioning, and an Inaccurate group which did not.

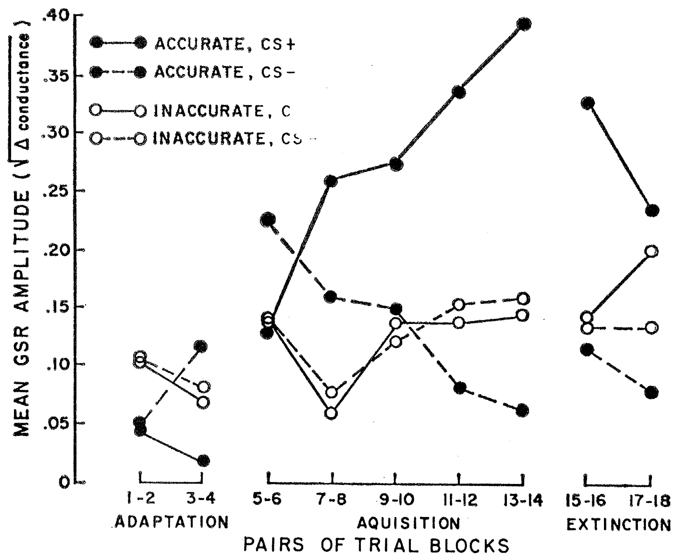

Fig. 2. Second-interval conditional GSR differentiation over trial blocks for an Accurate group, which correctly verbalized the stimulus contingencies during an interview following conditioning, and an Inaccurate group which did not.

whose verbalizations were independently judged by the three raters to contain an accurate statement of the differential stimulus contingencies. An indication of high reliability among ratings is that the three raters failed to achieve unanimity for only one subject's verbal reports and another subject's interview. For both of these subjects, two of the three ratings justified assigning them to the Inaccurate group. On the basis of intertrial reports, 15 subjects were classified in the Accurate group and 11 subjects in the Inaccurate group. Ratings of the interviews resulted in 18 subjects' being classified in the Accurate group and 8 subjects in the Inaccurate group. Three subjects who did not accurately verbalize the differential contingencies during intertrial reports did so when interviewed after the conditioning session.

As in an analysis suggested by Stewart, Stern, Winokur, and Fredman (*6*) the 8-second interval between tone onset and tone offset was divided into two subintervals. A GSR occurring during intertrial reports did so when tone onset was scored as a first-interval response. A GSR occurring during the remaining interval, terminating 1 second after tone offset, was scored as a second-interval response. A third-interval response was scored for a GSR occurring 1 to 5 seconds after offset of the tone. Amplitude of the GSR was expressed as the square root of conductance change.

For each interval, trial blocks were comprised of pairs of consecutive shock (CS+) and non-shock (CS−) tones. Separate, three-factor analyses of variance (Accurate and Inaccurate groups based on interview analyses, CS+ and CS−, and trial blocks) were performed on first-interval GSR's during adaptation, acquisition, and extinction. Figure 1 illustrates first-interval GSR amplitudes during pairs of trial blocks. Amplitude of GSR's to CS+ and CS− during adaptation did not differ significantly for the Accurate and Inaccurate groups combined ($F = .81$, $df = 1, 24$; $P > 0.5$), nor did the Accurate and Inaccurate groups differ in this respect ($F = .71$, $df = 1, 24$; $P > .05$). During acquisition, markedly differentiated GSR amplitudes were obtained between CS+ and CS− when the two groups were combined ($F = 14.9$, $df = 1, 24$; $P < .01$). With respect to the central concern of this study, it should be emphasized that differentiation of GSR amplitudes between CS+ and CS− was not similar for the Accurate and Inaccurate groups ($F = 8.5$, $df = 1, 24$; $P < .01$). As shown in Fig. 1, the Accurate group demonstrated prompt and stable GSR differentiation. On the other hand, the Inaccurate group did not respond differentially. Furthermore, the difference between the two groups was maintained during extinction ($F = 5.9$, $df = 1, 24$; $P < .025$). Although Fig. 1 suggests that the combined amplitudes of GSR to CS+ and to CS− were higher for the Accurate group than for the Inaccurate group during acquisition trial blocks, this difference was not statistically significant ($F = 1.7$, $df = 1, 24$; $P > .05$).

Second-interval GSR amplitudes for groups are illustrated in Fig. 2. Marked GSR differentiation during acquisition occurred for the Accurate group, but not for the Inaccurate group. Second-interval GSR's for the Accurate group showed a growth of differentiation during acquisition which is not discernible in first-interval GSR's (Fig. 1). The nonparametric Wilcoxon test was applied since it was appropriate to the distribution of mean amplitudes per subject of GSR to CS+ and to CS−. During acquisition, the Accurate group showed significant GSR differentiation ($T = 4$, $N = 18$, $P < .01$), but the Inaccurate group did not ($T = 17$, $N = 8$, $P > .05$). The differentiation of GSR's continued for the Accurate group during extinction ($T = 6$, $N = 18$, $P < .01$). Third-interval GSR amplitudes were assessed during extinction trial blocks. The Accurate group produced significantly differentiated GSR's to CS+ and CS− ($T = 23$, $N = 18$, $P < .01$). The Inaccurate group did not show significant response differentiation ($T = 17$, $N = 8$, $P > .05$).

Assigning subjects to Accurate and Inaccurate groups on the basis of intertrial reports rather than interviews after conditioning yielded parallel results. For each subject, summed amplitudes of GSR to CS+ and summed amplitudes of GSR to CS− were computed for first- and second-interval responses during acquisition trial blocks, and for first-, second-, and third-interval responses during extinction trial blocks. In all comparisons for the Accurate group, summed amplitudes of GSR to CS+ were significantly greater than amplitudes to CS− (Wilcoxon test, $P < .05$). None of the comparisons were statistically significant for the Inaccurate group.

The data were also analyzed to determine whether conditional GSR differentiation was related to the trial in which an accurate statement of the stimulus contingencies was initially reported. For these analyses, the seven subjects who initially made an accurate intertrial report within trial blocks 6 to 10 were classified as "early verbalizers." The eight subjects who initially reported the stimulus contingencies within trial blocks 11 to 14 were classified as "late verbalizers." For each subject in both groups, amplitudes of GSR to CS− were subtracted from amplitudes to CS+ to yield an algebraic difference score for each trial block. For first- and second-interval GSR's, median difference scores were calculated for acquisition trial blocks 6 to 10 and 11 to 14, and for extinction trial blocks 15 to 18. For third-interval GSR's, a median difference score was calculated only for trial blocks 15 to 18.

For the first-interval responses during extinction trial blocks, the median difference score of 0.247 for the late verbalizers differed significantly from the median difference score of 0.000 for the early verbalizers (Mann-Whitney $U = 11$, $N = 7, 8$; $P < .05$). None of the other comparisons yielded statistically significant evidence for a temporal relationship between intertrial verbal reports and conditional GSR differentiation.

Our findings appear to converge with results of studies in which preparatory instructions and procedural shifts were used. Our data provide additional evidence for congruence between conditional autonomic differentiation and cognitive differentiation of conditional stimulus contingencies. Accurate verbalization of stimulus contingencies during interviews after conditioning was associated with conditional GSR differentiation. When verbalizations concerning the stimulus contingencies were omitted or inaccurate, no demonstrable GSR differentiation appeared. These results are consistent with a theoretical viewpoint that treats human classical conditioning as a problem-solving activity in which verbal processes are of fundamental importance (*7*). This viewpoint requires elaboration by studies of the relationship between autonomic and cognitive changes for different conditioning paradigms and autonomic response modes.

The congruence between autonomic and cognitive changes also could be established by content-analysis of intertrial verbal reports. Intertrial verbal reports were less useful when the trial number of the first accurate report was considered for investigating synchrony between cognitive and autonomic differentiation. The relative lack of positive results may be attributable in part to the limited number of subjects involved. The only reliable finding was that the first-interval responses of a group whose initial accurate report occurred during the later acquisition trials showed greater resistance to extinction than the responses of a group whose initial accurate report occurred during earlier trials. Regardless of whether the initial accurate report occurred promptly during acquisition trials or was delayed, differentiated GSR's appeared in the first few acquisition trial blocks. Some subjects may have delayed reporting until they were confident of the accuracy of their reports. This consideration is amenable to instructional manipulation.

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Temperature Effects on the Peripheral Auditory Apparatus

Abstract. *Cooling with a thermoelectric cold probe, well localized in the region of the cochlea, produces a rapid, reversible decrease in the amplitude and increase in the latency of the action potential induced by clicks. These changes closely resemble those produced by reducing click intensity. Temperature also affects the amplitude of the cochlear microphonic, but the amount of change is considerably less than, and is poorly correlated with, the amplitude change of the action potential. It is speculated that temperature may act on a hypothetical "excitatory process" in the cochlea, which comes after the cochlear microphonic in the sequence leading to production of the action potential of the auditory nerve.*

A study has been made of the effect of temperature change on the cochlear microphonic and on the action potential of the auditory nerve. The temperature of the auditory end organ was varied by placing the tip of a "thermoelectric cold probe" (*1*) firmly against the bony ridge just beneath the round window.

With a previously described technique (*2*), action potentials induced by clicks were recorded from the round window, and, in some experiments, also from the auditory nerve, of anesthetized cats. Temperature was monitored by a thermocouple affixed to the surface of the thermoelectric cold probe near the tip. A heat lamp was used to maintain a normal overall body temperature (measured rectally). Thus, the recorded temperature changes were, in all likelihood, well localized in the region of the cochlea.

The following results are in agreement with the results of other investi-