*DISCRIMINATION OF CHANGES IN HEART RATE:
TWO UNSUCCESSFUL ATTEMPTS¹*

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With varying degrees of popularity, so-called emotions have been inferred from physiological events, or behavioral events, or some combination of the two. The combination of visceral discharge and verbal behavior in particular has received much theoretical attention. This preference must be contrasted with the lack of experimental evidence about the relationship between visceral events and verbal behavior. The major reason for this experimental shyness probably may be found in the peculiar conditions of acquisition of "emotional" verbal behavior in the human organism. Frequently, "emotional" words are responses to private stimuli and "*differential reinforcement cannot be made contingent upon the property of privacy*" (Skinner, 1945). In other words, behaviors such as "I have a toothache" and "I am anxious" are under control of stimuli, or are believed to be under the control of stimuli, which are not subject to the usual inspection and reinforcement procedures of the community. With the advent of modern physiological recording techniques, however, it has become possible to externalize some of these stimuli. In this report, we would like to present two attempts to make verbal behavior contingent upon visceral events—changes in heart rate.

In our first attempt, a subject was asked to respond to the relative rate of his heart beat. *S* was placed in a comfortable chair, and electrodes to measure heart rate and galvanic skin response, as well as a pneumograph, were attached. He was then instructed to make guesses freely as to whether his heart rate was going slower or faster, i.e., whether his rate was increasing or decreasing at the moment of responding. The required verbal response was either "SLOW" or "FAST." At the same time, his heart rate was monitored visually on a Grass cardi tachometer. He was told that he had made a correct judgment whenever his heart rate had increased or decreased for at least two beats preceding the appropriate verbal response. The results are shown in Fig. 1. Using this procedure (Procedure I), *S* made 600 responses on the first day. As the figure shows, his responses, in groups of 100, showed little deviation from chance performance around 50%. On the following day, another 600 trials showed a dramatic increase from around 45% hits to over 80% hits. On the third day, *S* showed similarly promising behavior for the first 180 trials, after which the procedure was changed to Procedure II. In this procedure, *S* was no longer permitted to make judgments freely, but rather was required to respond "FAST" or "SLOW" whenever the experimenter instructed him to respond. This procedure was followed for 360 trials, and the order of fast and slow instances was randomized. *S* was instructed to make a response whenever the cardi tachometer showed an increase or decrease over at least two beats, but the order of "fast" and "slow" responses was determined by a table of random numbers. Figure 1 shows that after a decline in performance, *S* achieved 100% correct performance in the last block of 60 trials. On the fourth and last day of testing, two further procedures were used. For the first 180 trials, *S* was instructed to make the appropriate responses freely, but no reinforcement was administered (Procedure III). Finally, in the last

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Figure 1. Discrimination of heart-rate changes under four procedures.

240 trials, *S* was again instructed when to respond and reinforcement was withheld (Procedure IV). While there is some decline in performance under these last two conditions, it is still well above chance level. It appeared that under these conditions it was possible to bring verbal behavior under the control of a previously private visceral response.

Subsequent interview of the subject and analysis of his respiratory record revealed, however, that the apparent heart-rate discrimination was spurious. What had actually controlled his verbal behavior was a well-developed change in his respiratory cycle. It is well known that normal variations in heart rate can be ascribed to the phenomenon of sinus arrhythmia, i.e., that inspiration cycles are accompanied by increasing heart rate, expiration cycles by deceleration. The more even, well-spaced, and deeper the respiratory cycle, the more pronounced the distinction between acceleration and deceleration phases of the heart cycle. What our subject had obviously achieved was a particularly pronounced respiratory cycle conditioned to the periods when he was required to respond. Figures 2, 3, and 4 demonstrate this relationship. Figure 2 shows the relationship between respiration and heart rate discussed above, while Fig. 3 shows the absence of a well-developed respiratory or cardiac cycle. The latter tracing was obtained from the *S* during the very early stages of the experiment. Finally, in Fig. 4, the effect of instruction on the respiratory cycle is well illustrated. When *S* is instructed to start responding, the respiratory cycle shifts from a relatively shallow picture to one of deep, even cycles. This activity slowly decays after he is told to stop responding, but is immediately recovered as soon as instructions to respond are given again. The attendant changes in cardiac cycles are obvious.

In the first subject, we achieved, therefore, a well-developed change in respiratory activity (and heart rate) which came under good environmental control. However, according to our data and the *S*'s report, his responses of "FAST" and "SLOW" were under control of his respiratory activity, not his heart rate.

In our second attempt, therefore, we decided to give another subject minimal instruction as to the nature of the discrimination to be learned, and to let the conjunction of heart-rate change and reinforcement operate without eliciting responses which are *a priori* re-

lated to some visceral event.² *S* was instructed that we were interested in a study of physiological concomitants of guessing behavior. Electrodes and pneumograph were again attached; but, in addition, *S* was presented with two light bulbs at eye level about 4 feet in front of him. *S* was instructed that the right and left bulbs were going to be lighted in an order predetermined by the experimenter; and following a signal from the experimenter, his task was to guess which of the two bulbs was going to be lighted. He was also told to respond as quickly as possible, without trying to "figure out" any sequences. In fact, the order of the right- and left-bulb sequence was determined by a table of random numbers, and, in addition, a particular bulb was lighted only to coincide with an acceleration or deceleration of the *S*'s heart rate. Thus, for example, if the random sequence indicated that the next trial would be with the right bulb, the experimenter gave the signal for *S*'s response during an acceleration phase of the cardiac cycle; and following the *S*'s response (which could be either "RIGHT" or "LEFT"), the right bulb was activated. Similarly with the left bulb and

Figure 2. Relationship between respiratory and cardiac cycle. The upper tracing shows respiratory activity, the lower tracing shows beat-to-beat interval recorded from the cardiograph. The length of each line is a function of a discrete beat-to-beat interval, the shorter the line the faster the heart rate. The center channel shows the galvanic skin response.

deceleration of the cardiac cycle. The reinforcement sequence, in the case of a correct response, may be described thus:

Heart Acceleration—Verbal Response "RIGHT"—Right bulb lights. *S* was run for 10 successive days with approximately 450 trials each day, for a total of 4675 trials. Here, again, we are interested in whether *S*'s performance becomes better than 50% chance hits.

At no time during the experimental sessions did *S* show any important consistent devia-

²One other method of obtaining heart-rate discrimination was attempted, but abandoned for the time being. The heart beat of an *S* was amplified over a loud-speaker, and *S* was required to respond to the increasing and decreasing rate of this auditory stimulus. It was planned to decrease the volume of the auditory stimulus gradually below threshold, with the expectation that after the discrimination had been achieved the *S*'s heart rate would "take over" as the discriminative stimulus. In one case, *S*, from the beginning, was unable to make the rate discrimination; in another case, *S* immediately verbalized the contingency of the rate of the auditory stimulus and his respiration.

Figure 3. Respiratory and cardiac cycles in the untrained *S*. The scale next to the cardiac channel shows heart rates equivalent to the beat-to-beat intervals.

tion from chance level. His record was divided into 187 blocks of 25 trials. Chance performance would produce a score of 12.5 hits per block; the range extended from 7 to 20 hits per block of 25 trials. The total sequence of 187 blocks was divided into thirds in order to examine the data for any over-all trends. Table 1 presents this analysis. As compared with chance behavior, the means of the 60-odd blocks of 25 trials in the three thirds showed little variation from 12.49 to 13.00. It should be noted that the most successful block of 25 trials—with 20 hits—occurred in the first third. There was a significant trend in the reduction of the variance; i.e., *S*'s behavior deviated less from chance as the experiment continued. We have no ready explanation for this curious finding, which indicates that as the experiment progressed the proportion of hits in successive blocks of 25 trials more and more approximated chance levels; fewer blocks showed either very successful or very unsuccessful performance.

Figure 4. Changes in respiration and heart rate as a function of instructions to the *S*. "Start" and "stop" indicate when *S* was instructed to start or to stop making responses. The center channel shows galvanic skin response.

Table 1
Means and Variances for Three Groups of Blocks of 25 Trials

	Mean	Variance
Chance Expectancy	12.50	6.25
First Third	12.76	7.99
Second Third	12.49	6.35
Third Third	13.00	4.65

It is pertinent to note here what the temporal relationships were among the stimulus to be discriminated, the verbal response of the *S*, and the reinforcement. (The latency of the recording circuit is not critical here.) Depending on the heart rate of the *S* at the time, the criterial deceleration or acceleration of heart rate over two successive beats took about 1.5 to 2 seconds. For both *Ss*, the instruction to respond, when appropriate, occurred at the end of this period. Except for the first block of 100 trials, the appropriate responses (SLOW or FAST, and RIGHT or LEFT) occurred within 1.5 seconds. The occurrence of the reinforcement, when appropriate, was limited only by the reaction time of the experimenter (i.e., it was less than 0.5 second). In the first experiment, the correctness of the *S*'s response was judged in terms of the two heart beats immediately preceding his response when he was making responses freely; when his response was contingent upon the experimenter's signal, he was instructed to judge his heart rate at the time that the signal occurred. In other words, Procedures I and III for the first *S* involved a stimulus of less than 2-second duration, terminated by the response and followed within 0.5 second by reinforcement. Under Procedure II and IV the response occurred about 1.5 seconds after the stimulus. A similar contingency exists for the conditions under which the second *S* was run, except that the response usually occurred within 1 second. Considering the results obtained from the first *S* (Fig. 1), the increased temporal distance between stimulus and response does not seem to have been crucial.

Our main question—whether the “right” and “left” responses could be brought under control of changes in heart rate—received an unequivocal negative answer from the present data. We should say in summary that we found this surprising in that we had expected that for an adult *S* such control should be quite easily achieved. We might suggest that such discrete changes in heart rate, in a resting subject, do not easily develop into discriminated stimuli, but that the “private” stimulus conditions which control “emotional” verbal behavior are likely to be grosser visceral changes.

REFERENCE

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