CLASSICAL CONDITIONING OF DECREASES IN HUMAN SYSTOLIC BLOOD PRESSURE¹

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Decrease in human systolic blood pressure of 4.35 mm Hg (range: 0 to 12 mm Hg) were classically conditioned in normal and hypertensive subjects using a delayed conditioning paradigm in which a 30-sec auditory stimulus (the conditioned stimulus) was followed immediately by tilting the subject 15° head-down to elicit small decreases in blood pressure. Conditioning occurred within five trials. A control group demonstrated that sensitization of the reflex by repeated tilting could not account for the blood-pressure decreases associated with the conditioned stimulus in experimental subjects.

DESCRIPTORS: blood pressure, classical conditioning of decreases, hypertension, Pavlovian conditioning, respondent conditioning, humans

Studies of the interactions between classical and operant conditioning paradigms would be facilitated by the availability of a convenient method for classically conditioning human blood-pressure decreases. DeLeon (1972) showed classical conditioning of increased systolic blood pressure in humans using electric shock as the unconditioned stimulus (US). However, shock is a nonspecific stimulus for a variety of autonomic changes. No English-language reports have shown classical conditioning of decreases in human blood pressure, although Soviet investigators (Markarychiv and Kurtsin, 1951; Yaroshevskiy, 1953; both cited by Figar, 1965) have reported such conditioning using acetylcholine and citric and nicotinic acid as the US. The present study used tilting of the subject 15° head-down from the horizontal as the US. This is a safe and convenient method of eliciting decreases in systolic blood pressure via the carotid sinus reflex.

METHOD

Subjects

Six nonhypertensive volunteers formed one experimental group, and four nonhypertensive volunteers formed a control group used to test

for sensitization, *i.e.*, the tendency for repeated presentation of a US to cause any stimulus to elicit the reflex independently of its temporal association with the US. Four patients with essential hypertension (systolic pressure range, 132 to 162 mm Hg; three on medication for hypertension) formed a second experimental group. Sex was mixed.

Apparatus

An automatic Parke-Davis sphygmomanometer was used to measure blood pressure. This consisted of a cuff inflated by hand, and a microphone used to detect the Korotkoff sound and cause a light to flash on the pressure meter. Use of this system reduced observer judgement in deciding when the Korotkoff sound occurred. A motor driven tilt-table was used to tilt subjects. The axis of rotation was the top of the head. The CS was a soft noise (70 to 72 dB) produced by a 30-sec mechanical timer followed by the "ding" of the timer (87 to 88 dB) and the sound of the tilt-table motor.

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Procedure

Each subject served in a single 90-min session. The instructions read to all subjects stated that this was a study of changes in blood pressure in response to auditory stimuli and to tilting, and that there was nothing for the subject to do except lie quietly, although he/she must not fall asleep. Following instructions, the experimenter took baseline systolic blood-pressure readings at 1-min intervals until three consecutive readings were within 3 mm Hg and were not systematically increasing or decreasing.

Experimental subjects were given 30 trials of which trials 1, 7, 11, 16, and 20 to 30 were CS-only test trials. The remaining 15 trials were CS + US conditioning trials. For control subjects, 15 CS-only and 15 US-only trials were presented in random order, and CS and US were never paired.

On CS + US trials, a delayed conditioning paradigm was used. The CS lasted 30 sec and was followed immediately by tilting.

Because the sphygmomanometer cuff had to be inflated by hand, it was not practical to determine blood pressure more than once on each trial. However, the time course of the reflex decrease in blood pressure was known to vary across subjects. Therefore, on the first CS + US trial (or the first US-only trial for control subjects), the experimenter measured blood pressure three times in rapid succession and used the interval from termination of the CS (or from tilting for US-only trials) to the lowest blood pressure measurement to determine approximately when to measure blood pressure on subsequent trials for each subject. On subsequent trials, only one blood pressure determination was made. The interval between termination of the CS and measurement of blood pressure ranged from 3 to 45 sec across subjects, but was kept as constant as possible within subjects. Following blood-pressure measurement, the subject was returned immediately to the horizontal position if the trial had involved tilting.

For all subjects, trials were separated by 60-sec intervals designated intertrial intervals. Blood pressure was taken once at the end of each intertrial interval to assess changes in baseline.

RESULTS

The hypothesis that conditioning occurred in the two experimental groups was tested by an analysis of variance with one between-subjects factor (hypertensive *versus* normal) and two within-subjects factors (successive test trials, and intertrial blood pressure *versus* test-trial blood pressure). CS-only test trials 1, 7, 11, 16, and 20 were used in this analysis. Intertrial blood pressures refer to the intertrial interval immediately preceding each test trial. The main effect for diagnostic group was significant ($F(1/8) = 25.58, p < 0.01$), as was the main effect for intertrial *versus* test trial ($F(1/8) = 36.21, p < 0.01$). The main effect for trial number was not ($F(4/8) = 3.68, p > 0.05$). Of the interaction terms, only the interaction between trial number and the intertrial *versus* test-trial factor was significant ($F(4/32) = 8.11, p < 0.01$). This analysis indicated what Figures 1 and 2 suggest, *i.e.*, that normals had lower blood pressures than hypertensives, and that CS-only test trials were reliably associated with lower pressures during conditioning than intertrial intervals except on Trial 1, which occurred before the CS was paired with the US.

The significant interaction between trial number and the test trial *versus* intertrial factor was further tested by combining the data from normals and hypertensives and testing the difference between test-trial and intertrial blood pressures at each CS-only test trial. Sheffe tests revealed that CS-only test trials were associated with significantly ($p < 0.01$) lower systolic blood pressure than intertrial intervals on Trials 7, 11, 16, and 20, but not on Trial 1.

As shown in Figures 1 and 2, CS-only test trials 7, 11, 16, and 20, which occurred during conditioning, were associated with mean de-

NORMAL SUBJECTS

Fig. 1. Classical conditioning (Trials 1 to 20) and extinction (Trials 21 to 30) in normal subjects.

creases (all experimental subjects) of more than 4 mm Hg (range: 0 to 12 mm Hg) relative to the immediately preceding intertrial (baseline) blood pressure. By contrast, CS-only trial 1, which occurred before conditioning, was associated with an average increase of 1.8 mm Hg (all experimental subjects).

The hypothesis that extinction occurred was tested by a separate analysis of variance with one between-subjects factor (hypertensive *versus* normal) and two within-subjects factors (successive extinction trials, and CS test trial *versus* intertrial blood pressure). CS-only trials 21 to 30 were used in this analysis. Extinction data were not available for one subject from each group. The main effect for diagnostic group was significant ($F(1/6) = 22.83$, $p < 0.01$), but the main effects for trial number and CS *versus* intertrial period were not significant. Of the in-

teraction terms, only the interaction between trial number and the CS *versus* intertrial factor was significant ($F(9/54) = 2.42$, $p < 0.05$), as predicted by the hypothesis that extinction occurred. However, as Figures 1 and 2 show, this significant interaction was partially attributable to the tendency for the CS to elicit blood-pressure increases at the end of the extinction period. One normal subject showed a paradoxical increase in blood pressure to the CS on the first few extinction trials, whereas all the others showed decreases; this subject biased the extinction curve for the normal experimental group in Figure 3.

The systolic blood pressures for the normal subjects in Figure 2 are low compared to the population at large, but they appeared to be accurate. Agreement between blood pressures taken with the Parke-Davis sphygmomanometer

and pressures taken with a stethoscope were within 3 mm Hg except for one subject (7 mm Hg difference). These were young adults who had reclined for 10 to 15 min before the session began.

Figure 3 shows systolic pressures for subjects in the sensitization control group. For these subjects, in whom CS and US were never paired, the CS elicited increases in blood pressure, as it had for experimental subjects before conditioning. The US was consistently associated with decreases in blood pressure from baseline.

DISCUSSION

The results show that systolic blood-pressure decreases can be classically conditioned both in normal and hypertensive subjects using tilting of the subject 15° head-down as the US. Conditioning occurred within five trials, but condi-

tioned responses were small, averaging 4.35 mm Hg. However, conditioned responses were of the same magnitude as unconditioned responses to the US. This suggests that larger conditioned responses might be obtained by using a stronger US.

The tendency for the auditory stimulus used as CS to elicit increases in blood pressure before classical conditioning is consistent with reports of this same phenomenon in some strains of rats (Farris, Yeakel, and Medoff, 1935; Smirk, 1949). Although the CS was not a neutral stimulus before conditioning, its unconditioned effects on blood pressure are opposite to the conditioned response, and thus enhance the evidence for classical conditioning.

The method described here may find application in studies of the interaction of classical and operant conditioning paradigms. For example,

HYPERTENSIVE SUBJECTS

Fig. 2. Classical conditioning (Trials 1 to 20) and extinction (Trials 21 to 30) in hypertensive patients.

CONTROL SUBJECTS

N=4

Fig. 3. Sensitization control procedure. CS and US were never paired.

the authors have compared the rate of learning of blood-pressure reductions in hypertensive patients who underwent this classical conditioning procedure combined with biofeedback *versus* patients who received biofeedback only. A larger proportion of patients in the combined training group showed reductions in both systolic and diastolic pressure outside the laboratory following only 5 hr of training, which suggested that the classical conditioning procedures facilitated the biofeedback training.

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