THE EFFECT OF VERBAL STRESS ON SALIVARY OUTFLOW, HEART RATE, AND VASOMOTOR ACTIVITY¹

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The effect of verbal stress on physiological indices and its relationship to the level of anxiety (MAS) and of experimentally induced tension (EIT) was tested on 100 Ss. When the stressor was given, EIT was found to be related significantly to the amount of change in salivary outflow (inhibition) and volume pulse amplitude (inhibition), while MAS failed to exhibit any significant relationship to the changes in physiological responding. Sex differences were not found in any of these indices. Several discrepancies in results between the present study and other such investigations were discussed.

Kotake (1943) in his study of conditioned salivary reflex in humans reported that CR was well established when the *S* adapted to the experimental situation. This finding may well be explained in terms of Pavlov's external inhibition which grows out of unfamiliar experimental surroundings. In such alimentary conditioning, the inhibitory or disturbing effect of the experimental situation will be minimized by giving the *S* a sufficient period of time to adapt to the situation. However, one of the difficulties with which most of the investigators of aversive conditioning in humans meet is that the *E*'s instruction on pain-to-come has itself a fairly effective influence upon the *S*'s physiological activities. Before starting aversive conditioning, the *E* would give the instruction to the *S*, informing him that an electric shock or an air-puff will be applied in the experiment. This communication to the *S* allows him to fall into a state of high anxiety resulting from the *S*'s expectation of a painful stimulus. The reactions we observe and measure under the condition as such, have a considerably sensitized level of reactivity than those obtained under a resting condition.

Complete adaptation, in a true sense, to the instruction of pain-to-come may almost never be expected in this type of experiment.

If the instruction of pain-to-come is not given to the *S*, the matter will become much worse, because the *S* will lie on a bed with a variety of expectations as to the future of the experiment; some are relaxed and others fearful, as shown in the author's previous study (Miyata, 1961). Therefore, to keep the *S*'s attitude homogeneous at the start of the aversive experiment, instruction to the *S* is not to be omitted.

Thus, the *S*'s "fearfulness-in-the-experimental-situation," if we may be allowed to use Kamin's term (1955), motivated the present study to see how the stress verbally induced during the experiment affects physiological reactions such as salivary outflow, heart rate, and vasomotor activity. And also investigated was the extent to which the physiological changes appearing under the stress are related to the level of experimentally induced tension (EIT), or of anxiety scaled by a manifest-anxiety test (MAS).

METHOD

Subjects: Fifty male and fifty female university students volunteered for the investiga-

¹ This is one of the serial studies on conditioned activity of the human subject under the guidance of Prof. Y. Kotake of Kwansei Gakuin University.

tion. The mean age of the *Ss* was 20.4. None of them had had any prior experience with experiments of this kind, and none was aware before the test that the electric shock might be applied in the experiment.

Physiological indices: Three indices, i.e., salivary outflow, heart rate, and vasomotor activity were continuously recorded. Recording of vasomotor activity and heart rate from the left middle finger with a photoelectric plethysmograph was followed, using exactly the same routine as that described earlier by the author (Miyata, 1961). Volume pulse amplitude, as one of the components of vasomotor activity, was recorded in the present study. Salivary outflow was weighed by means of a dental cotton technique (Razran, 1935; Miyata, 1959).

Procedure: The *S* lay down on a bed in a dark shielded room and attached to him was photo-cell cup which was connected to an amplifier and recording apparatus in the next room. The experiment consisted of 12 trials, of which 11 trials were for control measurement of the basal level of activity under the rest condition, and one trial (the 7th trial) for assessment of the effect of stress on the physiological reactions. The duration of each trial was 120 sec during which period a continuous recording was made of the above indices. Salivary outflow was measured for 120 sec, while heart rate and pulse amplitude after 40 sec from the onset of the trial were computed from the data recorded for 80 sec. The data during the first 40 sec was discarded because of the instability of the record of vasomotor activity caused by the procedure for measuring salivation. Between trials, 30 sec intervals were inserted. The *S* was instructed thus before the beginning of the first trial: "I would like to measure your salivation and heart rate. You will not be shocked, so relax and be calm." On the 7th trial, however, he was informed, "When a weak tone is heard, you will receive a severe electric shock in your right arm." The tone as a shock-signal and the electric shock, however, were not presented to the *S*. After this stressful trial was over, the *E* again informed the *S*: "The remaining

trials will be quite safe, as nothing else will happen. So don't be tense. Just relax and be calm."

Paper test and questionnaire: Before the experiment, all the *Ss* were administered Taylor's Manifest-Anxiety Scale (MAS) modified and adapted by Matsunaga (1957). After the experiment, then, the following seven questions were asked to the *Ss* in order to measure the level of experimentally induced tension (EIT).

- 1) Did you feel tense or anxious before the beginning of the experiment?
- 2) Did you feel tense or anxious when you were told that the experiment would start?
- 3) Did you feel tense or anxious when you were informed that a shock would be applied?
- 4) Did you feel tense or anxious when the tone failed to sound, no matter how long you waited?
- 5) Did you feel a palpitation of your heart?
- 6) After the stressful trial was over, did you still feel tense?
- 7) Did you pay attention to the sound of the mechanical instruments, if you heard them at all?

From the answers to these questions the level of EIT of each *S* was scaled by a 3-point-rating method. Those who scored below the 15th percentile and above the 85th percentile on the distribution of MAS and EIT scores were selected as the *Ss* in the case of the high-low comparison. The number of the high anxious (HA) and low anxious (LA) were 18 (9 males & 9 females) and 16 (9 males & 7 females) respectively, and the high tensioned (HT) and low tensioned (LT) were 19 (10 males & 9 females) and 15 (8 males & 7 females). We did not obtain an equal number of *Ss* in the high and low groups, because there were a few *Ss* who got the same scores on MAS or EIT tests.

RESULTS

The results were analysed on the basal level, the effect of stress, and their relations to the level of anxiety and experi-

mentally induced tension. When statistical treatment was desired, all the raw data were transformed to a logarithmic value.

Basal level: The basal level of each one of the three indices was determined by averaging the data obtained from the 4th, 5th, and 6th trials in a resting condition. The data of the 1st, 2nd, and 3rd trials were not included in defining the basal level. This was done to avoid the influence of some factors upon the basal level which might emerge from the S's unfamiliarity with the technique of salivary measurement. As a major interest of the present study has been to find the difference of physiological reactivity between sexes, the HA and LA Ss and the HT and LT Ss, the high-low and male-female comparisons were performed on the basal level of salivary outflow, heart rate, and pulse amplitude. The differences appearing between them were small as shown in Fig. 1 and 2, and in no case proved to be statistically significant. It is concluded, therefore, that if measured

FIG. 1. Basal level of salivary outflow (S), heart rate (HR), and pulse amplitude (PA) obtained from the HA and LA Ss.

FIG. 2. Basal level of salivary outflow (S), heart rate (HR), and pulse amplitude (PA) obtained from the HT and LT Ss.

in a condition without any particular stress, the anxiety, tension, and sex variables have not any significant effect on the basal level of physiological activity.

Effect of stress: The mean amount of salivary outflow, the mean heart rate, and the mean pulse amplitude on the 6th, 7th, and 8th trials before transformation to a log value are plotted in Fig. 3. It is obvious that the effect of stress introduced verbally on the 7th trial upon salivary outflow and pulse amplitude is remarkably demonstrated as an abrupt decrement, while heart rate shows a hopping-up-effect. The effect of stress in each case is highly significant at less than the 1% level as shown in Table 1. Differences among the Ss are also of significance. Differences in the mean amount of salivation between the 6th and 7th trials, and between the 7th and 8th trials are highly significant ($t=6.612$ & 6.348 , $p<.01$, $df=99$, respectively). Differences in the mean heart rate between the 6th and 7th trials, and between the 7th and 8th trials are also significant ($t=3.275$, $.02>p>.01$; $t=4.280$, $p<.01$, $df=99$, respectively). In the mean pulse amplitude significant differences were found between the 6th and 7th trials, and between the 7th and 8th trials ($t=16.445$ & 15.682 , $p<.01$, $df=99$, respectively).

As for the sex difference, it was not proved to be significant in any one of the three indices.

Thus, the physiological activities are

FIG. 3. The effect of stress on salivary outflow (S), heart rate (HR), and pulse amplitude (PA). The stress was induced on the 7th trial in each case.

TABLE 1
Analysis of variance of the amount of salivary outflow (S), heart rate (HR),
and pulse amplitude (PA) obtained on the 6th, 7th, and 8th trials

Source	df	MS			F		
		S	HR	PA	S	HR	PA
Trials	2	1.4739	.0054	2.2251	28.02**	10.80**	171.16**
Subjects	99	.1620	.0112	.1103	3.08*	22.60**	84.85**
Error	198						
Total	299						

* $p < .05$

** $p < .01$

affected by the verbal information that made the Ss expect the coming of the electric shock (on the 7th trial). The information, however, that the shock would never be applied thereafter brought the level of activity back to normal (on the 8th trial).

One individual record of vasomotor activity is shown in Fig. 4, in which a remarkable inhibition of pulse amplitude occurred when the stress was introduced on the 7th trial, and prompt recovery

FIG. 4. Inhibition of volume pulse amplitude as a result of stress given on the 7th trial. (Sub-MS, ♀)

to the normal level was attained on the 8th trial as a consequence of the E's instruction, "Nothing else will happen." The mean amount of her salivary outflow was 750 mg per 2 min on the 6th trial, 300 mg on the 7th stressful trial, and 700 mg on the 8th trial. Heart rate increased from 70 to 74, but did not return to the prestress rate on the 8th trial, showing

75 beats per min.

Anxiety, tension, and sex compared: The effect of stress which was observed in the HA and LA Ss, when it is expressed in the change in percentage² is graphically presented in Fig. 5, and also the HT Ss

FIG. 5. The amount of changes in salivary outflow (S), heart rate (HR), and pulse amplitude (PA) obtained from the HA and LA Ss on the 7th trial.

FIG. 6. The amount of changes in salivary outflow (S), heart rate (HR), pulse amplitude (PA) obtained from the HT and LT Ss on the 7th trial.

² The change in percentage = $100(A-B)/B$, where A is the amount of reaction on the 7th trial, and B is the amount of reaction on the 6th trial.

TABLE 2
Analysis of variance (Anxiety $\times$ Sex) of the amount of change obtained
from the three indices on the 7th trial

Source	df	MS			F		
		S	HR	PA	S	HR	PA
Anxiety (A)	1	302.0644	.0757	48.7903	1.34	<1	<1
Sex (S)	1	29.8116	1.7823	13.5893	<1	<1	<1
(A) $\times$ (S)	1	182.2500	.0109	281.3905	<1	<1	<1
Error	30	225.3413	43.4319	742.7081			

TABLE 3
Analysis of variance (Tension $\times$ Sex) of the amount of change obtained from the
three indices on the 7th trial

Source	df	MS			F		
		S	HR	PA	S	HR	PA
Tension (T)	1	1720.1757	2.4492	1005.5241	10.38**	<1	10.12**
Sex (S)	1	86.7643	0.2757	2.7556	<1	<1	<1
(T) $\times$ (S)	1	54.1009	5.7360	365.1921	<1	1.27	3.68
Error	30	165.6937	4.5305	99.3591			

** $p < .01$

are compared with the LT Ss, as shown in Fig. 6. It is clear that the inhibitory effect of stress was apparent in both salivary outflow and pulse amplitude, while heart rate showed an facilitated effect, acceleration. The analyses of variance of the amount of change produced on the 7th stressful trial are summarized in Table 2 (Anxiety $\times$ Sex) and 3 (Tension $\times$ Sex). The heart rate index did not yield any significant difference between the HA and LA Ss, and between the HT and LT Ss. The salivary outflow and the pulse amplitude did not yield any significant difference between the HA and LA Ss, but a significant difference was proved between the HT and LT Ss. Thus the present analysis failed to give any support to a significant relationship between the MAS and changes in physiological activity. But the EIT was found to be highly related to them. Here again sex differences were not significant in any case.

DISCUSSION

The verbal instruction of electric shock-to-come produced remarkable effects on autonomic activities, which in turn returned swiftly to their normal basal level upon the instruction that nothing painful would be applied thereafter.

The distinct inhibition of salivary outflow observed in the present experiment confirms the results reported by Winsor (1930). In his study a decrement of approximately 83% appeared due merely to the expectation of the bell that would follow the shock. On the contrary, facilitation of secretion was found in a cold pressor test by Lewinsohn (1956) and the amount of increase on the stressor-test was statistically significant. The discrepancies of results may be reduced to the difference of the stress-inducing technique employed.

In regard to the effect of stress upon heart rate it was demonstrated signifi-

cantly as acceleration. Though numerous studies proved the acceleration effect under stressful conditions, a few studies presented a deceleration effect (Deane, 1958, 1961; Morris, 1941; Notterman, 1952). It is not clear at present whether the heart rate is accelerated or decelerated under a stressful condition. It may be assumed, however, from Deane's and Notterman's cases that the instruction or cue which informs the *Ss* of the definite time of application of the shock plays an important role. In Deane's case the *Ss* discriminated a danger signal which told them the coming of a shock, and Notterman's *Ss* had also a clear signal of shock-to-come. Thus, the presence of the definite cue of "Now-shock-will-come" brought about a different effect, deceleration, from that of the present result, in which no specific cue was available for the *Ss* to tell the time of shock-application. They were only threatened with the instruction that the shock would be given in the following trial.

The last index, volume pulse amplitude, was also inhibited strikingly on the stressful trial. The diminution of pulse amplitude, i.e., an indication of vasomotor constriction, can be observed under various conditions (Kitamura, 1960; Miyata, 1961; Nagashima et al., 1957). Mental activities such as computation, subvocal reading of the multiplication table, and association furnish examples. Emotional disturbance and the perception of a novel stimulus result in a diminution of the pulse amplitude. Thus the change observed in the present study indicates the presence of a state of tension among *Ss* who are waiting anxiously for the appearance of a shock signal, a tone.

Concerning the relationship between the amount of effect of stress upon the three physiological indices and the level of MAS or of EIT, the MAS had not a specific relation to it. In the EIT score, however, the HT *Ss* showed more marked effects of stress than those scored as the LT. The differences between changes in per-

centage obtained from the HT and LT *Ss*, as shown in Table 3, were significant in salivary outflow and pulse amplitude, but not in heart rate. This failure to prove a significant relationship of MAS to physiological responding, which may be predicted from a drive theory put forth by Spence and Taylor (Taylor, 1956), has been repeated in several other studies (Beam, 1955; Berry & Martin, 1957; Raphelson, 1957), in which a low correlation was found between MAS and physiological activities. Sarason (1960) pointed out that these negative findings on the validity of MAS-type scales may be explained by its drawing upon sources of anxiety other than autonomic functioning, and partly due to the undependability of a single physiological measure as an indicator of general physiological activity. The success of finding a higher relation of EIT scale to the physiological effects under the stress assumes that the level of the *S's* tension during the experiment is a more dominant determiner of the degree of the changes of physiological reactions under stressful conditions than is MAS. The author's questionnaire to define the level of tension has a question item to check the existence of autonomic feedback (question 5) and apparatus stress (question 7), which were suggested by Mandler et al. (1958) and Kamin (1955). Mandler with his associates found a significant correlation between the degree of report of autonomic activity on a questionnaire and the degree of autonomic activity measured during a stressful situation. Furthermore, he found no correlation between the degree of autonomic activity and MAS.

One interesting finding should be mentioned concerning sensitization and verbal conditioning performed by Cook and Harris (1937). In the present study there were a few *Ss* whose data were discarded because of the *E's* failure in mechanical control. On the 7th stressful trial, a weak spot of light was mistakenly presented in front of the *S*. Then, an abrupt levelling

up of the base line of the record of vasomotor activity was observed. On the same S, however, the same error was repeated on the 10th trial, in which the stressor had been removed by the E's instruction to relax. No reaction was observed in this case. It may be generalized from this fact that physiological reactivity was highly sensitized on the stressful trial to yield a reaction even to a neutral stimulus. In view of the study of Cook and Harris, their CRs established through verbal reinforcement which included the threatening instruction that CS would follow the shock, would, therefore, not be strictly conditioned ones, but might reasonably interpreted as a mixture of sensitized and conditioned reactions.

SUMMARY

The chief purpose of the present study was to investigate the effect of verbal stress upon physiological activities. It was also intended to test whether the amount of physiological change is related to the level of anxiety scaled by a manifest anxiety test (MAS) and to the level of tension experimentally induced (EIT).

Salivary outflow, heart rate, and volume pulse amplitude were recorded from 100 human Ss. Twelve trials, of which 11 trials were for measuring a basal reactivity, while one trial was given for assessment of the effect of stress. The stressor, a verbal instruction of shock-to-come, was introduced on the 7th trial. After the experiment, the Ss were administered a questionnaire devised to determine the level of tension felt during the experiment.

Results showed: (a) that any significant difference in a basal level of reaction was not found between high and low scorers of MAS and EIT, and (b) that when the stressor was put in, diminution of salivary outflow, acceleration of heart rate, and inhibition of volume pulse amplitude were observed, and (c) the differences of the amount of changes appeared on the

stressful trial in three indices between the HA and LA Ss were not significant, but significant differences between the HT and LT Ss were obtained in salivary outflow and pulse amplitude. Sex differences were not proved in any aspect of the present study.

Several discrepancies between the present results and those of other investigations were discussed.

REFERENCES

- BEAM, J. C. Serial learning and conditioning under real-life stress. *J. abnorm. soc. Psychol.*, 1955, **51**, 543-551.
- BERRY, J. L., & MARTIN, B. GSR reactivity as a function of anxiety, instructions, and sex. *J. abnorm. soc. Psychol.*, 1957, **54**, 9-12.
- COOK, S. W., & HARRIS, R. E. The verbal conditioning of the galvanic skin reflex. *J. exp. Psychol.*, 1937, **21**, 202-210.
- DEANE, G. E., & ZEAMAN, D. Human heart rate during anxiety. *Percept. mot. Skills*, 1958, **8**, 103-106.
- DEANE, G. E. Human heart rate responses during experimentally induced anxiety. *J. exp. Psychol.*, 1961, **61**, 489-493.
- KAMIN, L. J. Relations between discrimination, apparatus stress, and Taylor scale. *J. abnorm. soc. Psychol.*, 1955, **51**, 595-599.
- KITAMURA, M. Vasomotor reflex observed during the reception of various stimuli. *Jap. J. den. Med.*, 1960, **2**, 1-27. (In Japanese).
- KOTAKE, Y. Preliminary study on salivary conditioned reflex in humans. *Jap. J. Psychol.*, 1943, **17**, 459-462. (In Japanese).
- LEWINSOHN, P. M. Some individual differences in physiological reactivity to stress. *J. comp. physiol. Psychol.*, 1956, **49**, 271-277.
- MANDLER, G., MANDLER, J. M., & UVILLER, E. T. Autonomic feedback in the perception of autonomic activity. *J. abnorm. soc. Psychol.*, 1958, **56**, 367-373.
- MATSUNAGA, I. Standardization of the manifest-anxiety scale. Read at the 21st Annual Meeting of JPA, 1957.
- MIYATA, Y. On salivary conditioned reflex in humans. *Hum. Rev.*, 1959, **10**, 144-172. (In Japanese).
- MIYATA, Y. Orienting reflex: The effect of verbal instruction on vasomotor reflex to auditory stimuli. *Jap. psychol. Res.*, 1961, **3**, 28-41.

- MORRIS, D. P. Blood pressure and pulse changes in normal individuals under emotional stress: Their relationship to emotional instability. *Psychosom. Med.*, 1941, **3**, 389-398.
- NAGASHIMA, C., UEDA, G. *Nervous control of human blood vessels*. Tokyo: Univer. Tokyo Press, 1957. (In Japanese).
- NOTTERMAN, J. M., SCHOENFELD, W. N., & BERSH, P. J. Conditioned heart rate response in human beings during experimental anxiety. *J. comp. physiol. Psychol.*, 1952, **45**, 1-8.
- RAZRAN, G. H. S. Conditioned responses: An experimental study and a theoretical analysis. *Arch. Psychol.*, 1935, **28**, No. 191.
- RAPHELSON, A. C. The relationship among imaginative, direct verbal, and physiological measures of anxiety in an achievement situation. *J. abnorm. soc. Psychol.*, 1957, **54**, 13-18.
- SARASON, I. G. Empirical findings and theoretical problems in the use of anxiety scales. *Psychol. Bull.*, 1960, **57**, 403-415.
- TAYLOR, J. A. Drive theory and manifest anxiety. *Psychol. Bull.*, 1956, **53**, 303-320.
- WINSOR, A. L. Factors which indirectly affect parotid secretion. *J. exp. Psychol.*, 1930, **13**, 423-437.

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