Measurement and analyses of gross skin conductance (GSC) of rats in a grid-box: The effects of shock intensity and thirst

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The present experiments were conducted to obtain basic data on some factors that could influence rat's coping processes in grid-shock situations by measuring the current flow through the rat. Unsignaled 1-s shocks were delivered repeatedly through a grid floor by a fixed impedance ac shock source. The current-flow measure was indexed by "gross skin conductance (GSC)". In Experiment I, the shock intensity was the independent variable, and rat's GSCs under four shock levels (75 V, 150 V, 300 V and 600 V) were measured. The rats under the higher shock conditions showed higher GSC than did the rats under the lower shock conditions. In Experiment II, the effects of water deprivation (0 h, 24 h, 48 h and 72 h) upon rat's GSCs were investigated. Generally, the higher thirst has led to lower GSC. In Experiment II when the grid-floor rods were thicker and the space between rods wider than in Experiment I, there was less tendency for rats to jump and move about, which have led to higher GSC and smaller variability in GSCs than Experiment I.

Key words: rat's coping processes, grid-shock situations, gross skin conductance, shock intensity, water deprivation, structure of the shock boxes.

Rats in a shuttle box run back and forth between two compartments to escape from or avoid grid shocks. Even before the route to the safe compartment is found, they make various attempts to reduce aversiveness of shocks on the electrified grid floor: They move vigorously about, jump up and sometimes roll over on their fur back. In a classical aversive conditioning experiment, usually brief inescapable grid shocks are given. Even in such an inescapable-shock situation, it is not implausible that rats would make attempts to reduce pain coming from electric shocks. For example, Perkins (1968) assumed that rats, upon the presentation of a signal, would learn to make preparatory behavior to reduce aversiveness of the oncoming shock. If "the aversiveness of shock stimulation is proportional to the current flowing through the rat" (Campbell & Masterson, 1969, p. 27), a rat should learn to adopt such a preparatory behavior to reduce the current-flow through it.

In spite that numerous number of experiments have been carried out in a grid box, no systematic efforts have been made to study in a quantitative manner conceivable primary coping attempts of rats in a grid-box situation. Recently Imada, Mino, Sugioka, and Ohki (1981) devised a technique to measure gross skin conductance (GSC) in freely-moving rats in a grid box. An experiment, using this technique and standing on the Perkins' (1968) preparatory response hypothesis revealed that the GSC was greater, hence the current-flow greater, in rats under the signaled shock condition than in those under the unsignaled shock condition. The results were obviously contradictory

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to what had been expected from the Perkins' hypothesis. The study, however, introduced a promising technique to analyze the nature of rat's behavior in a grid-shock situation in detail and in a quantitative manner.

However, before this technique is widely applied to study rat's overall coping attempts in various shock situations, the effects of some basic relevant variables on GSC have to be well investigated. In the two experiments reported in the present paper, the effects of some of these variables on GSC were investigated.

Experiment I

One of the most important variable in shock experiments is the shock intensity. In Experiment I, the effects of shock intensity upon rat's GSC were studied. The duration of grid-shocks was 1 s as in the previous study, but the shock box was made larger than the one used previously (Imada et al., 1981). This modification was made with an assumption that the effects of varying intensities of shocks on coping behavior of rats, if there were any, would be revealed more conspicuously in a larger box.

Method

Subjects. The subjects were 34 experimentally naive male albino rats of the Wistar strain. They were divided into four groups differing in the intensity of shock given: Group 75 (n=8), Group 150 (n=9), Group 300 (n=8), and Group 600 (n=9), the numbers designating the shock intensities in volt. The means of the body weight of these four groups at the start of the experiment were 346.0 g (315-375 g), 346.1 g (326-363 g) 345.6 g (324-372 g), and 347.4 g (316-380 g), respectively. They have had continuous access to food and water in their home cages.

Apparatus. The shock box used was the one which has been used in rearing escape/avoidance conditioning studies in the present writers' laboratory (Imada, Shimai & Imada, 1981; Shimai, 1977; Shimai & Imada, 1978; Shishimi & Imada, 1977). It was made of brown Bakelite plates and transparent acrylic plates, and the inside dimensions were 20×14.8×30 cm (height). The floor of the box consisted of copper rods, 4 mm in diameter and separated from each other by 15 mm, measured from center to center. The source of illumination was a 20 W electric bulb suspended 25 cm above the ceiling of the box. These were placed in a soundproof enclosure, and its blower fan served as masking noise at a level of 78 dB(c).

The shock generator was of an ordinary ac type, as shown in Fig. 1. A total of 250 kΩ current limiting resistance was put in series with the rat, and 1-s shock was given through a scrambler (TAKEI KIKI). The current flow through a rat was indexed by using a measure designated "gross skin conductance" (GSC). When the electric shock was applied to

Fig. 1. Circuit diagram of the shock generator and the measuring GSCs.
the rat, the voltage drop across $X$ and $Y$ changes in accordance with the rat's movements and/or changes in its skin resistance, and they are reflected in moment to moment changes in the height of 60 positive peaks of 60 Hz alternating current. These changes were converted into digital values through an A/D converter of a minicomputer, PDP-11/10 (AR 11), which provided the GSC measure.

Procedure. Rats were placed individually into the shock box and, after 5 min, the first shock was given. The shocks were of 1 s duration, and were given 90 times in a day with a mean ISI of 40 s (range; 10–70 s) through the grid floor. The levels of shock intensity were 75 V, 150 V, 300 V, and 600 V, measured on the secondary side of the transformer. All experimental controls were conducted by the experimental controlling monitoring system, TYMES (Takigawa & Mino, 1981).

Measures. In the previous experiment (Imada et al., 1981), in which a small shock box was used, a single measure of GSC was suffice. In the present experiment, however, due to the high ceiling and large floor space of the box, rats could sometimes remove itself from the grid-floor surface during the 1-s shock. For this reason, following three measures were used, i.e., GSC(60), number of PEAKS and GSC(PEAKS).

When a rat jumps up from the grid surface, the circuit becomes incomplete and no current flows. In such a case positive peaks should be missing, which otherwise should total up to 60. The measure, 'number of PEAKS', represents number of those missing PEAKS, which was proportional to the amount of time a rat was off the grid and hence is a rough measure of rat's jumping. The mean GSC was then calculated from the remaining effective PEAKS, and this measure was named mean GSC(PEAKS). This represents the GSC when a rat's feet were touching the grid floor surface. The mean GSC(60) was calculated from both PEAKS and PEAKS. In calculating both the means of GSC(60) and GSC(PEAKS), the mean per positive peak was calculated. In the former, the total positive peak-height per 1-s shock was divided by 60 and in the latter, it was divided by the number of PEAKS, or by the number subtracting the number of PEAKS from 60.4

The GSCs of 432, 371, and 325 approximately correspond to the resistance values of 50, 100, and 150 kΩ, respectively, as shown by the reference resistance level (RRL) along the right ordinate of Figs. 2, 4, 5, and 6.

Results and Discussion

Figure 2 represents the means of GSC (60) in blocks of 10 trials for each group.  

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3 The resistance values between $X$ and $Y$ were $5.13 \, k\Omega$ (75 V), $2.53 \, k\Omega$ (150 V), $1.48 \, k\Omega$ (300 V), and $0.98 \, k\Omega$ (600 V).

4 In the previous experiment (Imada et al., 1981), median GSC, rather than mean GSC, was calculated. Assuming that means are the better index of the total amount of current flow through the rat, means were used in the present study.
The GSC(60) changes very little throughout the session in Group 75 and Group 150, but in Group 300 and Group 600 it increases gradually over trials. The results of 4 (groups) by 3 (30-trial blocks) analysis of variance showed the main effect of groups not to be significant ($F=1.1$). But the main effect of trial-blocks and the interaction effect of the two terms were significant ($F(2, 60)=18.04, p<.001; F(6, 60)=7.06, p<.001$, respectively). Furthermore, the effects of groups for the last 30-trial block was significant ($F(3, 30)=4.30, p<.025$).

Figure 3 represents the means of the number of PEAKS in blocks of 10 trials for each group. This was shown in order to examine the extent to which the GSC (60) was affected by differential coping attempts of rats under different shock-intensity conditions. As seen in the figure, the higher the shock intensities were, the greater was the rat's tendency to jump, especially in the first half of the session. The fact that 10 peaks were missing means that rats lessened the shock duration by one-sixth of a second on the average. The results of 4 by 3 analysis of variance showed that the main effects of groups and blocks and the interaction effect of the two terms were all significant ($F(3, 30)=12.70, p<.001; F(2, 60)=30.44, p<.001; F(6, 60)=4.29, p<.005$, respectively).

Figure 4 represents the mean GSC (PEAKS). The picture as a whole resembles that of GSC(60) in Fig. 2. The results of 4 by 3 analysis of variance showed the main effects of groups and blocks, and the interaction effect of the two terms to be significant ($F(3, 30)=11.20, p<.001; F(2, 20)=6.33, p<.005; F(6, 60)=7.02, p<.001$, respectively).

Putting together the results of Figs. 2, 3 and 4, one can summarize the present results in the following way: (1) In groups given intense shocks, the coping by jumpings occurred in the first half of the session. (2) This seemed to have been effective in reducing the GSC(60). (3) But the tendency to jump in strong shock groups became less as the trials progressed and this corresponded to the rise of the GSC(60) in these groups. Whether this effect was influenced by fatigue or by the "abandonment" of coping attempts after repeated experience of inescapable shocks (Maier, Seligman, & Solomon, 1969) is not clear. (4) It is not, however, possible to account for the rise of GSC(60) in the strong shock groups toward the end of the session only in terms of the decline of

![Fig. 3. Means of the number of PEAKS in blocks of 10 trials for each group (Experiment I).](image)

![Fig. 4. Means of GSC (PEAKS) in blocks of 10 trials for each group (Experiment I).](image)
jumping tendencies in these groups. For, it is clearly shown in Fig. 4 that the fact of high GSC in the strong shock groups remains even after eliminating PEAKS. It should be remembered that high GSC, meaning greater amount of current flows, is disadvantageous to the rats. The fact of high GSC(PEAKS) under strong shock conditions is consistent with the findings of Campbell and Teghtsoonian (1958), Campbell and Masterson (1969) and Kotani (1934). The results of the last is shown in Table 1 of Nishizawa and Iwamoto (1962).

Experiment II

One of the major determining factors of rat's skin conductance should be the dryness of skin surface, which is assumed to be a function of the degree of water deprivation or of thirst of rats. The first purpose of Experiment II was, then, to investigate the relationship between the thirst level of rats and GSC. The second purpose of Experiment II was to measure GSCs of rats in a conventional operant chamber for rats, which is frequently used in conditioned suppression experiments. Since Experiment II was run in exactly the same way as Experiment I, shock intensity being kept at 150 V, it was possible to compare the results of 0-h deprivation group of Experiment II with those of Group 150 of Experiment I, and to analyze the effects of the difference of the shock boxes upon GSCs.

Method

Subjects. The subjects were 24 experimentally naive male albino rats of the Wistar strain. They were devided into four groups of 6 rats each, being matched in body weight. The means of the body weight on the day of the experiment were 400.7 g (339–488 g).

Apparatus. The experimental chamber was a modified BRS/LVE (RTC-022) chamber without a lever. The inside dimensions were 30.5×24.0×27.3 cm (height). The houselight was 26 cm above the floor at the center of the front panel and was turned on during experimental sessions. The floor of the chamber consisted of stainless steel rods 5 mm in diameter and 19 mm apart from center to center. The experimental chamber was placed in a soundproof enclosure, and its blower fan served as masking noise at a level of 76 dB(c).

Procedure. Four groups of rats, after being deprived of water for either 0 h, 24 h, 48 h, or 72 h, were run in exactly the same way as in Experiment I. The shock intensity was 150 V ac.

Results and Discussion

A remarkable difference of Experiment II from Experiment I was that virtually no jumping occurred in Experiment II in all groups. Out of possible 32 400 PEAKS of each group (i.e., 6(rats)×60(peek)×90(trials)), the number of PEAKS were 1, 0, 6, and 0 for Groups 0, 24, 48 and 72, respectively. It was

Fig. 5. Means of GSC in blocks of 10 trials for each group (Experiment II).
therefore, not necessary to take three different measures as in Experiment I and the single measure of GSC, equivalent to GSC(60) of Experiment I, was sufficient. The means of the GSCs thus calculated for four groups are shown in Fig. 5 in blocks of 10 trials. Except for Group 72, the longer the deprivation time was the lower were the GSCs. There seems to be a slight tendency for the GSCs to increase with the progress of trials. The results of 4×3 analysis of variance showed the main effects of groups and trial blocks to be significant \( F(3, 20)=28.59, p<.001; F(2, 40)=11.64, p<.001 \), respectively. But the interaction effect of the two terms was not significant \( F(6, 40)=2.11, p<.10 \). Why, then, was the GSCs of Group 72 higher than those of Group 48? One conceivable factor is a relative inactivity or inanition due to the long period of water deprivation in Group 72, thus may have led to poorer coping or GSC-reducing responses in this group than in Group 48, which may have offset the severe water-deprivation effect in Group 72.

**General Discussion**

Group 150 of Experiment I and Group 0 of Experiment II were run in exactly the same way except for the difference of the shock boxes used. The facts that Group 150 rats jumped considerably (see Fig. 3) whereas no jumping occurred in Group 0, therefore, have to be attributed to the following differences in the shock boxes. (1) Difference in the size of the floor surface of the box: 20.0×14.8 cm (Experiment I) vs. 30.5×24.0 cm (Experiment II). The small sized floor of Experiment I may have facilitated rearing or jumping responses along the walls of the box. (2) Difference of the diameter of the rods of the grid floor and of the gap between rods: The diameter of rods were 4 mm in Experiment I and 5 mm in Experiment II. The space between rods were 11 mm in Experiment I and 14 mm in Experiment II. Wider space between rods in Experiment II may have discouraged jumping, because under such a condition a rat would have more chances to step off the rods at the time of landing after jumping. The combination of (1) and (2) is also a conceivable factor for causing less jumping in Experiment II than in Experiment I. (3) Difference in the spatial position through which a rat was placed in the shock box. In Experiment I, the rats were placed in the box from above by removing the ceiling of the box. In Experiment II, the front wall, hinged at the bottom, served as the door and the rats were placed in the box from the front through this door. Rats in Experiment I may have jumped up to escape from the ceiling, although it was firmly closed. (4) Difference of the material of rods: copper (Experiment I) vs. stainless steel (Experiment II), for which one cannot think of any possible reason for causing the difference in jumping. As a whole, nothing definite can be said regarding the reason or reasons for the difference in jumping tendency in the two experiments.

Apart from the above difference in behavior patterns, Group 150 of Experiment I and Group 0 of Experiment II differed also in the mean GSC(PEAKS) as shown in Figs. 4 and 5. The means of the GSC through the session were 393.09 (approximately equivalent to 80 kΩ) in Experiment I and 431.22 (approximately equivalent to 50 kΩ) in Experiment II, and the difference of these means was statistically significant \( t(13)=2.14, p<.05 \). Although it is not clear if, again, the difference in the material of rods has brought about this difference, one possible way to account for this difference is given below.

The fact that there were virtually no PEAKS in Group 0 of Experiment II suggested that rats’ reaction of this group to the grid shocks may have been prancing using four legs. Since the skin conductance of forepaws is known to be higher
than that of hindpaws (Nishizawa & Iwamoto, 1962), dominance of four-leg prancing in Group 0 and frequent occurrence of jumping, or of behavior using only hind legs, in Group 150 of Experiment I, suggest higher GSC(PEAKS) in the former than in the latter group, which fits the obtained facts. The above speculation also leads to the following deduction: The variability of GSC (PEAKS) within a single shock should be greater in Group 150 than in Group 0. In order to test the validity of this deduction, standard deviations (SDs) of GSC(PEAKS) were calculated for each shock as a measure of peak-to-peak variation within a single shock presentation, with PEAKS disregarded. Then the means of these SDs were calculated in blocks of 10 trials for the two groups and shown in Fig. 6 along with mean GSC(PEAKS). The mean SD of Group 150 is larger than that of Group 0 and the respective means of SDs throughout the session were 62.41 and 34.81 and the difference was statistically significant (t(12) = 3.31, p < .01).

The fact that differences in the nature of the shock box has led to such difference in behavior pattern and GSC is of interest and has importance in itself for those engaged in rat studies using aversive stimulation. Which of the two types of shock boxes used in the present study is more ideal for the future studies using electric shocks, of course, depends upon the interest and concern of the researcher. If a researcher is concerned with administering electric shocks as constantly as possible over trials, the box as used in Experiment II seems to be more appropriate. If, however, a researcher is interested in analyzing different coping attempts of rats under various experimental conditions, the box used in Experiment I may leave more room for various differences to appear.

It will be concluded that the technique and methods of analysis presented in this paper is promising for the microscopic analyses of the nature of rat’s behavior in a grid-shock situation and may be used for various purposes. For example, one may be able to measure general activities of rats using SD measures presented above by administering grid shocks of subliminal intensity. It may also be possible to correlate various behavioral topographies of rats with peak-patterns, which may lead to the quantification of behavioral topographies.

References


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