Punishment in the goldfish as a function of electrode orientation

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For each response to a nipple from which they were trained to take liquid food, goldfish were punished with a brief ac shock administered through a pair of stainless steel electrodes placed either to the right and left of the animal, over and under it, or in front and back of it. As anticipated, on the assumption that the aversiveness of shock is a function of the potential difference across the animal's body, the right-left orientation of the electrodes was found to produce the least suppression of feeding and the front-back orientation the most.

If intensity of shock is a function of the potential difference across the body of an animal, then, as Kellogg (1958) has noted, "any sensible fish should place itself perpendicular, not parallel, to the flow of current" in an electrical field (p. 652), since the potential difference across its body is minimal in the perpendicular orientation and maximal in the parallel one. In support of this interpretation, Kellogg reported lower shock thresholds, not only for fishes, but also for human Ss lying in shallow water, when the long axis of the body was perpendicular rather than parallel to the electrodes, and lower thresholds for large fishes than for small ones. Further evidence comes from informal observations of the behavior of rats and cockroaches standing on a resistive surface in different orientations to points on the surface at which a voltage was applied (Longo, Holland, & Bitterman, 1961). In the present experiment, we studied the effect of suprathreshold response-contingent shock on the consummatory behavior of goldfish as a function of the position of the electrodes.

METHOD

Eight 3-in. goldfish were trained to take liquid food (a mixture of Biorell and cornstarch cooked with water) in a situation like that described by Holmes and Bitterman (1969). Each contact of the animal with a nipple from which it took the food was detected by means of a crystal phonograph cartridge; a light rod supporting the nipple was clamped into its needle holder. The output of the cartridge was used to operate a relay that recorded the response and activated a Davis pump to replace the food taken. The animal was brought to the experimental enclosure in its individual 2-gal living tank and worked

in a smaller chamber set in the tank. Two walls of the chamber were 5.5 x 6.5 in. stainless steel plates which served as electrodes. The chamber could be inserted in such a way that the electrodes were either to the right and left of the animal as it faced the nipple, over and under it, or in front and back of it. (One of the electrodes had a 1-in. circular hole in its center through which the nipple was accessible in the front-back orientation.) Since the animal was shocked only when it fed from the nipple, its orientation to the nipple determined its orientation to the electrodes.

After exploratory work with a number of voltages designed to give some idea of a workable range, formal tests were made with a 0.14-sec, 0.56-V/in. ac shock, given automatically for each response, a value great enough to produce some suppression even in the least effective orientation of the electrodes, yet not so great as to produce marked suppression in all orientations. There were two tests, each consisting of six daily 15-min sessions, with no punishment on odd days, punishment on even days, and electrode orientation balanced over animals and days. The number of responses made by each animal in the last 3 min of each session was recorded by a printing counter.

RESULTS

The results for both tests are shown in Fig. 1 in terms of the median suppression ratio for each orientation of the electrodes, with performance on unpunished days providing the baseline. The two sets of data agree closely, and a nonparametric analysis of variance shows the effect of electrode orientation to be significant at a level of confidence well beyond 1%. The front-back arrangement was the most effective, producing almost complete suppression; the right-left arrangement was least effective, producing very little suppression; and

the over-under arrangement was intermediate in its effectiveness. Given the shape of the goldfish, which is longer than it is high, and higher than it is wide, this order of effectiveness follows from the assumption that potential difference across the animal is a critical variable. It may be, however, that the effectiveness of the over-under arrangement is not due entirely to shape, but in some measure also to the fact that the animals tend to tilt upward slightly while feeding from the nipple.

DISCUSSION

These results have some obvious implications for the design of training situations for the fish in which shock is used. For example, in a shuttlebox with a hurdle over which a fish must swim from one compartment to another (Horner, Longo, & Bitterman, 1961), shock delivered through the side walls discourages neither orientation in the direction of the hurdle (as would front-back electrodes) nor an upward tilt in crossing (as would over-under electrodes). In CER experiments, it is important that the animal not be able to minimize the intensity of shock by turning away from the manipulandum or (in a consummatory situation) from the feeder, which would introduce an unwanted instrumental contingency. Although over-under electrodes have been recommended on that ground by Wilson, Darcy, and Haralson (1970), the present data suggest that the right-left arrangement is preferable, since rolling over minimizes shock from over-under electrodes, while no change in orientation benefits the animal in the right-left case. It also is important, however, that variation in the intensity of shock (apart from the direction of change) be minimized, a

Fig. 1. Suppression of feeding in the goldfish by shock as a function of electrode orientation: front-back (front), over-under (top), and right-left (side).

*This research was supported by Grant MH17736 from the Public Health Service. Miss Jennifer Davis assisted in collecting the data.

criterion which does seem to call for the over-under arrangement, given the fact that the animal is more likely to change its orientation in the horizontal plane than in any other. It might be thought that a pair of electrodes in each of the three planes along with a scrambler to shift the voltage rapidly from pair to pair would provide a general solution to the problem, but that is not so. With such an arrangement, the electrodes inactive at

any given moment (being better conductors than water) would carry most of the current.

REFERENCES

- HOLMES, N. K., & BITTERMAN, M. E. Measurement of consummatory behavior in the fish. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 39-41.
 HORNER, J. L., LONGO, N., & BITTERMAN, M. E. A shuttle box for the fish and a control circuit of general applicability. *American Journal of*

- Psychology*, 1961, 74, 114-120.
 KELLOGG, W. N. Galvanotropism as an avoidance response. *Journal of Comparative & Physiological Psychology*, 1958, 51, 652-657.
 LONGO, N., HOLLAND, L. R., & BITTERMAN, M. E. The resistive sheet: A gridless and wireless shocking technique. *American Journal of Psychology*, 1961, 74, 612-618.
 WILSON, W. L., DARCY, J. M., & HARALSON, J. V. Reserpine and conditioned suppression in the fish *Tilapia h. macrocephala*. *Psychonomic Science*, 1970, 20, 47-49.

A telemetry system for measuring chewing behavior in humans*

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A system is described for detecting and recording human chewing behavior. A small transmitter mounted in the side frame of eyeglasses was used to detect muscle movement associated with chewing. The transmitter signal was received and converted to a direct-current voltage which varied at a rate proportional to the S's chewing movement. Exploratory data are presented which suggest that individuals chew at about the same rate per second, but vary in the total number of chews emitted to consume the same amount of foodstuff.

Very little descriptive or experimental work has been done by psychologists on the chewing behavior of humans. With the exception of some early work by Hollingworth (1939) and Freeman (1940), dealing with the relationship between chewing and tension reduction, chewing has been of interest primarily to dentistry and nutrition.

To date, the methods employed for studying human chewing have a number of characteristics which make them undesirable for most psychological studies. Hollingworth (1939), for example, measured the response by visual observation, a method limited to gross measures, such as chewing or not chewing. Duckworth and Shirlaw (1958), recording chewing in cows, placed an inflated balloon between the animal's jaw and head strap. The jaw movements varied the balloon air pressure, which was recorded. Although precise measures such as chews per minute can be recorded using this method, it is limited to animals whose chewing involves large jaw movement and would be difficult to use with humans.

Electromyographic (EMG) methods have been used extensively to study muscle activity associated with chewing movements (see Kawamura, 1964, for a review of the literature). Measuring EMG, however, requires that electrodes be attached to the S's skin over a muscle or under the skin with wires leading to the recording equipment. This limits the S's mobility and undoubtedly calls his attention to the behavior under study. And, of course, EMG recordings are frequently affected by the S's emotional state, head position, and the type of electrodes used (Kawamura, 1964).

Another method is the cinematographic technique (Beyron, 1964; Ahlgren, 1966). Films are made of the S's chewing and later analyzed, using a projector. A great deal of information can be gleaned from the films, but the method usually requires that the S's head remain stationary and that clamps be fitted such that the S's lips are held open while chewing.

Tooth transmitters have recently been developed (Kavanagh & Zander, 1965; Roeber, Pameijer, & Glickman, 1968) which send bite information to nearby receivers and recorders. Although an excellent method, the use of tooth transmitters is generally restricted to dentists who have the technical ability to install such devices. This procedure would also be difficult to employ without the S's being aware of the purpose of the experiment. It is not clear as yet what effect S

awareness may have on the S's chewing behavior. However, when a S knows that chewing behavior is being observed, it is likely that he consciously controls the movements. These consciously controlled movements may be considerably different from the more normal nonobserved chewing patterns. The telemetry system described below overcomes the above limitations and provides a method of measuring and recording detailed chewing information.

APPARATUS

General Description

Chewing in humans involves the contraction and relaxation of the temporalis muscle near the temple area. When the jaw is clenched, the muscle contracts and produces a slight bulge on the surface of the skin near the temple. In our laboratory, this movement is used to frequency-modulate a small transmitter concealed in the side frame of a set of eyeglasses worn by the S. The transmitted signal is received (see Fig. 1) and mixed with the receiver's beat frequency oscillator (BFO) signal to generate an audio output. This audio output varies in frequency as the individual chews, i.e., it increases when the S "bites down" and decreases when the jaws open.

With this technique the audio signal may be tape-recorded and analyzed at a later time, and/or it may be fed directly into a frequency-to-voltage converter circuit. The output of the frequency-to-voltage circuit is a dc voltage varying at a rate proportional to the chewing of the S. The dc signal may be recorded on a chart recorder for later analysis or digitalized via an analogue-to-digital converter and analyzed on a small computer.

Transmitter

The transmitter (see Fig. 2) is a 3-MHz oscillator circuit, similar to the one described by Wolff (1967). The components of the transmitter are mounted in holes cut in the side frame of a set of wide-framed eyeglasses.

*This research was supported in part by United States Public Health Service Grant MH-15616 to David Premack. The author wishes to thank David Premack and Eric Jacobson for their criticism of the manuscript and George Stevens for providing facilities.