fects of lesions in the central nervous system on the respiratory rates of cortical slices (Table 1). As previously reported (*4*), addition of potassium produced an increase of respiratory rate in all animals. Cortical slices taken from rats with sham operations or rats with lesions in the caudate nucleus responded in the same manner as slices from normal control rats (92 to 95 percent stimulation). However, cortical slices taken from rats with lesions in the septal area showed only a 40 percent stimulation following the addition of potassium chloride. These results were reproduced in three separate experiments in which fresh groups of rats were used.

It is clear that a subcortical lesion can produce significant changes in the metabolic response of cortical tissue in vitro. Although previous work in this laboratory has revealed a variety of behavioral, pharmacological, and biochemical changes following lesions in the septal area of the rat (*1, 2, 6*), the experimental literature provides no clear evidence for either anatomical or electrophysiological changes in cerebral cortex following such lesions (*7*). Therefore, it is not clear whether the effects on cerebral metabolism reported here represent some functional change in the intact animal which might account for the increased sensitivity to barbiturates.

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Intracranial Reinforcement Compared with Sugar-Water Reinforcement

Abstract. *Three ways in which electrical, intracranial reinforcement is reputed to differ from conventional reinforcement were tested in an experiment which equated the form of the responses being reinforced and the response-reinforcement relation. Four groups of rats performed instrumental or consummatory responses reinforced by intracranial reinforcement or sugar. In no comparison did the kind of reinforcement produce a difference, but in every comparison the kind of response reinforced did produce a difference. It is inferred that reputed differences between intracranial reinforcement and conventional reinforcement are artifacts.*

Responses maintained by intracranial reinforcement (ICR) are remarkably rapid and persistent, cease abruptly when reinforcement is terminated, and are peculiarly dependent upon reinforcement of each response. These three generalizations have been made repeatedly and now appear in textbooks (*1*). The statements are based on comparisons between responses for ICR and those for conventional incentives (for example, food) in what is schematically the same apparatus; however, they overlook one, possibly crucial, difference in the temporal-spatial relation between the response and reinforcement. The most common experimental procedure followed with ICR places the subject in an apparatus that delivers ICR as the subject depresses a lever. For conventional reinforcement, the lever press is but one of a chain of responses preceding the reward. Consideration of the distinction leads to the realization that the lever press for ICR is temporally similar to a consummatory response whereas the lever press for food is instrumental. The reports comparing ICR with conventional reinforcement and implying them to have different effects have confounded the variables of kind of reward with delay of reward.

In our experiment we arranged the contingencies of response and reinforcement in two ways. One arrangement required the subject to press a lever as the means of making ICR or sugar water available a little distance away at a dipper cup—the arrangement typical of conventional reinforcement. The other arrangement made ICR or sugar water available immediately when the subject touched the cup in accepting the different incentives—an arrangement analogous to the typical ICR study.

Four albino rats, weighing 250 g each, were randomly assigned to each of four experimental groups. All were brought to 85 percent of their normal body weight and maintained at that weight by limited feeding after each daily experimental session. The subjects scheduled for ICR were fitted with permanent indwelling bipolar electrodes (*2*) with the stimulating tip near the median forebrain bundle and lateral to the ventromedial nucleus of the hypothalamus (*3*).

The experimental chamber was 25 by 25 by 42 cm. A Lehigh Valley retractable lever and a liquid dipper aperture were on one wall. Outside the wall, two liquid dippers were placed so that either (one with a 25 percent solution of sugar water and one dry) could be slid into position under the aperture. A circuit for sensing contacts between the rat and a metal conductor was connected to each dipper. An isolated source of 60-cycle alternating current of 50 to 70 μa, individually adjusted for each rat, served as the ICR.

For two of the experimental conditions, a lever press made reinforcement available at the dipper. For one of these, the sugar-contingent (S-C arrangement), the lever press activated the dipper, filling it with sugar water. Additional pressing accomplished nothing until the subject had contacted the dipper. In the other arrangement, the ICR-contingent (ICR-C), the lever press activated the dry dipper and armed the ICR circuit, thus permitting the subject to obtain reinforcement by contacting the dipper. Since about 1 second was needed for the subject to drink a dipper of sugar water, ICR was made available for a total of 1 second. Multiple trains of stimulation were possible during this 1 second because each contact produced ICR.

In the second pair of conditions, the subject had merely to lap sugar water directly (S-D) or to touch the dry dipper cup to get ICR directly (ICR-D). One second after contact was made, the dipper mechanism was activated and "refilled," thus making possible more reinforcement as the subject made further contact. During the brief time the dipper mechanism was in operation, no reinforcement was possible.

In 3 to 5 days of preliminary training, the ICR-C and S-C groups learned to respond to the click of the dipper mechanism by going immediately to the dipper for reinforcement. The ICR-D and S-D groups were given comparable experience with their respective incentives. No subject had any opportunity to perform the particular response that it was later trained to do.

Each subject was then given 3 days of training—1 day to learn the particular task of its group and 2 days to stabilize the habit. Each day's training session continued until the subject had activated the dipper mechanism 100 times.

On the 4th day, training was continued with reinforcement for 25 dipper-activation cycles. Reinforcement was then withheld for a 30-minute extinction period. For the groups reinforced with sugar, termination of reinforcement was effected by sliding the dry dipper into position; for the ICR groups the brain stimulation was turned off.

Following extinction, the two groups pressing the lever were retrained, first with reinforcement of each response, then with intermittent reward. The intermittency was begun at a low ratio of responses to reinforcements, then increased progressively over several daily sessions until the ratio was 20 presses to 1 reward (FR-20).

In acquisition and while responses were being maintained by reinforcement, rates of lever pressing, dipper activations, and dipper contacts did not differ reliably between groups making the same responses but receiving the different incentives. However, the rates were different ($p < .05$) when the comparisons were between the different responses necessitated by the conditions of contingent reinforcement versus direct reinforcement. Figure 1 shows cumulative records of contacts with the dipper on the day prior to extinction. The comparison of the ICR-D and the S-C subjects shows the relation reputedly an effect of ICR. The relation would be even more dramatically apparent if the record of the more time-consuming, lever-pressing response of group S-C were substituted for dipper contacts.

Figure 2 shows cumulative records of lever presses when the reinforcement ratio was 20 to 1 and the response and reinforcement contingencies were made as similar as could be contrived. The response records were not appreciably different, nor were they at the lesser ratios leading up to 20 to 1. Taken together, these curves of Figs. 1 and 2 show that maintenance records for ICR will appear anomalous when illegitimate comparisons are made, but that they need not appear so.

A similar conclusion can be drawn from the records made following termination of reinforcement (Fig. 3). The comparison of groups ICR-D and S-C (this is the kind of comparison which has been made in the literature) confirms the generalization that extinction "is quite slow for habits based on food or water reward but . . . if the experimenter turns off the voltage to the rat's electrode, responses cease very abruptly" (*4*). However, analyses of variance (*5*) calculated on lever presses, dipper activations, and dipper contacts showed no differences between the two kinds of reinforcement. The analyses did show more lever presses by the "C" groups than dipper activations by the "D" groups [F (1,12) $= 8.50$; $p < .05$] and a more precipitous decline in dipper contacts by the

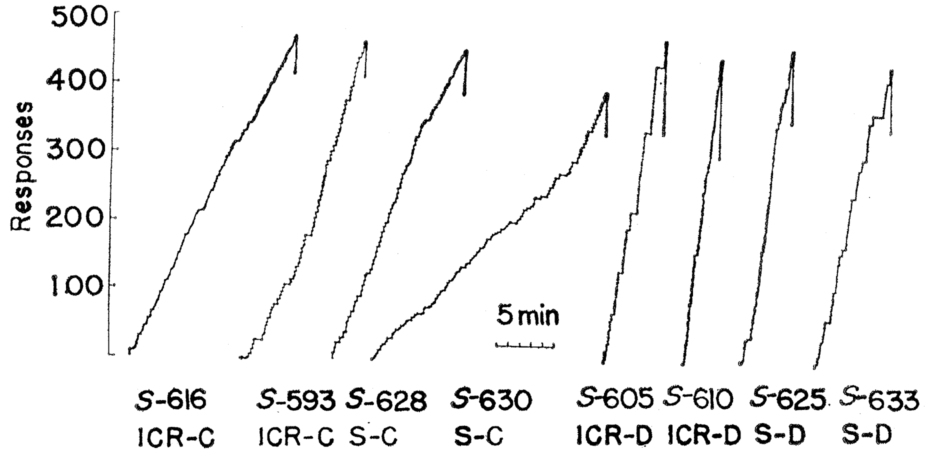

Fig. 1. Cumulative response records (contacts with dipper) of two subjects of each group.

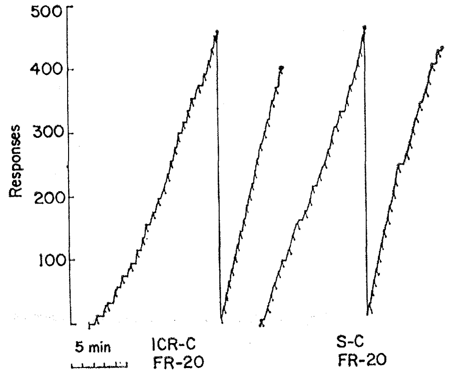

Fig. 2. Response records (lever presses) on a FR-20 schedule of reinforcement for ICR and for sugar water.

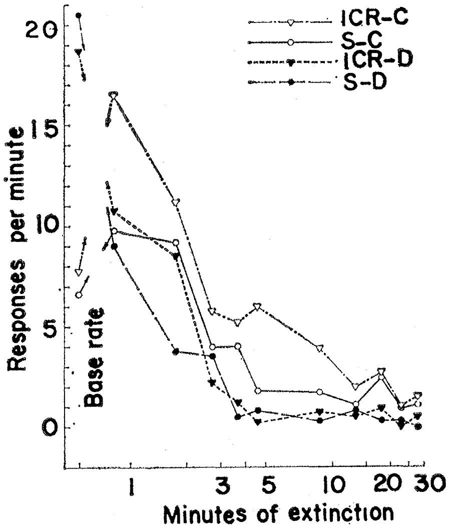

Fig. 3. Response rates (lever presses for the "C" groups and dipper activations for the "D" groups) during extinction compared with those rates the previous day. Responses are represented by 1-minute means on the left and by 5-minute means on the right.

"D" groups than lever presses by the "C" groups [$F\ (29,348) = 2.33$; $p < .05$].

The present findings are not the only ones which can be interpreted as contradicting the generalizations of our opening paragraph. Maze running for ICR has shown considerable resistance to extinction (*6*). Other recent investigations also show that extinction of behavior maintained by ICR is similar to the extinction of food-reinforced behavior when the subjects are required to perform similar tasks (*7*). Together these results suggest that anomalous behavior associated with ICR is an artifact of the reinforcing contingencies and not that ICR is essentially different in function from conventional reinforcers.

One other feature of Fig. 3 should be noted. The response rates of the ICR-C and the S-C groups show an increase in the first minute of extinction relative to the rates during regular training the day before; those of the ICR-D and S-D groups do not. It has long been recognized that withdrawal of reinforcement may result in more vigorous behavior (*8*), but Fig. 3 suggests the possibility that this behavioral activation is limited to instrumental, as contrasted with consummatory, responses. If so, such a difference would be but one more reason to distinguish between behaviors mediately and immediately reinforced—a distinction poorly made by many investigators of ICR, including one of us (P.B.P.), over the last 10 years.

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Age, Personality, and Somatosensory Cerebral Evoked Responses

Abstract. *Cerebral responses to stimulation of the median nerve were recorded in 89 healthy subjects, aged 15 to 80 years. Relationships between response characteristics, age, sex, and Maudsley Personality Inventory variables were determined. Amplitudes increased significantly with age. Age interacted with "extraversion" so that more "extraverted" subjects under 20 and fewer "extraverted" subjects over 40 had larger responses.*

The quantitative characteristics of sensory-evoked cerebral responses, recorded from the intact human scalp by averaging methods, vary considerably among individuals. In this report we present evidence that age and a personality factor, designated as "extraversion" in the Maudsley Personality Inventory (*1*), contribute significantly to interindividual variation of somatosensory responses in healthy persons.

The subjects were 89 paid volunteers, recruited as normal controls for comparison with psychiatric patients. Their ages ranged from 15 to 80 years (median, 28); 51 were male, 38 female. Those aged over 60 received a systematic psychiatric examination to exclude mental illness before acceptance as controls; all others were accepted if they denied that they had had previous psychiatric illness or had used psychologically active drugs. Their occupations included: student, hospital attendant, nurse, janitor, housewife, merchant, farmer; several had retired but were active in community affairs. The Maudsley Personality Inventory was administered to obtain additional personal information. The Inventory provides scores for "extraversion" (E) and "neuroticism" (N); subjects answer "Yes", "No", or "Question" to the questions presented. Tests containing more than ten question-mark answers were rejected; 81 valid tests were obtained.

Responses were evoked by stimulating the right median nerve at the wrist through chlorided silver electrodes, affixed with collodion, placed 3 cm apart (anode distal). A constant current stimulator, triggered by a Grass S4 stimulator and isolation unit, generated the stimulus pulse. Duration was 0.1 msec and intensity was 10 ma above the individual's sensory threshold; the intensity-response curve is asymptotic for most subjects at this stimulus strength (*2*). Repetition interval was 1 second. Recording electrodes were placed 6 cm apart in the parasagittal plane 7 cm left of midline; the posterior lead was 2 cm behind a line from vertex to auditory meatus. The electroencephalogram was amplified with Tektronix 122 units and a subsidiary amplifier (frequency response, 0.8 to 10 kc/sec) and led into a Mnemotron computer of average transients for summation. Analysis time was 250 msec. Stimulation occurred at the 20th computer ordinate; a square-wave calibration signal of microvolt potential was placed on each sweep in the midportion of the preceding ordinates (*3*).

Data reported here are based on responses to single stimuli obtained during recovery function tests in which paired and unpaired stimuli were alternated (*4*); they include 19 averaged responses, each to 50 stimuli, for each subject. To quantify the responses, we identified ten successive peaks, consistent both between and within subjects, beginning with the initial negative deflection (latency about 20 msec). The recovery-function tracings were often useful in identifying peaks that may be obscure in responses to single stimuli, for example, points 5 and 6 in Fig. 1. Peaks 2 and 3 were rare in tracings from subjects over age 30, although they appeared regularly during the early phases of recovery; consequently, they were omitted from statistical analysis. For each peak, the amplitude