pairs of filters which clearly differ in their transmission characteristics.

Twenty-six naive observers were tested in two groups to verify the interocular independence of the adaptation. These observers were first shown the test pattern (Fig. 1, projected on the screen by a third projector) and asked to indicate any differences in color, however faint, which they could detect between the two halves. They then watched for 2 minutes while the orange and blue fields without grating patterns were presented alternately, and they indicated afterward in writing the color appearance of the test pattern for each eye. No color aftereffects were consistently reported at this stage. All observers then covered the right eye and observed orange-vertical and blue-horizontal with the left eye for 4 minutes, giving test pattern responses with the left eye after 2 and 4 minutes. Then they covered the left eye, gave responses with the right eye alone, and then observed orange-horizontal and blue-vertical with the right eye for 4 minutes, giving test pattern responses after 2 and 4 minutes with the right eye. They were finally asked to compare the appearance of the test pattern to the left and right eyes, by opening and closing the eyes alternately. The test pattern was varied in position by rotation between and during all tests.

Twenty-two of the 26 observers reported at least 12 of the 16 possible color aftereffects in the series. Of these 22 observers, 20 reported colors seen with the left eye which were consistently the reverse of those seen with the right eye. One of the 22 reported seeing colors with the right eye before adaptation of that eye, and the colors reported were the same as those just obtained by adaptation of the left eye. Most observers also reported that all color disappeared when the test pattern was rotated 45° into an oblique position.

Chromatic fringe adaptation and the "phantom" aftereffects are visible in monochromatic light. Hay, Pick, and Rosser have accordingly pointed out that wherever adaptation of the same kind takes place, "it should manifest itself in ineradicable color fringes along high contrast borders in monochromatic illumination." Observations made with the test pattern shown in nearly monochromatic light (Corning narrow-band-pass filters 4-102, 3-110, or 2-77 held in front of the projector) confirm the expectation that the color-adaptation of edge-detectors is visible in such light. After adaptation to orange-vertical and blue-horizontal, the right half of Fig. 1 appears yellow-green or orange in green, yellow, or orange light, and the left half appears green or blue in such colored light. These observations strengthen the supposition that chromatic fringe adaptation, as seen in experiments with prismatic spectacles, is explainable as color adaptation of oppositely oriented, vertical edge-detector systems.

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A Brief Temporal Gradient of Retrograde Amnesia Independent of Situational Change

Abstract. *Rats were given a single electroconvulsive shock at varying intervals after receiving a punishing shock to the feet immediately after stepping into a compartment. Significant amounts of retrograde amnesia for the memory of the punishment was shown when electroconvulsive shock was administered up to and including 30 seconds after the punishment but not at 60 seconds. This brief temporal gradient cannot be explained in terms of changed stimulus cues or learned interference analogous to retroactive inhibition.*

Previous studies have shown that electroconvulsive shock (ECS) given shortly after a learning experience can interfere with the learning. This interference typically has been interpreted as a disruption of a consolidation of the memory trace (*1*). Two other interpretations, however, are possible: (i) that ECS reduces the amount of learning by removing the subject from the stimulus situation, and thus preventing him from adequately noticing it, and possibly from rehearsing in it, after the reinforcement has indicated its biological significance, or (ii) that ECS conditions many random brain impulses to the cues involved in the immediately preceding learning and hence produces a learned interference analogous to retroactive inhibition. The purpose of this study was to secure additional information on the effects of the interval between the learning experience and ECS, and to test hypothesis (i) by substituting sudden removal for ECS, and hypothesis (ii) by administering ECS after subject had been removed from the situation, a procedure which should reduce the chances for retroactive inhibition.

Subjects were 310 male rats of the Holtzman strain, 90 to 150 days old, housed in individual wire-mesh cages and having free access to food and water. An equal number of rats from each shipment was assigned to the various groups to cancel out shipment effects. The apparatus, a modification of that described by Jarvik and Essman (*2*), was a compartment 38 by 38 by 44 cm, with a vertical slot cut into one end, into which fitted a start box (19 by 15 by 15 cm) which could be raised and lowered by means of a lever. A guillotine door separated the two compartments. The entire apparatus was constructed of ¼-inch (0.6-cm) Plexiglas, except for the floors, which were made of stainless steel rods 3/32 inch (0.24 cm) in diameter, spaced 1.25 cm on centers. The interior was illuminated from above by a 100-watt bulb. A 60-cy a-c grid shock (GS) of 1.0-ma intensity was delivered for 2.0 seconds to the grid floor of the large compartment through a 820,000-ohm resistor connected in series with the rat. An ECS (100 ma for 0.3 second) was delivered through small padded alligator clips, soaked in saline, attached to the animal's ears before the animal was placed in the start box. Subjects that did not exhibit tonic flexion or tonic extension in response to ECS were discarded. Durations of GS and ECS, as well as time intervals between GS and ECS, were automatically triggered and timed by a system of relays and timers. Actual intensities of GS and ECS were monitored on milliammeters.

A rat was placed in the start box and

was lowered until level with the large compartment. The guillotine door was opened, activating a timer which was stopped when all four of the rat's paws were in the large compartment. The door was immediately closed and GS was delivered. Closing the door prevented retracing, which could have occurred in previous studies and confused the interpretation by making any aversive effects of ECS summate with any amnesic ones, as demonstrated by Coons and Miller (*3*).

The effects of the GS-ECS interval were studied with eight experimental groups ($N = 30$, for each group) with 0.1, 1.0, 2.0, 5.0, 7.5, 15.0, 30.0, and 60.0 seconds separating presentation of GS and ECS. In all of these groups ECS was administered in the large compartment. Three control groups were also run: a "no-GS, no-ECS" group ($N = 10$), a "GS, no-ECS" group ($N = 20$), and an "ECS, no-GS" group ($N = 10$). In the "ECS, no-GS" control group, four animals were convulsed immediately after stepping into the large compartment; three, after 15 seconds; and three, after 60 seconds. (As there were no differences among these ten animals, results for the three subgroups were combined into one group.) All animals were removed from the large compartment immediately after they had convulsed.

To test hypotheses (i) and (ii), two further groups were treated as follows. In one group (black bag, no-ECS group), 20 subjects were removed by hand from the large compartment and were dropped into a black cloth bag within 2 seconds of the termination of the GS. Subjects not in the bag at the end of an automatically timed 2 seconds were discarded. Mean time for removal from the compartment to the bag was 1.5 seconds. Subjects were left in the bag for 60 seconds. Rats of the second group (black bag, ECS 2.0 seconds) were lifted by hand from the large compartment and dropped into the bag, in which they were convulsed 2 seconds after the termination of the GS. This procedure produced a more drastic stimulus change than could be accomplished by leaving the animal in the compartment and, for example, turning off a light and a tone.

Retention was tested 24 hours later, with the same procedure as in initial training, except that no GS or ECS was administered. Retention of the avoidance response was indicated when subjects failed to step out into the large compartment within 180 seconds.

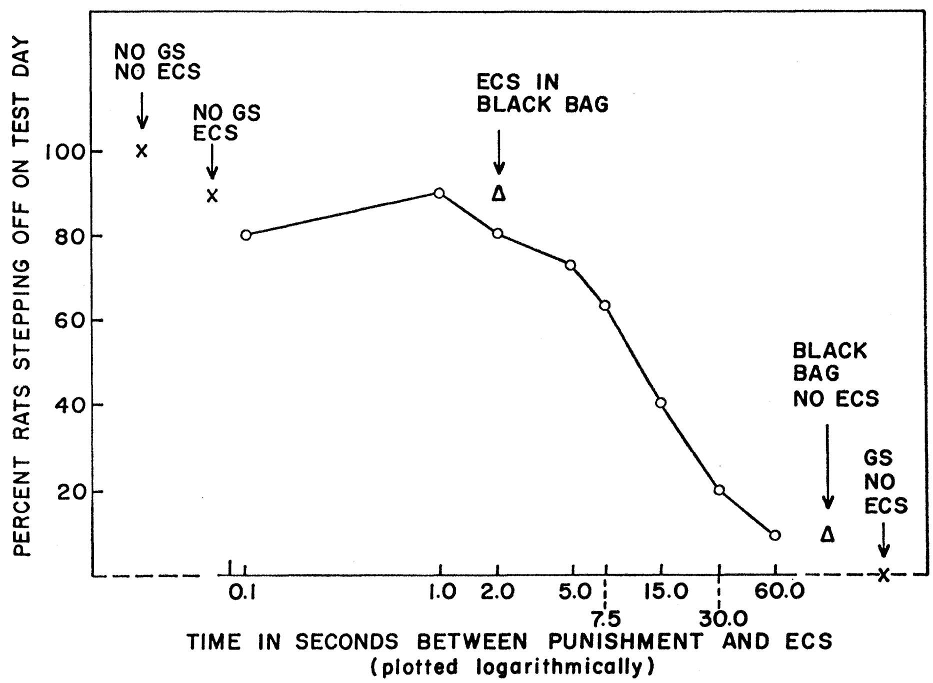

Fig. 1. Effects of electroconvulsive shock (ECS) as a function of GS-ECS interval and situation. The punishment was a grid shock (GS). It was administered to both "black bag" groups, one of which received ECS. The time scale is plotted logarithmically.

The percentage of subjects in each group which stepped out within the criterion time was considered a more appropriate measure than response latencies, since none of the control group receiving GS but no ECS stepped off on the test day. These data, plotted logarithmically, are shown in Fig. 1. An overall analysis of the experimental groups (the GS-ECS interval differing from one to another) indicates that the percentage of subjects failing to avoid the large compartment on the test day is inversely related to the GS-ECS interval ($\chi^2 = 75.46$; $p < .001$). Comparisons between the "GS, no-ECS" control group and the ECS groups (Fisher's exact probability test) showed: (i) significant retention deficits occurred when ECS was administered up to and including 30.0 seconds after termination of GS ($p < .05$ at 30.0 seconds), but not after 60.0 seconds ($p = .2$); (ii) no significant difference between the "ECS, no-GS" and the "no-ECS, no-GS" control groups ($p = .5$), indicating that the single ECS did not have aversive properties. The "black bag, no ECS" group was similar to the 60-second group and not reliably different from the one receiving no ECS. The "black bag, ECS 2.0 seconds" group was significantly different ($p = .01$) from the control group with no ECS, and not significantly different ($p = .2$) from the group given ECS at the same interval in the apparatus itself.

When the data are plotted in terms of latencies, the curve is essentially the same, except for the fact that the "0.1 second" group is slightly above, instead of below, the "1.0 second" group. The mean number of bolluses excreted by each group also yielded a curve similar to that in Fig. 1, except that it was inverted. This would be expected, since memory for the shock should produce fear, and hence increase the number of feces.

These results demonstrate that as the GS-ECS interval is increased there is a significant increase in the percentage of subjects avoiding the large compartment, and that a delay of 30.0 seconds is the maximum interval at which significant amnesic effects are produced under the present conditions. The absence of any impairment of retention in the "black bag, no ECS" group indicates that the rapid change of stimulus cues used in this experiment cannot account for the impaired avoidance learning. Although it is possible that ECS produces a still more drastic change of stimulus cues than removal to the black bag, if stimulus change is an important determinant of the retention deficits, then the present drastic procedure should have produced at least some effects.

It is also clear from the results of the "black bag, ECS 2.0 second" group that the effects of ECS are independent of location of the rat at the time of administration of ECS. These results, utilizing a drastic change of stimulus cues, confirm those which Leonard and Zavala (*4*) found with a less drastic one. It would appear, therefore, that the retention deficits produced by ECS in this study cannot be accounted for in terms of a learned interference analogous to retroactive inhibition, and are the result of a true amnesia, probably brought about by physiological changes.

The brief GS-ECS interval necessary for amnesia in this study shows excellent agreement with the temporal curve recently observed by Chorover and Schiller (*5*). However, since other studies have shown significant retention deficits with much longer ECS delays, this leaves a puzzle. It is possible that these differences may be in part the result of different task and procedural variables employed in "one trial" situations. For example, studies which have shown significant ECS effects with long GS-ECS intervals have generally used learning tasks in which the subjects have received considerable training under deprivation of food or water before the punishment shock is administered (*6*). It is possible that the greater response strength before punishment in these studies is a factor determining the effective ECS interval. On the other hand, it is possible that different stages of the consolidation process are disrupted by different intensities of ECS or by different types of treatment. Further information on the foregoing possibilities should give clues to the physical basis for the memory process.

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Dental Caries in Tehuacán Skeletons

In "Human skeletons of Tehuacán" [*Science* **148**, 496 (1965)], J. E. Anderson says, in reference to a low rate of increase in the incidence of dental caries coincident with the change to agriculture:

> An explanation for this unexpectedly low increase is that the water of the valley is rich in minerals, and these were deposited (even as now) on the teeth as a heavy calculus which effectively plugs potential caries sites.

While I do not question that such a deposition of calculus might result in less caries, I must question the ascribed causation of the heavy calculus deposits. The congenital enamel pits described occur on the palatal surface of the maxillary molar and on the buccal surface of the mandibular molars. Neither location is normally associated with calculus deposition, as this usually occurs adjacent to duct openings of major salivary glands (on the lingual surface of the mandibular incisors and the buccal surface of the maxillary first permanent molar). Assuming, then, that Anderson is referring to the buccal pits on the lower molars, normal calculus deposition would not occur in this area. It is doubtful that a high mineral content of ingested water would contribute to the deposition of calculus, if only because the exposure of the minerals to the oral environment is very brief. However, as I have seen such depositions in Guatemalans, a more logical explanation is suggested. In these populations, as in Anderson's, the main carbohydrate staple is maize, usually consumed as tortillas, prepared by grinding the maize kernel into a dough after prolonged soaking, either in limewater solutions or in water to which wood ash is added. When eaten, this foodstuff, which is still very alkaline and high in concentration of calcium and phosphate, tends to accumulate in areas which are poorly self-cleaning (such as the buccal surface of mandibular molars); hence conditions are optimum for the precipitation of calcium phosphate as calculus deposits in these areas.

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