

susceptible soils in a closed system, uplift by the expansion of water upon freezing, as proposed by Inglis, is possible. Figures 1-4 illustrate the sequence of events.

The film is available on loan from the Commanding Officer, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. Further study of the freezing of soils and related phenomena is being carried on in that laboratory.

CHESTER W. KAPLAR
U.S. Army Cold Regions Research and Engineering Laboratory,
Hanover, New Hampshire 03755

6 July 1965

Retrograde Amnesia

Failure of persons to recall events that occurred just prior to a severe concussion or electroconvulsive shock (ECS) has been of considerable interest to neurologists, psychologists, and physiologists. Such failure, called retrograde amnesia, seems to imply that memory traces are initially in a relatively vulnerable state, and that they require a period to become "consolidated." In view of current efforts to identify the physical or chemical nature of the trace mechanism, great importance is attached to estimates of the length of the period of retrograde amnesia.

Currently it has become evident that the time course of consolidation, as inferred from experiments in which electroconvulsive shock is administered to animals at various times after learning, needs careful reconsideration. Shock, especially with repeated administration, has aversive effects which in many of the classical studies have led to a confounding of variables (1). In some cases amnesic effects have been erroneously inferred even in studies in which a single shock treatment was used (2). In this respect Tenen's recent report (3) has been of interest, for it seems to have overcome many of the objections to former studies. We would, however, like to express our concern regarding the conclusion Tenen draws. He suggests, on the basis of his own study and the studies of others, that electroconvulsive shock might exert limited amnesic effects even 3 hours after reinforcement. This conclusion seems to be unwarranted on at least two grounds:

1) Tenen employed only two intervals between learning and shock, 12 seconds and 3 hours. In order to establish the nature of the amnesic gradient, several other intervals should have been used. Since the group subjected to shock after a 3-hour interval does not show a significant amnesic effect, the only thing Tenen can conclude is that electroconvulsive shock produces retrograde amnesia when administered 12 seconds after learning.

2) The effects described in the study Tenen cites in support of the 3-hour effect (4) are probably not due to retrograde amnesia (2).

We have been carrying out a series of experiments in the psychology department at M.I.T. on the time course of retrograde amnesia. When confounding variables are eliminated, the amnesic effects of electroconvulsive shock seem to be very short, perhaps no longer than 10 seconds. This seems to apply to one-trial learning situations involving both positive and negative reinforcement (5).

STEPHAN L. CHOROVER
PETER H. SCHILLER
Massachusetts Institute of Technology,
Cambridge 02139

References

1. E. E. Coons and N. E. Miller, *J. Comp. Physiol. Psychol.* **53**, 524 (1960); W. J. Hudspeth, J. L. McGaugh, C. W. Thompson, *ibid.* **57**, 61 (1964).
2. S. L. Chorover and P. H. Schiller, *ibid.*, in press.
3. S. S. Tenen, *Science* **148**, 1248 (1965).
4. J. Bureš and O. Burešová, *J. Comp. Physiol. Psychol.* **56**, 268 (1963).
5. S. L. Chorover, in *Learning, Remembering and Forgetting* (American Institute of Biological Sciences, Washington, D.C., 1965), vol. 1; — and P. H. Schiller, *J. Comp. Physiol. Psychol.* **59**, 73 (1965).

5 August 1965

Chorover and Schiller object to a sentence in the last paragraph of my paper. The sentence is here italicized:

However, the greater number of hole explorations of the delayed-ECS group over the immediate-ECS group did not reach significance ($p = .10$). *Thus it seems possible that ECS might exert some limited retrograde amnesic effects even 3 hours after reinforcement.* A longer reinforcement-ECS interval might have produced a significant difference making the findings more conclusive.

I think Chorover and Schiller have mistaken a control group for an experimental one and have elevated a *post hoc* speculation to a conclusion. The rats given shock after a 3-hour delay provided a control to assess the proactive effects on the test performance

of the one-trial learning task. I originally thought that a 3-hour interval would be clearly long enough to prevent any interference with a possible consolidation process. In order to demonstrate that the delayed ECS had no proactive effects, three criteria, involving statistical comparison of groups, had to be met. Two of these were met, whereas the statistical test of the third (the one stated above) only approached significance. Although it was possible that a larger N might have resulted in the expected significant difference, several other considerations led me to speculate that a longer interval between reinforcement and ECS might be the more crucial variable. However, Chorover and Schiller are completely correct in pointing out that this study was not (nor was it intended to be) designed to explore reinforcement-ECS intervals and that one cannot *conclude* from the data presented that the delayed ECS produced any retrograde amnesic effects.

I have since conducted an experiment in which the reinforcement-ECS intervals were: immediate (about 15 seconds), 5 minutes, 10 minutes, 15 minutes, 30 minutes, 60 minutes, and 5 hours. All intervals up to the 5-hour one resulted in scores significantly lower ($p < .05$) than that of the reinforced pseudo-ECS group. The score of the 5-hour group was also lower but not significantly so. This suggests that shock delayed as much as 1 hour produces retrograde amnesia and justifies, in part, the *post hoc* speculation in the report. This interval is considerably longer than the 10-second limit suggested by Chorover and Schiller. These authors' analysis of the effects of a long interval between reinforcement and ECS found with negative-reinforcement techniques does not apply to an appetitive reinforcement. It is possible that the retrograde amnesia produced by ECS is a result of more than one mechanism and hence that the hypothesis of a consolidation process (or processes) need not always be invoked. Even if one adheres to this hypothesis, the time course of consolidation and its stability might vary with different tasks or reinforcement systems. All that is clear at this point is that additional investigation is necessary.

S. S. TENEN
Medical Research Laboratories,
Chas. Pfizer & Co., Inc.,
Groton, Connecticut

20 August 1965