in the averaged evoked cortical potential wave form and the dotted lines show the frequency that each perceived number of flashes (N_s) was reported. For example, subject C.W. most frequently reported seeing one flash when one to four flashes were presented, two flashes when four to seven flashes were presented, three flashes when seven to ten flashes were presented, and so forth.

The results indicate that there was an initial fusion period, after the onset of stimulation, when the short flash-trains were perceived as fused (the subjects most frequently reported seeing one flash). The duration of the fusion period varied between subjects, ranging from 50 to 100 msec (flashtrains containing three to five flashes). In all cases, this period ended after the first major deflection in the evoked cortical potential wave form. Otherwise, there was no apparent relationship between the evoked potential wave form and the perception of number during this period.

After the initial fusion period, that is, when the subjects most frequently reported seeing two or more flashes, the periodicity of the averaged evoked potentials appears to reflect the rate at which the successive perceived counts were added up to 350 msec after the onset of the flash-train. This relationship did not hold for subjects M.L. and R.H. when flash-trains longer than 350 msec were presented. To compare the rates at which the successive evoked potential components and the successive perceived counts were added, the average interval between the points in time when each N_s was maximally perceived was compared to the average interval between the corresponding evoked cortical potential peaks or troughs (whichever the case may be). The respective average between count and between component intervals for each subject (in msec) were 103 and 107 (C.W.), 95 and 102 (M.L.), 97 and 90 (R.H.), and 102 and 103 (J.A.). If the similarity of these two average periods is a coincidence, it is indeed a striking one. Furthermore, the fact that both measures have 10 counts per second has considerable generality in view of the number of studies which have reported evoked potential data (3, 6) and perceptual data (1-4) similar to that reported here.

Our results may be summarized as follows: (i) the temporal nature of averaged evoked cortical activity was similar for potentials evoked by both single flashes and trains of flashes; (ii) the first large deflection in the averaged evoked cortical potential wave form appeared to reflect the minimal period of time required for the perception of two flashes, assuming a conductiontime latency of 35 msec; and (iii) after the initial fusion period, the periodicity of the averaged evoked cortical potential wave form appeared to reflect the frequency at which additional perceptual flashes were added for flash-trains up to 350 msec in duration. (Sufficient data were not collected to speculate on this relationship for longer flashtrain durations.) These and other results suggest that the onset of stimulation initiates a central process which may have a marked effect on both the cortical and perceptual response to subsequent stimulation.

In conclusion, the findings of our study possibly are related to those of other studies concerned with cortical excitability cycles in humans (7, 8). In these studies, the excitability of the cortex was shown to fluctuate rhythmically after stimulation by a brief flash of light; when a pair of flashes was presented, the amplitude of the evoked cortical potential resulting from the second flash varied as a function of the time between the two flashes. The evoked cortical potential wave form elicited by the first flash may reflect the periodicity of the excitability cycle (8). In humans, a complete excitability cycle had a duration of approximately 100 msec, which is in accord with the duration of each perceived flash and evoked potential oscillation in our experiment. Apparently the flashes presented within a single excitability cycle (possibly reflected by the periodicity of the evoked cortical potential wave form) were grouped into a single perceptual unit and were perceived as a single flash. These findings are relevant to the current theoretical interest in the concept of central intermittency in perception (2, 9).

M. RUSSELL HARTER

C. T. WHITE

U.S. Navy Electronics Laboratory, San Diego, California 92152

References and Notes

- D. M. Forsyth and A. Chapanis, J. Exp. Psychol. 56, 385 (1958).
 C. T. White, Psycholog. Monogr. 77, Whole 2. C.
- 3. 632 (1967).
- 4. P. G. Cheatham and C. T. White, J. Exp.
- F. G. Cheatham and C. I. white, J. Exp. Psychol. 44, 447 (1952); C. T. White and P. G. Cheatham, *ibid.* 58, 441 (1959).
 R. G. Eason, L. R. Aiken, C. T. White, M. Lichtenstein, Perceptual Motor Skills 19, 875
- (1964). 6. R. G. Eason, D. Oden, C. T. White, *Electro*-
- encephalog. Clin. Neurophysiol., in press. 7. L. Cigánek, Ann. N.Y. Acad. Sci. 112, Art. 241 (1964).
- 8. H. Gastaut, A. Roger, J. Corriol, R. Naquet, Electroencephalog. Clin. Neurophysiol. 3, 401 (1951).
- 9. P. Bertelson, Quart. J. Exp. Psychol. 18, 153 R. Harter, *Psychol. Bull.*, B. Lindsley, *Electroencephe ophysiol.* 4, 443 (1952); J. (1966); M. R press; D. B. Psychol. Buu., Electroencephalog. (1952): J. M. press; Clin. Neurophysiol. 4, 443 (1952); J. M. Stroud, in Information Theory in Psychology, H. Quastler, Ed. (Free Press, Glencoe, Ill., 1955), p. 174; N. Wiener, *Cybernetics* (Wiley, New York, 1948), pp. 156-167.
 We thank R. G. Eason for assistance. Supported in part by NSF grant GB-4067 and ported the New York Dispersion. Leberatory.
- in part by the Navy Electronics Laboratory. 24 October 1966: 14 March 1967

Permanence of Retrograde Amnesia Produced by Electroconvulsive Shock

Abstract. The permanence of retrograde amnesia produced for a single training trial by a single electroconvulsive shock was studied. No recovery from amnesia was found with either single or repeated retention tests. Amnesic effects were found to be permanent with retention intervals as long as 1 month.

Electroconvulsive shock (ECS) can produce amnesia in animals, if applied shortly after training (1). It has generally been assumed that ECS produces amnesia by disrupting time-dependent processes which underlie memory storage (2). This interpretation has been supported by evidence that the amnesia produced by a single ECS given shortly after a single learning trial is permanent for at least 1 month (3).

This permanence of amnesia produced by ECS has been seriously questioned in recent reports (4). Zinkin and Miller have reported evidence which indicates that amnesia produced by ECS may diminish when animals are given repeated retention tests. However, their data do not permit determination of the basis for the increased response latencies used to index recovery of retention. The change in performance may have arisen from several sources: repeated exposure to the test situation, passage of time after ECS treatments, or simply, nonreinforced increments in avoidance which are not directly related to ECS treatments.

The experiments reported here examine the degree of permanence of amnesia produced by ECS with single and repeated tests at retention intervals of different lengths. The amnesia did not decrease either as a function of time or as a function of repeated tests. Within the limits of these experiments, amnesia appeared to be permanent. Thus, amnesia produced by ECS continues to be most adequately explained as a consequence of interference with time-dependent processes underlying memory storage.

Eighty male Swiss-Webster mice, 55 to 65 days old at the beginning of training, were used in each of three experiments. With the exception of the retention interval between training and testing, the procedures used in each experiment were identical. The retention intervals for the three experiments were 12 hours, 7 days, and 32 days, respectively.

As preliminary training, the 80 mice in each experiment were given one trial every 12 hours for 2 days on an inhibitory avoidance apparatus (5). Each mouse was placed on a small metal platform (2.25 by 6.25 cm) which extended from beneath a hole (3.75 cm in diameter) in the wall of a darkened box. The mouse was allowed to step from the highly illuminated platform (40-watt bulb, 19 cm above the platform) into the box and remain there for 5 seconds before it was removed to the home cage. No shock was given during preliminary trials. Training was given 12 hours after the last of these preliminary trials. Four experimental groups of 20 mice each were used in each experiment during training. The mice were housed eight to a cage, including two mice from each of the four experimental groups. Mice in the first experimental group received momentary footshock (FS) (5 ma) as they stepped from the platform into the box, followed within 15 seconds by an ECS (15 ma, 0.2 second) delivered through corneal electrodes. Artificial respiration was given until normal respiration was resumed. Mice in the second group received the footshock and were immediately removed to their cages without ECS (NECS). Mice in the third group received no footshock (NFS), but were given ECS 15 seconds after entering the box. Mice in the fourth group reFig. 1. Median response latencies for each experimental group at each different retention test interval. Response latencies for preliminary and training trials were uniformly low.

ceived neither footshock nor ECS. The retention trials, given after the appropriate interval, were identical to preliminary trials, and no further treatment was given. The time required for each mouse to step from the platform into the box was used as a retention measure. In general, mice that have received footshock require a much longer period of time than control mice or mice that have not received footshock. During the retention tests an avoidance response was recorded if the response latency exceeded 30 seconds.

The results of all three experiments are summarized in Fig. 1 (6). Over all the retention intervals used in the three experiments, the FS-NECS groups showed high retention with long latency scores, and none of these groups differed from the others despite differences in retention intervals (7). By contrast, the three FS-ECS groups showed latencies that were significantly shorter (Kruskal-Wallis, df=3, P < .001) than those of the groups receiving only



Fig. 2. Median response latencies for FS-ECS and FS-NECS animals on successive retention tests. Tests were conducted using procedures of preliminary trials. Testing was discontinued 192 hours after training.

footshock. Like the FS-NECS groups, the FS-ECS groups did not differ significantly from one another despite differences in retention intervals. Therefore, since the differences between the results of the FS-NECS and the FS-ECS groups are comparable over the three experiments, it appears that ECS has a stable disruptive effect on retention, independent of the interval of time between training and testing. Furthermore, comparisons of the NFS-ECS and the NFS-NECS groups showed that ECS alone did not increase response latencies on the retention test. The differential response latencies of the FS-ECS and the FS-NECS groups cannot, consequently, be attributed to a performance effect of ECS alone. This supports the hypothesis that ECS produces its effects through a direct disruption of memory storage processes.

Comparison of the latencies of the FS-ECS and the NFS-ECS groups over the three retention intervals gives an indication of the extent of the amnesia produced by the ECS. With the retention intervals of 12 hours and 32 days, the latencies of the FS-ECS groups were significantly longer (P < .002 and P < .004 for the two intervals, respectively) than those of the NFS-ECS group. This suggests that ECS given within 15 seconds after a single trial does not eliminate all residual memory of that trial. In the case of the 12hour interval, this difference between FS-ECS and NFS-ECS groups disappeared when the animals were given an additional test 12 hours after the first test or a total of 24 hours after training. The fact that the residual memory did not increase but instead decreased with the passage of 12 additional hours and with the presentation of an additional trial suggests that any residual memory remaining after ECS was transient and labile.

The latencies of animals tested at 32 days were significantly (P < .05) longer than those of animals tested at either 12 hours or 7 days, under all four experimental conditions. Within the 32-day experiment, however, the latencies of the four experimental groups formed a pattern comparable to those found in the 12-hour and 7-day experiments. It seems likely that this overall increase in the latencies of the 32-day groups is due to the ages of these animals.

It has been suggested (4) that repeated testing may somehow cancel the

21 APRIL 1967

performance deficits produced by ECS. The results of giving additional tests to animals originally tested at 12 hours are shown in Fig. 2. There was no evidence that the additional tests eliminated performance deficits produced by ECS. The FS-ECS animals showed the short response latencies mentioned above, and the large differences in the latencies of the FS-ECS and the FS-NECS groups remained unchanged through several additional tests at different retention intervals. Quite clearly, the trained animals can maintain a high level of performance over many additional tests. The stability of the learned response as well as the amnesia produced by ECS are thus equally well demonstrated.

Over the intervals examined in our experiment, retrograde amnesia produced by ECS appears to be permanent. The differences in the latencies of the FS-ECS and FS-NECS groups remained constant both over several retention trials (Fig. 2) and when tested at different times after training (Fig. 1). These findings support and extend the findings reported by Chevalier (3).

Our data do not show the apparent recovery of retention reported by Zinkin and Miller, who, using repeated retention tests, demonstrated increased response latencies over trials for most of their experimental groups. The increased latencies were somewhat greater in their ECS-trained group than in their other experimental groups; however, comparisons between groups on any single test trial suggest that the ECS-trained group apparently does not attain the performance level of the

The Plio-Pleistocene Boundary

In an article entitled "Isotopic paleotemperatures" [Science 154, 851 (1966)], Cesare Emiliani states, with reference to the definition of the Pleistocene, that "this epoch, characterized by the repeated occurrence of major glaciations, has been defined, by unanimous decision of the 7th INQUA Congress (Denver, Colorado, 1965), as the time that has elapsed since the first appearance of the benthonic foraminiferal species Hyalinea (Anomalina) baltica (Schroeter) in the late Cenozoic section at Le Castella, Calabria, southern Italy." Though it is probable that this matter was discussed and possibly approved

control group. Unfortunately, an evaluation of these findings is quite difficult since highly stable retention was not obtained for the control animals. The data may be interpreted as revealing some of the transient properties of ECS treatment or as demonstrating spontaneous fluctuations of a poorly learned response. Not enough information is available for a valid interpretation.

Our findings, unlike those of Zinkin and Miller, demonstrate permanent retrograde amnesia and support the hypothesis that ECS produces retrograde amnesia by interferring with time-dependent memory storage processes.

> MARVIN W. LUTTGES JAMES L. MCGAUGH

Department of Psychobiology, University of California, Irvine 92664

References and Notes

- C. P. Duncan, J. Comp. Physiol. Psychol. 42, 32 (1949); J. L. McGaugh, in The Anatomy of Memory, D. P. Kimble, Ed. (Science and Be-Memory, D. P. Kimble, Ed. (Science and Behavior Books, Palo Alto, 1965); R. Thompson and W. Dean, J. Comp. Physiol. Psychol. 48, 488 (1955); C. A. Pearlman, S. K. Sharpless, M. E. Jarvik, *ibid.* 54, 109 (1961).
 Z. J. L. McGaugh, Science 153, 1351 (1966); S. E. Glickman, Psychol. Bull. 58, 218 (1961).
 J. A. Chevalier, J. Comp. Physiol. Psychol. 59, 125 (1965).
 S. Zinkin and A. J. Miller, Science 155, 102 (1967); R. M. Copper and R. S. Konpenaal

- (1967); R. M. Cooper and R. S. Koppenaal, *Psychonom. Sci.* 1, 303 (1964).
- W. B. Essman and H. Alpern, *Psychol. Rep.* 14, 731 (1964). 6. Twenty mice were initially used in each group;
- however, mice were eliminated if full tonic extension was not produced by ECS, if initial latencies were excessive, or for other procedural reasons. No more than three mice were deleted from any group. 7. Mann-Whitney U-tests
- were used for comparisons between pairs of groups. Kruskal-Wallis one-way analysis of variance was used for comparisons of more than two groups Supported by PHS research grants
- .. мн 8. Supported Supported by PHS rese 12526-01 and MH 10261-03. research grants

.

25 January 1967; 14 March 1967

by the Subcommission on Marine Stratigraphy of the INQUA Stratigraphic Commission, no such decision appears in the report of the Stratigraphic Commission to the General Assembly of the 7th INQUA Congress (as yet unpublished), nor was any motion made for approval of such a decision on the floor of the General Assembly, of which I was Secretary General. Furthermore, because the Stratigraphic Commission of INQUA is itself the Subcommission on Quaternary Stratigraphy of the International Union of Geological Sciences, its decisions must await approval by the Stratigraphic Commission of that Union, which does

not meet until the International Geological Congress is held in Prague in 1968. Emiliani's statement is thus inaccurate and, had it been accurate, was premature.

GERALD M. RICHMOND International Association for Quaternary Research, Denver, Colorado 9 January 1967

In reply to Richmond's comment, I wish to quote a passage from each of three written communications which I recently received. These are from R. Selli of the University of Bologna, S. Venzo of the University of Parma, and André Cailleux of the University of Paris.

. . . I remember perfectly well that this proposal [to establish the section at Le Castella as type section for the Plio-Pleistocene boundary] was presented to the General Assembly on the last day of the Congress by the Chairman of the Commission on Nomenclature and Correlation of the Quaternary. The proposal was approved unanimously, as also re-corded in the notes which I took at the Congress.---R. SELLI

. What you write about the Plio-Pleistocene boundary is correct. In the paper by R. Selli and S. Venzo "La partecipazione italiana al 7° Congresso Internazionale del Quaternario, Denver-Boulder, Colorado, 1965" (Ricerca Scientifica, 1966, No. 12), we write "S. Venzo represented Italy within the Sub-Commission on the Plio-Pleistocene boundary. Of particular interest to Italy is the proposal, later approved by the General Assembly, to establish the section at Le Castella (Calabria) as the type section of worldwide significance for the Plio-Pleistocene boundary."-S. VENZO

. It is true that I was president [of the General Assembly]. I am completely sure that there was no objection nor any disagreement on the reports of the Commissions, and, in particular, there was no disagreement whatsoever on the choice of Le Castella as the type section for the Plio-Pleistocene boundary .-- ANDRÉ CAIL-LEUX

The above statements agree exactly with my own recollection and with what I wrote in Science and elsewhere. It would seem that the Secretary General did not follow the proceedings with sufficient awareness, did not take down accurate minutes, and assembled a record which is in fact incomplete.

CESARE EMILIANI

Institute of Marine Science, University of Miami, Miami, Florida 33149

Note

^{1.} This communication is contribution No. 775 of the Institute of Marine Science, University of Miami. 13 March 1967