[9] Fraser, D. M., and Kermack, W. O., *Brit. J. Pharmacol. Chemotherap.*, **12**, 16 (1957).
[10] Howells, R. E., and Bafort, J., *Ann. Soc. Belge, Med. Trop.* (1970, in the press).
[11] Cook, L., Grant, P. T., and Kermack, W. O., *Exp. Parasitol.*, **11**, 372 (1961).
[12] Polet, H., and Conrad, M. E., *Milit. Med.*, **134**, 939 (1969).
[13] Siddiqui, W. A., Schnell, J. V., and Geiman, Q. M., *Milit. Med.*, **134**, 939 (1969).
[14] Rudzinska, M. A., and Trager, W., *J. Biophys. Biochem. Cytol.*, **6**, 103 (1959).
[15] Howells, R. E., Peters, W., and Thomas, E. A., *Ann. Trop. Med. Parasitol.*, **62**, 271 (1968).
[16] Aikawa, M., Cook, R. T., Sakoda, J. J., and Sprinz, H., *Z. Zellforsch.*, **100**, 271 (1969).
[17] Aikawa, M., Huff, C. G., and Sprinz, H., *Milit. Med.*, **131**, 969 (1966).
[18] Macomber, P. B., O'Brien, R. L., and Hahn, F. E., *Science*, **152**, 1374 (1966).
[19] Ladda, R., and Sprinz, H., *Proc. Soc. Exp. Biol. Med.*, **130**, 524 (1969).
[20] Fitch, C. D., *Proc. US Nat. Acad. Sci.*, **64**, 1181 (1969).
[21] Bowman, I. B. R., Grant, P. J., Kermack, W. O., and Ogston, D., *Biochem. J.*, **78**, 471 (1961).
[22] Theakston, R. D. G., Fletcher, K. A., and Maegraith, B. G., *Life Sci.*, **9**, 421 (1970).
[23] Peters, W., *Ann. Soc. Belge Med. Trop.*, **45**, 365 (1965).
[24] Peters, W., Bafort, J., Ramkaran, A. E., Portus, J. H., and Robinson, B. L., *Ann. Trop. Med. Parasitol.*, **64**, 41 (1970).
[25] Pearse, A. G. E., *Histochemistry, Theoretical and Applied* (second ed.) (Churchill, London, 1961).
[26] Kerpel-Fronius, S., and Hagos, F., *Histochemie*, **14**, 343 (1968).
[27] Horwitz, C. A., Benitez, L., and Bray, M., *J. Histochem. Cytochem.*, **15**, 216 (1967).
[28] Peters, W., *Trop. Dis. Bull.*, **66**, 1 (1969).
[29] Ramkaran, A. E., and Peters, W., *Nature*, **223**, 635 (1969).
[30] Aikawa, M., and Beaudoin, R. L., *Amer. J. Trop. Med. Hyg.*, **18**, 166 (1969).
[31] Ray, A. P., Singh, H., and Sen Gupta, G. P., *Bull. Nat. Soc. Ind. Mal. Mosq. Dis.*, **6**, 5 (1958).
[32] Seeler, A. O., *J. Nat. Mal. Soc.*, **4**, 13 (1945).
[33] Peters, W., *Ann. Trop. Med. Parasitol.*, **60**, 25 (1966).
[34] Jacobs, R. L., *J. Parasitol.*, **51**, 481 (1965).
[35] Trager, W., *J. Protozool.*, **14**, 110 (1967).
[36] Trager, W., *Trans. NY Acad. Sci.*, Series II, **28**, 1094 (1966).

Amnesic Syndrome: Consolidation or Retrieval?

by
ELIZABETH K. WARRINGTON
L. WEISKRANTZ*
The National Hospital,
Queen Square,
London

Amnesic patients can remember verbal material if they are tested with a method of partial information. The present experiments show that such retention depends more on the method of retrieval than on the method of acquisition. It is suggested here that long-term memory can be demonstrated in the patients if methods are used that eliminate incorrect and interfering responses.

Amnesic subjects are not so forgetful as was once thought. Learning and retention of motor skills such as rotary-pursuit tasks and tracking tasks were possible if not altogether normal in one severely amnesic subject[1]. Perhaps more strikingly, amnesics can learn to recognize a series of fragmented pictures and words and show evidence of retention over days and even weeks[2,3]. Moreover, the principle of providing partial information as a stimulus for retrieval has been shown to operate for verbal as well as perceptual stimulus material[4]. Why, then, do amnesic subjects learn and retain verbal material using this method when the same items are relatively unavailable using conventional methods? Is such retention by amnesics made possible by their having learned the material in a particular form, or by being presented with material in that form at the retention stage? Moreover, is it merely a favourable retrieval technique for all subjects, amnesics and controls alike, or is there a special factor which disproportionately affects the amnesics' performance?

The aim of this experiment was to manipulate independently both method of learning and method of retrieval. The results suggest that in amnesic subjects the retrieval procedure is more relevant than the method of learning and that the method of retrieval itself is critical in determining their performance on tasks of retention. The effectiveness of partial information in eliciting stored items of information raises various theoretical questions and allows one to relate the human amnesic syndrome to the relevant animal experiments.

Four patients with severe amnesic states, one following a temporal lobectomy and three with alcoholic Korsakoff psychosis (Nos. 1, 2, 5 and 6 reported in a previous study[3]), were available for these experiments. They had normal intellectual capacities other than memory defect. There were fourteen control patients with extra-cerebral neurological disease who took part in these experiments, six in experiment 1 and eight in experiment 2. No control subject did both experiments. These control subjects were tested in two subtests of the Wechsler Adult Intelligence Scale (WAIS) (Vocabulary and Block Design) and were matched as closely as possible for age and intellectual level with the amnesic group.

In the first experiment the learning conditions (using the fragmented word technique, see Fig. 1) were kept constant, and subsequent retention was measured using three different retrieval methods: recall, recognition and one partial information technique (fragmented words). Because amnesic subjects can learn by this method, the three retrieval methods may be directly compared.

Three lists of nine words, all of high frequency, were drawn from the Thorndike–Lorge word count. Two

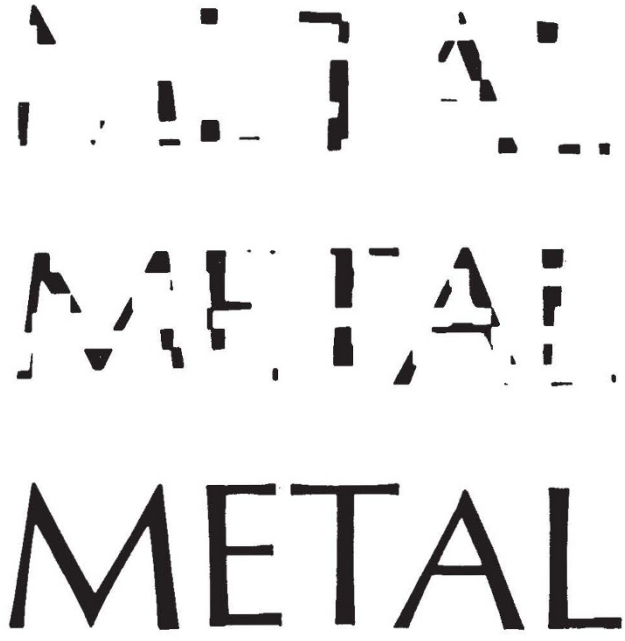

Fig. 1. Example of fragmented word.

* Present address: Department of Experimental Psychology, University of Oxford.

fragmented versions of each word were prepared as described previously[3]. On each learning trial the most incomplete version of the word was presented first, then the less incomplete version followed by the complete word, and so on through the list of nine words. Subjects identified each word as soon as possible. The error score was defined as the number of additional versions (other than the most fragmented version) required for identification. Five learning trials plus a retention test were given on each of the three lists.

There were three retention conditions, each being attempted by all subjects in a counterbalanced order. Retention was assessed 1 min after each learning task was completed; the interval was filled by counting backwards from 100. There was an unfilled interval of 5 min between each condition. (1) Recall: the subject gave a spoken report of words from the test list. (2) Recognition: the subject was required to respond "Yes" or "No" sequentially at self-paced rate to each of eighteen words (printed in the same size and type of lettering as the stimulus list), nine new words and the nine old arranged in a random order. (3) Partial information: a further sixth trial using the method of fragmented words was given. The mean error score for each group in experiment I on the five learning trials for all lists combined is shown in Table 1. The score on trial 1 is an indication of the perceptual difficulty of the task before any further memory component has been introduced. The word lists for each condition were of approximately equal difficulty and it can be seen that the controls were reasonably well matched with the amnesics on the perceptual measure.

The retention scores (expressed as percentage correct) for each method of retrieval are given in Table 2. The recognition score was calculated by subtracting the number of false-positive errors from the number of items from the stimulus list correctly identified. The fragmented word retention score is expressed in terms of a savings measure between the fifth and sixth trials.

Though the amnesic group learned nearly as efficiently as the control group (Table 1), there was a clear-cut deficit on retention, both by recall and by recognition, in the amnesic group ($P < 0{\cdot}002$ and $0{\cdot}01$ respectively). Neither group showed any significant degree of decrement on retention by partial information. As there was a ceiling effect in the control group with the recognition procedure, it is not clear from these findings whether or not retention elicited by partial information is differentially affected in amnesic subjects. It is clear, nevertheless, that learning the material with the partial information technique does not make the information normally available to recall and recognition by amnesics.

In the second experiment different methods of retrieval were again used to assess retention after a constant learning condition, but in this case a conventional word learning task (reading a word list three times) was followed by one of four retention conditions. It is known that retention of such material measured by recall and recognition in amnesics is very poor[5]. The question is whether material originally presented in this conventional manner can be shown to be retained using methods of partial information.

Lists of eight five-letter words, all of high frequency in the Thorndike–Lorge count, were used as test stimuli. Subjects were given three learning trials followed by a retention test. There were four retention conditions and each subject learned three lists for each retention condition. A learning trial consisted of reading aloud a list of eight whole words (printed in large black capital letters on white cards) presented at a two-second rate. Retention was assessed in all subjects (after a 1 min delay filled with counting backwards) by each of the following methods in a counterbalanced order: (1) recall; (2) recognition; (3) partial information—fragmented words; (4) partial information—initial letters of words. The procedure for the first three retrieval conditions was the same as described for experiment 1; in condition (4) the first three letters of each word were presented and the subject required to identify the stimulus word. For each retention condition there were no inter-list intervals, though between each retention condition there was a 5 min unfilled interval.

A preliminary task preceded the preparation of the word lists for the two retrieval methods using partial information. First, subjects were shown fragmented words (20 per cent patterned) used in method 3, and any word which could be identified in this incomplete version was rejected from the test list. Each test list for each individual subject was made up of eight words which thus could not be read in the fragmented form. Second, the subjects were shown the first three letters used in method 4 and asked to think of a five-letter word. The final lists were constructed individually for each subject using only words which were not responses in the guessing task.

Mean retention scores for each of the four methods of retrieval for each subject group are given in Table 3. An analysis of variance was computed using arcsine transforms of the mean retention scores for subject groups and retention conditions. With conventional methods of assessing retention (see Table 3), that is, by recall and by recognition, the amnesics were significantly worse than the controls ($P < 0{\cdot}02$ and $< 0{\cdot}001$ respectively by the one-tailed t-test; the differences were also significant by the Mann–Whitney U test, $P < 0{\cdot}02$ in both cases). No significant difference between subject groups was found for either of the methods of partial information (see Table 3) and in neither case could a ceiling effect account for the similar level of performance in the two groups. Although the overall difference between the amnesic and control group was not significant, the difference between retention conditions was significant ($P < 0{\cdot}001$). Furthermore, the group x retention conditions interaction term was significant ($P < 0{\cdot}05$) indicating that the retention conditions had a differential effect on the amnesics and the control groups. Retrieval by recognition was superior to retrieval by recall in the control group ($P < 0{\cdot}0001$) but not in the amnesic group, while retrieval by partial information was superior to retrieval by recall in the amnesic group ($P < 0{\cdot}05$) but not in the control group.

Table 1. MEAN ERROR SCORE ON LEARNING AND RETENTION TRIALS

	Trial No. 1	2	3	4	5	6
Amnesic group N=4	6·0	2·9	1·8	2·1	1·4	1·5
Control group N=6	7·9	3·0	1·7	1·1	0·7	0·8

Table 2. RETENTION SCORES—EXPERIMENT I

	Controls	Amnesics
Recall	48 per cent	14 per cent
Recognition	94 per cent	59 per cent
Fragmented words	96 per cent	94 per cent

Table 3. RETENTION SCORES—EXPERIMENT II

	Controls N=8	Amnesics N=4
Recall	13·0	8·0
Recognition	18·7	10·5
Fragmented words	11·1	11·5
Initial letters	16·0	14·5

It can be seen that the method of learning did not differentially affect retention in amnesic subjects, in contrast to the method of retrieval, which did. The fact that information in long-term memory is available even after learning by conventional methods, if a particular retrieval method is used, is further evidence that it is inappropriate to characterize the amnesic syndrome as being a failure of registration or consolidation. We have shown previously that the normal relationship between recall and recognition may not be valid for amnesics; there was a relatively greater deficit on the recognition task than the recall task in the amnesic group[6]. The present experiment is consistent with this finding and furthermore has shown that retention by partial informa-

tion is a particularly favourable retrieval method for the amnesics but not the controls.

It is paradoxical that partial information in the form of fragmented letters or the initial letters of the word should be a more effective retrieval method than a conventional "yes–no" recognition task where the whole word is presented. The paradox can be resolved if one considers the proposition that to store or retrieve too much is as disastrous as to store or retrieve too little for efficient and effective memory. One special property of retrieval by partial information is that the subject can eliminate incorrect false-positive responses. The number of alternatives which would match the fragmented words must be very limited if not unique and in the case of the parts of words the number of alternatives is finite and can be counted. It has already been shown that the number of alternatives that could be formed from the same first three letters is a significant variable for both amnesic and control subjects[4]. This possibility of rejecting incorrect responses would be evident if either long-term memory information were not appropriately categorized or if there were too many items of stored information. It has been shown that organizational processes are important in normal memory[7,8] and it can be shown that at least some classification processes are possible for amnesics. It is therefore suggested that in the amnesic syndrome information in storage is either not inhibited or not dissipated in a normal fashion. This would account for the observations of a high incidence of prior list intrusions in amnesic subjects in tests of recall[6,10,11]. Performance on recognition tasks is subject to proactive interference effects, and it has been shown that there is a very rapid build-up of proactive interference in a continuous recognition memory task[12], which might account for the fact that recognition is no more favourable a measure of retention than recall in the amnesic group. It may not be too far-fetched to suggest that effective normal day-to-day memory demands that previous events be forgotten or suppressed and the inability to do so in the amnesic subject produces responses analogous to prior-list intrusions recorded in formal verbal learning experiments. From this point of view normal forgetting may be a positive benefit for efficient memory.

We now have two types of task, motor learning and retention by partial information, which are relatively well preserved in amnesic subjects. Is there a common factor linking performance on these apparently dissimilar tasks? Learning of new motor skills in normal subjects is not necessarily rapid, but retention over long periods of time is good. One property of motor skills is that retention is remarkably unaffected by interference effects in general[13] and by proactive interference in particular[14]. It is therefore suggested that both types of task, not necessarily for the same reason, are resistant to proactive interference.

Hitherto there has been an apparent discrepancy between amnesic deficits in man, as judged clinically, and the results of animal experiments that have attempted to generate amnesia in the laboratory. The present interpretation, based on disinhibition and interference phenomena rather than on faulty consolidation, allows one to bring the human amnesic syndrome, in which the hippocampus has been implicated[5], directly into line with the results of experimental medial–temporal and hippocampal damage in animals. For example, hippocampectomized rats and monkeys are slower to extinguish, slower in discrimination reversal tasks and under-react to novel stimuli when performing strongly established responses. Kimble[15] suggests that a failure of internal inhibition, Douglas and Pribram[16] that a failure of dissipation of awareness of unrewarded events would account for these findings. No doubt the cognitive capacities of man are different, and the defect would therefore have a different manifestation, but it is possible that the underlying functional disorder is the same.

We thank Dr R. T. C. Pratt for providing facilities to carry out this work and Dr A. D. Baddeley for his comments on the manuscript. Support was received from the MRC.

Received August 26, 1970.

1 Corkin, S., *Neuropsychologia*, **6**, 255 (1968).
2 Warrington, E. K., and Weiskrantz, L., *Nature*, **217**, 972 (1968).
3 Weiskrantz, L., and Warrington, E. K., *Neuropsychologia*, **8**, 281 (1970).
4 Weiskrantz, L., and Warrington, E. K., *Psychonom. Sci.*, **20**, 210 (1970).
5 Milner, B., in *Amnesia* (edit. by Whitty, C. W., and Zangwill, O. L.), 108 (Butterworth, London, 1968).
6 Warrington, E. K., and Weiskrantz, L., *Neuropsychologia*, **6**, 283 (1968).
7 Tulving, E., and Pearlstone, Z., *J. Verb. Learn. Verb. Behav.*, **5**, 381 (1966).
8 Mandler, G., in *The Psychology of Learning and Motivation* (edit. by Spence, K. Q., and Spence, J. T.) (Academic Press, New York, 1967).
9 Warrington, E. K., and Weiskrantz, L., *Neuropsychologia* (in the press).
10 Baddeley, A. D., and Warrington, E. K., *J. Verb. Learn. Verb. Behav.*, **9**, 176 (1970).
11 Starr, A., and Phillips, L., *Neuropsychologia*, **8**, 75 (1970).
12 Shepard, R. N., and Techtsoonian, N., *J. Exp. Psychol.*, **62**, 302 (1961).
13 Adams, J. A., *Human Memory* (McGraw-Hill, New York, 1967).
14 Duncan, C. P., and Underwood, B. J., *J. Exp. Psychol.*, **16**, 445 (1953).
15 Kimble, D. P., *Neuropsychologia*, **7**, 235 (1969).
16 Douglas, R. J., and Pribram, K. H., *Neuropsychologia*, **4**, 397 (1966).

Experimental Production of Transients in Human Interaction

by
ELIOT D. CHAPPLE
Research Center,
Rockland State Hospital,
Orangeburg, NY 10962

A review of some methods for measuring aspects of human interaction, based on the rhythmic patterns of activity and inactivity which two people display when they meet.

In the measurement of interaction, the beginnings and endings of actions are operationally defined by observing the associated contractions and relaxations of muscle systems (in the human, chiefly those of the face and head, often associated with sound and usually coincident with movements of the mouth). The actions are, in effect, made up of the fixed action patterns of the animal[1]. With the criteria of contraction and relaxation, the flow of fixed action patterns can be broken into separable "action" units; this procedure contrasts with much ethological description. Durations, as well as frequencies, thus become available for quantitative analysis.

The sequence of measurements demonstrates that their regularities are rhythmic in character. Though these rhythms are the fundamental property of the actions (and inactions) of humans and other animals, uniformities are obscured by environmental factors, particularly by the interference of the rhythms of other individuals. If individual rhythms are not completely synchronized, transients are set in motion. One can, however, define the experimental conditions through which a perfectly synchronized or "free-running" state can be achieved, in a first approximation at least, as being parallel to such states in the circadian rhythms[2,3].