Perceptual and Motor Skills, 1966, 22, 273-274.

ON THE DUAL FUNCTION OF CONSOLIDATION

H. J. EYSENCK
University of London

Summary.—It is suggested that there are two types of consolidation. Primary consolidation is concerned with a process of making available to the learner for use neural traces acquired during massed practice; secondary consolidation is concerned with the protection of these learned effector patterns against traumatic events affecting the brain.

The hypothesis of memory-trace consolidation or "perseveration" has had a long history since its inception by Mueller and Pilzecker (1900), and recent experimental work has been well summarized by Glickman (1961). The hypothesis has been used to explain reminiscence and the superiority of spaced over massed practice in nonsense syllable learning (McGeoch & Irion, 1956); more recently Eysenck (1965) has applied it to pursuit rotor learning. In the course of doing this it became clear that consolidation has two entirely different functions and that clarification of the nature of these two functions would be of considerable importance in future theoretical and empirical work. In its original meaning, consolidation implied that "a neural fixation process was assumed to continue after the organism was no longer confronted with the stimuli to be learned. This fixation process was deemed crucial to efficient retention and interference with perseveration was presumed to have an adverse effect on an organism's ability to remember stimuli to which it had been exposed" (Glickman, 1961, p. 218). Thus the function of consolidation was a *protective* one; effective learning had taken place but needed protection from the retroactive effects of new learning, which might be disruptive of retention, particularly if the new material was similar to the old. In line with this conception was the emphasis of experimental work on retrograde amnesia, i.e., on the forgetting of already mastered material if the original learning process was followed by electroconvulsive shock, head injury, anoxia, anesthesia, certain types of brain stimulation, or extremes of temperature.

In contrast to this protective function of the perseveration process is an entirely different function which may be characterised in terms of its effectiveness in making the neural changes which underlie learning available to the organism for future action. Consider pursuit rotor learning. A period of 5 min. of massed practice gives rise to very little improvement in performance; if followed by a period of rest, performance is then resumed at a much higher level. Clearly certain neural patterns were laid down during massed practice but were not available to the organism for actual work, as shown by the lack of any marked improvement in performance. Rest is needed to ensure that the neural traces are transformed into learned action patterns which can be indexed in terms of improved performance after the rest (reminiscence). Evidence on this point comes from the work of Rachman and Grassi (1965) and various papers by McGaugh and colleagues, summarized by Eysenck (1965); these are quite different in kind from the studies supporting the hypothesis of protective consolidation. In the latter type of experiment, existing learning, demonstrated in performance, is wiped out by immediately succeeding traumatic events, such as electroconvulsive shock; in the former, hypothetical learning, presumed to have taken place during massed practice, is made demonstrable in actual practice through an interpolated rest pause, during which independent variables can be introduced to influence the amount of consolidation that takes place in predictable ways.

We may conceive of the course of learning in the following manner. First, there is massed practice of a task, during which neural patterns of a temporary character are laid down; we may call this the *neural stage.* This is followed by a period of rest, during which *primary consolidation* takes place; during this period, neural traces are made available to the experimental *S* for actual improved work. This, in turn, is followed by *secondary consolidation* (protective consolidation) during which the memory trace is protected against retrograde amnesia. It is not clear whether primary and secondary consolidation can go on simultaneously; there is no obvious reason why they should not do so, but there is no evidence that they do so. It seems likely that secondary consolidation goes on for much longer periods of time than primary consolidation, which in normal *S*s practicing on the pursuit rotor usually takes less than 10 min. [Schizophrenic *S*s seem to be characterised by a long period of slow primary consolidation (cf. Eysenck, 1961; Broadhurst & Broadhurst, 1964).] However, there has been practically no work on secondary consolidation in connection with tracking tasks, just as there has been comparatively little work on primary consolidation with verbal tasks. Much research remains to be done before these questions are clarified sufficiently to make possible a proper theoretical statement.

Consolidation has been made responsible for the well-known post-rest decline effect in performance (Eysenck, 1965); the writer put forward the hypothesis that consolidation interfered with post-rest performance, thus producing this decline. The obvious prediction that in terms of this theory one would expect post-rest decline to be less, or even to disappear with lengthening of the rest pause has been verified in two unpublished studies by K. Star and F. Farley. It seems possible that more detailed studies of this effect, with suitable spacing of rest intervals, could throw some light on the question of whether the interference was produced by primary or secondary consolidation. They might also answer questions relating to the duration of both these processes.

REFERENCES

BROADHURST, P. L., & BROADHURST, A. An analysis of the pursuit rotor learning of chronic psychotics. *Brit. J. Psychol.*, 1964, 55, 321-331.

EYSENCK, H. J. Psychosis, drive and inhibition: a theoretical and experimental account. *Amer. J. Psychiat.*, 1961, 118, 198-204.

EYSENCK, H. J. A three-factor theory of reminiscence. *Brit. J. Psychol.*, 1965, 56, 163-181.

GLICKMAN, S. E. Perseverative neural processes and consolidation of the memory trace. *Psychol. Bull.*, 1961, 58, 218-233.

MCGEOCH, J. A., & IRION, A. L. *The psychology of human learning.* London: Longmans, Green, 1956.

MUELLER, G. E., & PILZECKER, A. Experimentelle Beitraege zur Lehre vom Gedaechtniss. *Z. Psychol.*, 1900, Suppl. No. 1.

RACHMAN, S., & GRASSI, J. Reminiscence, inhibition and consolidation. *Brit. J. Psychol.*, 1965, 56, 157-162.

Accepted December 29, 1965.