Life Sciences Vol. 3, pp. 175-188, 1964. Pergamon Press, Inc. Printed in the United States.

AN EXPERIMENTAL TEST OF THE "INHIBITION" AND "CONSOLIDATION" THEORIES OF REMINISCENCE

H. J. Eysenck *

Institute of Psychiatry, University of London

(Received 27 January 1964)

Introduction

The writer has made considerable use, during recent years, of the Hull (1) - Ammons (2) - Kimble (3) theory of reminiscence; during this time much support was found for this theory, but in addition certain facts came to light which were difficult to fit into such a framework. In this paper, the writer proposes to discuss some of these obstreperous facts, and to report an experiment undertaken in order to throw some further light on these problems; it is hoped that some theoretical clarification may result from this undertaking. The experiment reported, like most of those undertaken in our Department in recent years, makes use of the pursuit rotor; this choice of instrument imposes certain limits to the generality of conclusions which will be discussed later in the paper.

An adequate theory of reminiscence is required to explain why, when a rest pause of ten minutes or so duration is interposed between two periods of massed practice on the pursuit rotor, the first ten-second post-rest trial is superior to the last ten-second pre-rest trial, superiority being measured

---

* The writer is indebted to the Maudsley and Bethlem Royal Hospital Research Fund for the support of this investigation. He is also grateful to Mr. C.Attwood who kindly allowed him to test apprentices at the Ford works at Dagenham.

in terms of time on target. The two main contenders in the field are the inhibition theory and the consolidation theory. The former explains the reminiscence effect as being due to the accumulation of some performance decrement or fatigue product (reactive inhibition or I_R in Hull's terminology) which dissipates during rest, thus allowing performance to proceed unimpeded after rest. The latter explains the reminiscence effect as being due to the need for rest on the part of the organism in order to consolidate the memory trace; elimination of this consolidation phase, as through brain injury or ECT, renders impossible any learning of the activity practised during the preceding time interval. Independent evidence for the existence of both inhibition effects (4) and consolidation effects (5) are strong, so that it cannot be said that these factors are invoked in any ad hoc fashion. In recent years, the inhibition theory, particularly in the form given to it by Kimble (3) and Ammons (2), has been widely accepted, while the consolidation theory has been relegated to the background, and dismissed as lacking "any great generality" (4). The reason for this wide acceptance is not far to seek; by combining conditioned inhibition ($_SI_R$) with I_R, Kimble and his followers were able to account for many of the findings of research in this field, beyond the single fact of reminiscence.* This "two-factor theory" of

---

* In using the Hullian formulations, Eysenck (6) has made one important change in this theory which appears to be dictated by the pressure of experimental investigations. Hull accepts the Mowrer-Miller "work hypothesis", according to which inhibition is a function of the actual physical work done by the organism; Bilodeau (7), Bilodeau and Bilodeau (8), and Ellis, Montgomery and Underwood (9), have adduced contrary evidence. The writer prefers a central rather than a peripheral type of hypothesis, relating inhibition rather to the amount of continued attention required by the task (i.e. a "mental work" hypothesis rather than a physical one). Evidence for the existence of reminiscence effects in almost purely perceptual tasks (10) and studies of bilateral transfer effects (11, 12) further serve to discredit the peripheral hypothesis.

reminiscence, it is suggested here, is only partially adequate to account for all the facts, and requires to be turned into a "three-factor theory" by the addition of consolidation as one of the determinants of reminiscence.

Consider the essential difference between the two theories. Inhibition theory postulates depression of pre-rest performance as the crucial feature of the reminiscence phenomenon; in other words, it is a performance theory. Consolidation theory postulates consolidation of the memory trace as the crucial feature of the reminiscence phenomenon; in other words, it is a learning theory. This is an important distinction in all modern learning theories, and the failure in much recent thinking to preserve the difference between performance and learning in reminiscence may be responsible for some of the apparent failure of prediction. Fig. 1 will make the theoretical distinction clear. According to inhibition theory, learning has taken place during phase I, and performance at point B is depressed below that at point C because of inhibition. According to consolidation theory, learning is a two-phase process, and the essential consolidation process has not yet taken place at point B, but occurs during phase II (Rest); it is the occurrence of this process which elevates C above B.

It will not be necessary here to recapitulate the facts which favour the inhibition theory; they are well-known and clearly summarized elsewhere (4; 6). It will be more apposite to list a few of the facts which are irreconcileable with inhibition theory, in order to see whether these facts can find an explanation in terms of consolidation theory. (1) The first fact in this list derives from the extensive studies recently undertaken to test the hypothesis, put forward by Kimble (13), that high drive should generate higher reminiscence than low drive (14, 15, 16). Results were in essential conformity with prediction, as far as reminiscence was concerned, but they provided additional information not predicted or predictable by the Kimble theory. According to inhibition theory, high- and low-drive groups should show different scores at point B. and identical scores at point C;

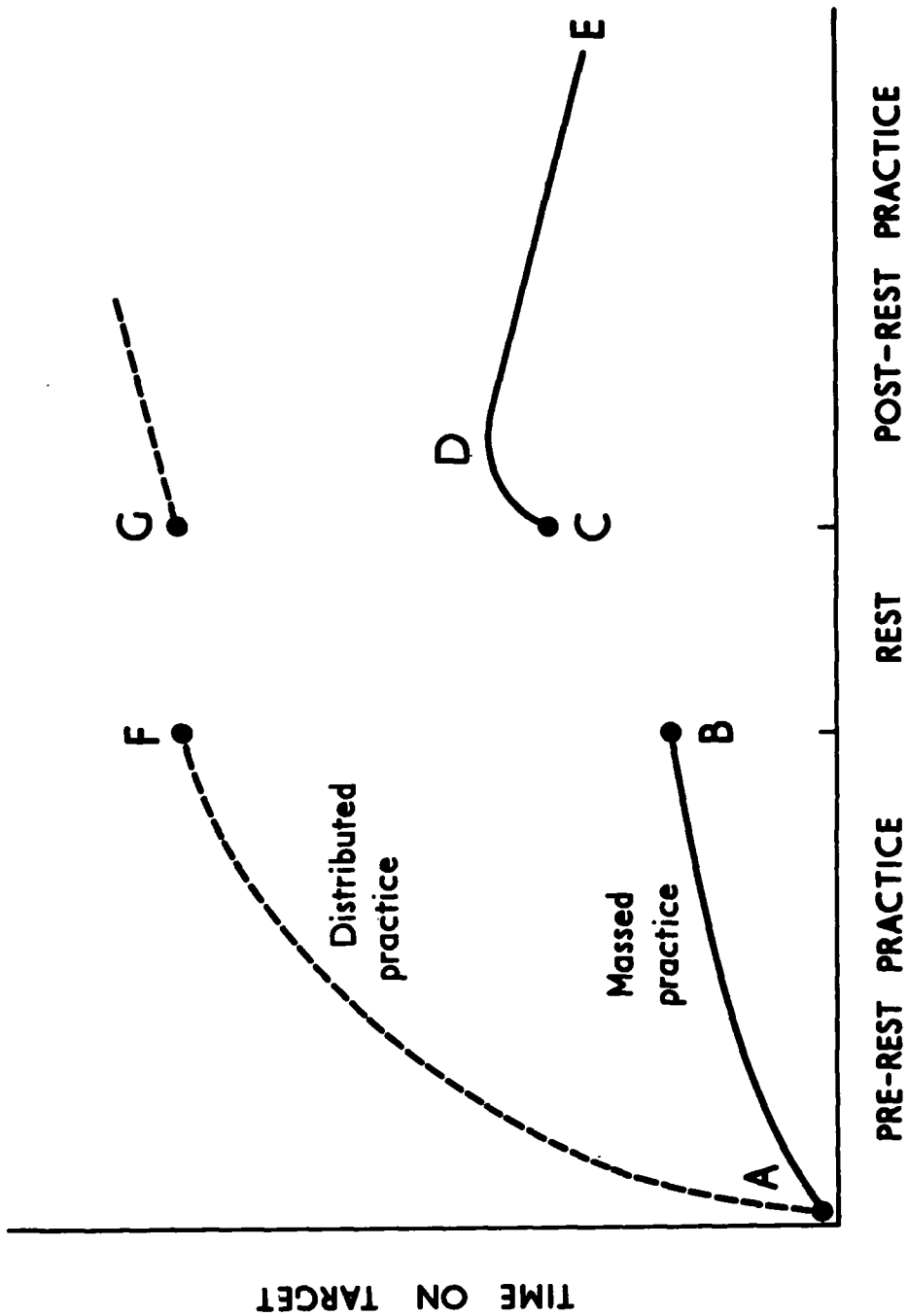

Fig. 1. Shape of work curves under conditions of massed and distributed practice.

in actual fact, the two groups showed identical scores at point B and different scores at point C. In other words, whatever it was that was differentially affected by drive occurred during phase II, not during phase I, and could not, therefore, be an inhibitory process of the classical kind. The data are essentially in conformity with a consolidation hypothesis, provided we are willing to postulate either that the duration of the consolidation process is a direct function of drive, or, that the amount of original learning in phase I, later consolidated during rest, is a direct function of drive. This postulate is necessary in order to explain the detailed relationship between reminiscence, drive level, and length of pre-rest period (17). Such a postulate fits more easily into theories of the Spence (18) type than those of the Hull (1) type, but is not otherwise incompatible with our present knowledge.

(2) Our next fact comes from the field of disinhibition experiments. Rachman (19) and Feldman (20) have argued that any strong "alien" stimulus applied shortly before the end of phase I, i.e. just preceding point B, should have the effect of disinhibiting such I_R as had been accumulated at this time; this would improve performance and raise point B, thus lowering reminiscence. The postulated lowering of reminiscence was indeed found, but it seemed to be due more to a lowering of point C than to a raising of point B. This is not deducible from the inhibition hypothesis, but fits in well with the consolidation hypothesis, provided we are willing to accept the following postulate: Strong irrelevant sensory stimulation preceding or coinciding with the consolidation period interferes with the consolidation process. An additional experiment of interest here would seem to be one in which the alien stimulus is applied immediately after point B, rather than immediately preceding it; on the consolidation hypothesis this should lower reminiscence, while on the inhibition hypothesis no such effect would be likely. It might be argued of course, on the inhibition hypothesis, that the alien stimulus interfered with the process of disinhibition, thus lowering

point C. The experiment would not therefore be a crucial one, unless the rest period were a rather protracted one.

Experiment

Three-hundred male applicants for an apprenticeship training scheme were administered the pursuit rotor under conditions of high drive (21). The apprentices were all aged between 15 and 17 years, and took the test as part of a selection battery, not knowing that scores would not in fact contribute to their acceptance or rejection. All Ss practised for five minutes, rested for ten minutes, and practised for another five minutes. No effort was made to prescribe what they should do during the rest interval, other than ensure that they did not play with or practise on the pursuit apparatus; it has been shown several times that activities even quite closely related to pursuit have no facilitating effect on reminiscence. The apparatus used has been described in detail elsewhere (21). Subjects who failed to learn the task were eliminated and others used to replace them, the criterion of "learning" being a score of at least one second on target during at least one of the 30 ten-second periods which constituted the pre-rest practice period. Practice was massed, recording being switched every ten seconds from one of two clocks to the other, to enable the score to be read and recorded. The first ten-second post-rest trial was preceded by two seconds of rotary pursuit, so that Ss should not enter the first trial "cold", but would have an equal chance on this as on succeeding trials of starting off "on target". Standard instructions were given to all Ss, and verbal correction applied if they did not act according to instructions. Scores were recorded to the nearest .01". The difference between the last pre-rest and the first post-rest trial was used as our measure of reminiscence.

Results

Ss were divided into five equal groups according to their scores during the first ten trials; this was done to rule out from subsequent analysis the influence of task ability, which is quite strong in the case of the pursuit rotor. (The highest group was on target about nine times as long as the lowest!) Each of these groups, which will be denoted A, B, C, D and E, from high to low, was in turn subdivided into two equal sub-groups, according to performance of its members during the terminal ten pre-rest trials; those showing the better performance will be given the subscript "h", for high, while the others will be given the subscript "l", for low. We thus have ten groups in all, divided according to initial and terminal performance. Fig. 2 shows the performance of the A to E groups, while Fig. 3 shows the combined performance of the "h" and the "l" groups. (A figure showing the performance of all ten groups was prepared, but was found too confusing; also it failed to add any important information, and has therefore been omitted in this account.)

The rationale underlying these divisions may now be indicated. According to the "inhibition" hypothesis, reminiscence is caused by depression of performance at point B; it would seem to follow that when we compare reminiscence scores of groups, equated for initial ability, but differing with respect to high or low performance at point B, then those with low scores at B should have higher reminiscence scores than those with high scores at B. According to the "consolidation" hypothesis, differences at B should be irrelevant to the size of reminiscence scores. We would thus appear to have a crucial test of the rival hypotheses. Table 1 sets out the observed mean reminiscence scores for the ten groups. It will be seen that there is no difference between the "h" and "l" groups; in other words, the position of point B does not determine the amount of reminiscence observed. This result would appear to support the consolidation theory, and to disprove the inhibition hypothesis. An analysis of variance was performed on these data

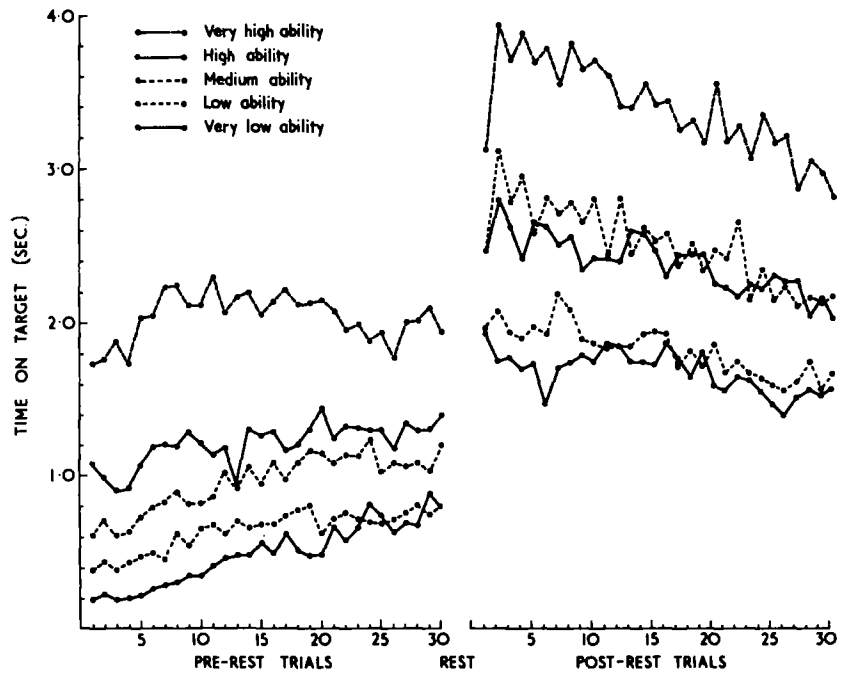

Fig. 2. Pre-rest and post-rest performance of five groups of subjects differing in pursuit rotor ability.

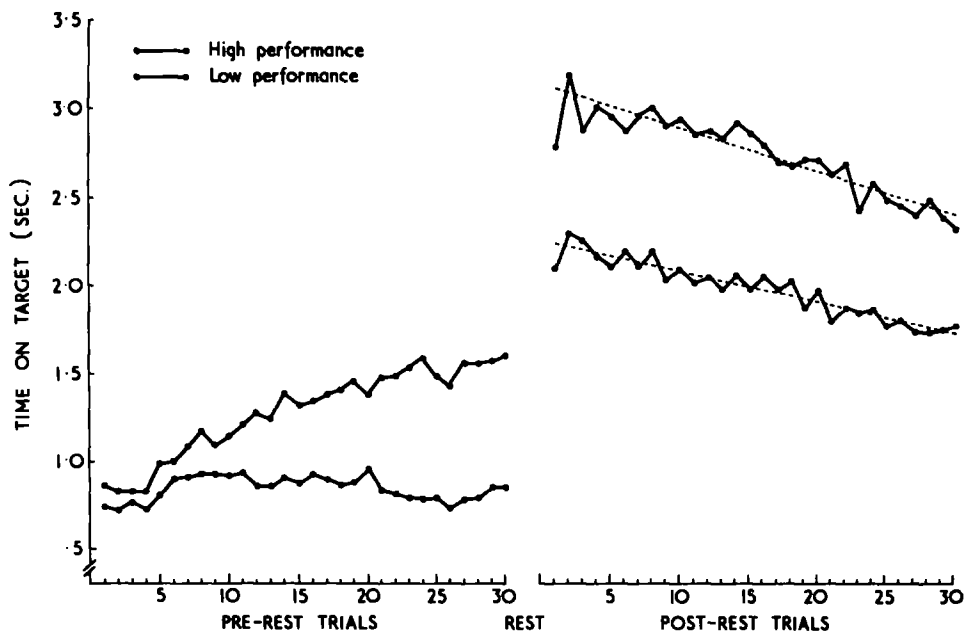

Fig. 3. Pre-rest and post-rest performance of subjects showing depressed or elevated performance during the last ten pre-rest trials, when equated for initial ability.

and showed this source of variance to be quite insignificant.

TABLE 1

Reminiscence Scores of Ten Experimental Groups

	"h"	"l"	Total
Group A	.79	1.56	1.18
B	1.31	1.03	1.17
C	1.36	1.50	1.43
D	1.25	1.11	1.18
E	1.29	.98	1.14
Total:	1.20	1.24	1.22

Differences according to original ability do not seem to give rise to differences in reminiscence; variation among scores in the last column is quite small. In the analysis of variance this source of variation also fails to disprove the null hypothesis. There is an almost significant interaction ($F = 2.380$, when 2.41 is required for significance at the 5% level); this effect is produced by the exceptionally low reminiscence values for groups A_h and E_l. No attempt will here be made to account for what is quite likely a chance effect.

In the discussion so far, we have used as our measure of reminiscence the simple arithmetical difference between the last pre-rest trial and the first post-rest trial. Ammons (2) has argued in favour of correcting for the "warm-up decrement", as he calls the phenomenon which gives rise to the rapid post-rest upswing in performance, by extrapolating backwards the downward course of post-rest performance from the top of the "warm-up" onwards; this suggestion has been accepted and followed by Kimble (3) and others. The present writer has argued that we are dealing with an upswing due to the

extinction of conditioned inhibition, and that consequently any correction would be spurious (22, 23); nevertheless, it may be of interest to discover what effect such a correction would have. The actual correction made is indicated in Fig.3; the corrected reminiscence values are 1.52 and 1.38 respectively for the "h" and "l" groups. While little precision attaches to these corrections, it will be seen that they displace the results in a direction contrary to the inhibition hypothesis; if anything, it is the "h" group that has higher corrected reminiscence values. Similar manipulations were carried out on all the five sub-groups (A, B, C, D and E), and an analysis of variance done on the resulting figures; no significant or suggestive results were obtained. We must conclude that correction for "warm-up decrement", even if it were advisable or admissible, does not alter our conclusion that reminiscence is not affected by depression or elevation of pre-rest terminal scores of groups matched on ability.

A further analysis was undertaken to test the two hypotheses under investigation. We may assume that both the postulated factors, "inhibition" and "consolidation", are likely to affect different individuals differently. This postulate of individual differences suggests that if we correlate scores at points A and B, and A and C, over all our Ss, then r_{AB} should be lowered by the hypothetical action of "inhibition", while r_{AC} should be lowered by the hypothetical action of "consolidation". A comparison of the relative size of these two correlations should therefore shed some light on our problem. It was found that $r_{AB} = .41$, while $r_{AC} = .30$, a difference which just fails to be statistically significant at the 5% level, but whose direction favours the consolidation hypothesis. It is interesting to note that in this it exactly reverses the trend found among correlation coefficients for massed practice on the alphabet printing task by Zeaman and Kaufman (24); quite rightly these authors interpret their finding as supporting the "inhibition" theory. An attempt to explain these divergent findings will be made in the next section; this explanation stresses task differences as being responsible for

different contributions of "inhibition" and "consolidation" to the total reminiscence score.

Discussion

Reminiscence is usually defined in terms of increments in learning which occur during a rest period (25): this author warns that before reminiscence "can be considered a fundamental learning phenomenon, explanation of it in terms of fatigue, motivation, and artifacts of measurement must be eliminated". Osgood (26) on the other hand defines reminiscence as "a temporary improvement in performance, without practice". (p. 509) "The term 'reminiscence' refers to the objective fact of improved performance." (Ibid.; our italics). The theory here proposed would split this "objective fact of improved performance" into two parts; one related to learning (consolidation hypothesis), the other to recovery of depressed performance (inhibition hypothesis). (To these would, of course, have to be added a third factor (conditioned inhibition), produced as a result of involuntary rest pauses due to increased reactive inhibition, but unlike the latter not dissipating with rest and therefore setting an upper limit to post-rest performance below that resulting from the action of consolidation.)

A theory such as this must immediately face a problem which has on the whole not been treated very much by theorists, namely the relation between theory and type of test used. Apart from making a distinction between learning of skills (as in the pursuit rotor test) and learning of verbal associations (as on the memory drum) there has been a tendency to treat all types of test material as exemplifying the same general laws. It will be seen from some simple considerations immediately following from our theory that this point of view is not acceptable. Different tasks obviously involve different degrees of inhibition and of consolidation in the production of the total effect known as "reminiscence", and may thus differ profoundly in the effects and correlates of this phenomenon. We have shown

that pursuit rotor performance is near the one end of a continuum going from "pure consolidation" to "pure inhibition"; there is little evidence in our data of any effect of "inhibition" on reminiscence. (It is not implied that inhibition was not being generated, but merely that it did not influence our measure of reminiscence.) Near the other end of such a continuum would be typical vigilance experiments (27); in these performance is nearly perfect from the beginning, and such reminiscence as is found is due almost entirely to the dissipation of inhibition. The same is probably true of perceptual tasks such as rotating spiral after-effects, where no learning is observed but only performance decrement due to massed practice (28). It is unusual to refer to vigilance tasks and perceptual experiments in terms of "reminiscence", but if we follow Osgood in his definition we can hardly refuse to class these phenomena with the more orthodox pursuit rotor and inverted alphabet printing tasks.

It will be seen, then, that what we propose is a three-factor theory of reminiscence, involving reactive inhibition, conditioned inhibition, and consolidation; it is further proposed that the relative importance of these three components depends fundamentally on the precise nature of the task used. It is also likely to depend on other factors, such as the drive state of the subjects, lack of sleep, stimulant or depressant drugs taken, and perhaps also the personality type of the subject (29). Future work may with advantage study task differences as an important variable in the determination of reminiscence effects.

Summary

An experiment was carried out to test contradictory predictions made on the basis of the "inhibition" and the "consolidation" theories of reminiscence. Three-hundred high-drive Ss were tested on the pursuit rotor, two five-minute work periods being separated by a ten-minute rest pause. Ss were divided into five groups according to task ability; each of these groups was again

subdivided into two according to whether their pre-rest performance was or was not depressed. Reminiscence was found to be independent of grouping by ability and of grouping according to depression of pre-rest performance; these results were interpreted as supporting the consolidation hypothesis.

References

1. C. L. Hull, Principles of Behavior. Appleton-Century-Crofts, N.Y. (1943).
2. R. B. Ammons, Psychol. Rev., 54, 263 (1947).
3. G. A. Kimble, J. exp. Psychol., 39, 15 (1949).
4. J. A. McGeoch & A. L Irion, The Psychology of Human Learning. Longmans, Green & Co., New York (1952).
5. S. E. Glickman, Psychol. Bull., 58, 218 (1961).
6. H. J. Eysenck, Dynamics of Anxiety and Hysteria, Routledge and Kegan Paul, London (1957).
7. E. A. Bilodeau, J. exp. Psychol., 44, 96 (1952).
8. Ina McD. Bilodeau & E. A. Bilodeau, J. exp. Psychol., 48, 455 (1954).
9. D. S. Ellis, V. Montgomery & B. J. Underwood, J. exp. Psychol., 44, 420 (1952).
10. Carol H. Ammons, An experimental study of temporary and permanent inhibitory effects associated with acquisition of a simple perceptual-motor skill. Unpublished Ph.D. thesis, Louisville, Kentucky (1955).
11. R. B. Ammons & Carol H. Ammons, Amer. Psychologist, 6, 294 (1951).
12. G. R. Grice & B. Reynolds, J. exp. Psychol., 44, 247 (1952).
13. G. A. Kimble, J. exp. Psychol., 40, 248 (1950).
14. H. J. Eysenck & A. E. Maxwell, Brit. J. Psychol., 52, 43 (1961).
15. H. J. Eysenck & R. A. Willett, J. ment. Sci., 107, 961 (1961).
16. M. P. Feldman, in: H. J. Eysenck (Ed.) Experiments in Motivation. Pergamon Press, Oxford (1964).
17. R. A. Willett & H. J. Eysenck, Life Sci., 4, 119 (1962).

18. K. W. Spence, Behavior Theory and Conditioning, Yale Univ. Press, New Haven (1956).

19. S. Rachman, Brit. J. Psychol., 53, 149 (1962).

20. M. P. Feldman, in: H. J. Eysenck (Ed.) Experiments in Motivation, Pergamon Press, Oxford (1964).

21. H. J. Eysenck (Ed.) Experiments in Motivation, Pergamon Press, Oxford (1964).

22. H. J. Eysenck, Acta psychol., 12, 349 (1956).

23. M. P. Feldman, Psychol. Bull., 60, 452 (1963).

24. D. Zeaman & H. Kaufman, Psychol. Mon., 69, No. 6 (1955).

25. C. I. Hovland, in: S. S. Stevens (Ed.) Handbook of Experimental Psychology, Chapman & Hall, London (1951).

26. C. E. Osgood, Method and Theory in Experimental Psychology, Oxford Univ. Press, New York (1953).

27. D. N. Buckner & J. J. McGrath (Eds.) Vigilance: a Symposium, McGraw-Hill, London (1963).

28. H. C. Holland, Brit. J. Psychol., 54, 261 (1963).

29. H. J. Eysenck, Brit. J. soc. clin. Psychol., 1, 127 (1962).