Br. J. Psychol. (1969), **60**, 3, *pp.* 373–384
Printed in Great Britain

POST-REST UPSWING AND DOWNSWING IN PURSUIT ROTOR LEARNING AFTER DISTRIBUTED PRACTICE AS A FUNCTION OF LENGTH OF PRACTICE

BY H. J. EYSENCK, A. ISELER, K. STAR AND R. A. WILLETT
Department of Psychology, Institute of Psychiatry, University of London

An experiment is reported to investigate some determinants of post-rest upswing (PRU; 'warm up') and post-rest downswing (PRD) in pursuit rotor learning. Seven groups of subjects were tested under high drive conditions, and another seven under low drive conditions; all were given five periods of practice (either 20, 30, 40, 60, 80 100, or 120 sec.), separated by 1 min. rest periods. Finally all groups were given 15 min. of massed practice, preceded by a 1 min. rest period. Practice periods were kept short in order to make possible a micro-genetic investigation of the very beginning of PRU; it is known that this occurs strongly with longer periods, but it seemed of interest to observe the phenomenon during an earlier stage of growth. Theories regarding both PRU and PRD had been put forward by Ammons and Eysenck; it was hoped that the experiment would confirm or disconfirm predictions made from these theories. Results on the whole were more in line with the more recent theories, but neither theory was able to account for all the observed results. Thus while the Eysenck theory could account for the fact that *amount* of PRD during the massed practice was a function of the length of pre-test practice, *duration* of PRD was not; this effect was not predicted. Other findings were that PRD increases over successive trials, and that longer practice periods produce more PRU. Drive was found to interact with other variables.

The phenomenon of reminiscence after massed practice in pursuit rotor learning has been studied in considerable detail, and several theories have been elaborated to account for it (McGeoch & Irion, 1952); much less attention has been paid to two other phenomena closely related to reminiscence, i.e. post-rest upswing (also sometimes called 'warm-up decrement' or WU) and post-rest downswing. When massed practice on the pursuit rotor, which typically shows a very slow, linear rate of improvement, is followed by a rest pause of several minutes, the first post-rest trial is typically much higher than the last pre-rest trial; this in in fact the phenomenon of reminiscence. But this first trial is followed in most cases, by a rapid rise of the curve of practice for a minute or so; this has been called 'warm-up decrement' by Ammons (1947) and other writers (e.g. Adams, 1961), but this term is question-begging because it assumes that we already know the cause for the phenomenon. As there are several alternative hypotheses in the field, a more neutral term seems preferable, and Eysenck (1965) has suggested 'post-rest upswing' as being descriptively more accurate and theoretically more neutral. This upswing, in turn, is usually followed by a long-continued decrement in performance, which by analogy may perhaps be called 'post-rest downswing'— another purely descriptive term without any theoretical implications.* Finally, after some 8 min. or so (the exact time depending on the

* PRD is not dependent on the occurrence of PRU and can and does occur even when there is no PRU. The position seems to be that massed practice on the pursuit rotor, followed by a rest, leads to PRD under almost any combination of parameter values when practice is resumed. PRU only occurs under certain parameter values, e.g. when pre-rest practice has been continued for longer than 120 sec.; PRD occurs even after 20 sec. of practice. When both PRU and PRD occur it may be assumed that the former largely masks the latter, so that it does not seem to begin until after the former process has run its

length of pre-rest practice, and the length of the interpolated rest pause) the downswing ceases, and the curve resumes its slow upward trend, parallel to and possibly continuous with, the pre-rest practice curve. Denny (1951) has suggested that the course of the upward trend of the practice curve would coincide with the trend of another group of subjects who continued with massed practice throughout; this is possible, but the only evidence available is visual; no proper statistical trials or experimental determinations with varying parameters seem to have been done to establish this point. Our data suggest that this hypothesis is not in fact correct.

Adams (1961) has reviewed the literature on post-rest upswing; he demonstrates that the warm-up hypothesis has much to be said in its favour as far as verbal learning is concerned (Irion, 1949; Irion & Wham, 1951; Hunter, 1955). These and other studies succeeded in finding tasks (such as colour-naming) which could not reasonably be thought of as strengthening goal responses, but which nevertheless produced rapid post-rest improvement—presumably by enhancing some form of set. For motor behaviour the hypothesis is much less attractive because, as Adams points out, 'the difficulty...at this time is that these neutral tasks have not yet been discovered, if they exist at all' (p. 265). Eysenck (1956) has proposed an alternative theory according to which post-rest upswing is produced by the extinction of conditioned inhibition through non-reinforcement by the reactive inhibition dissipated during the rest pause; this hypothesis has been criticized by Adams (1961, 1963) and defended by Feldman (1963). The particular inhibition hypothesis under discussion forms part of a comprehensive set of postulates deriving from Hull (1943) and Kimble (1949). According to this theory, reactive inhibition (I_R) is regarded as a negative drive which grows until it has cancelled out the positive drive (D) active in the testing situation. At this point performance stops and an involuntary rest pause (IRP) ensues. During this IRP, reactive inhibition dissipates, and performance is then resumed, until I_R again equals D, when another IRP occurs, and so on. A resting response is thus conditioned as a habit, through the reinforcement of the IRPs by the resting behaviour which follows practice, and it is maintained that early in post-rest performance this response is extinguished through non-reinforcement—the total dissipation of I_R during the programmed rest means that there will be no IRPs to reinforce the resting response, at least until enough I_R has again accrued to equal D. It is this extinction process which is indexed as post-rest upswing; theoretically it reaches its highest point just prior to the first IRP occurring and reinforcing the conditioned resting behaviour. (It is of interest that a similar theory has been advanced by Denny *et al.* (1955) to account for the fact that groups of subjects switching from massed to distributed practice finally achieve as high performances as groups of subjects starting with distributed practice and going on with distributed practice.)

As Feldman (1963) points out, 'it clearly follows from the above theory that there

course. Equally PRD must be presumed to detract from the maximum value which PRU can reach; if it were not for the decrement the upswing would be even more noticeable. Clearly this involved sequence of events makes unequivocal measurement very difficult; it also interferes with the measurement of reminiscence itself, as Ammons (1947) was the first to recognize. His method of dealing with the problem will be discussed later; it depends on a theory of PRU and PRD which is of doubtful value. In the absence of a widely accepted theory of these phenomena, simple descriptive statistics have been used in this paper to investigate the effects of parameter changes on these variables.

is a critical length of pre-rest practice below which WU will not be manifested, above which WU will gradually increase. The set hypothesis would not predict this sharp break between WU occurrence and non-occurrence. To date the evidence favours the inhibition hypothesis.' After quoting the work of Eysenck (1956, 1960) and Star (1957), Feldman showed that work involving the manipulation of the drive variable (Eysenck & Willett, 1961; Eysenck & Maxwell, 1961) also favoured the inhibition hypothesis. Many other experiments are cited by Feldman, all of them supporting the hypothesis when appropriate parameter values are chosen by the experimenters. The experiment to be reported below constitutes an attempt to throw further light on this problem.

If theories of post-rest upswing (PRU) are in doubt, theories of post-rest downswing (PRD) are even less advanced. Ammons (1947, 1952) proposed 'that the falling segment was due to an accumulation of temporary work decrement' i.e. reactive inhibition (I_R), but this suggestion is difficult to accept. Consider two groups of subjects, equated for ability and other relevant parameters; the control group performs for 15 min. of massed practice, while the experimental group has 5 min. of massed practice, 10 min. of rest, and another 10 min. of massed practice. The performance curve of the control group shows a gentle rise throughout; so does that of the experimental group pre-rest. Post-rest, however, after a short upswing, the performance curve drops for almost the entire length of the post-rest period. Ammons does not explain how this drop can be due to I_R when the control group, which has been accumulating I_R continuously since the beginning of the experiment, shows an *increment* in performance. Consider the position of both groups after 7 min. of practice (i.e. 2 min. after the cessation of the rest pause for the experimental group). The control group has been amassing I_R for 7 min., yet its performance is constantly improving. The experimental group, having dissipated all the I_R acquired during the first 5 min. of practice, has reacquired I_R for only 2 min., yet its performance curve is dropping dramatically. The only possible way out of this impasse would be for Ammons to assume that the post-rest performance of the experimental group, particularly the PRU part of it, is so superior to that of the control group that more I_R is being generated. This explanation would be entirely *ad hoc*, and counter to the hypothetical properties of I_R, but it needs to be disproved in order to be certain that this theory is not in fact viable.

No other theorist seems to have considered this problem until recently, when Eysenck (1965) derived PRD as a consequence of his general theory of reminiscence; on this account reminiscence is due to the consolidation of the memory trace, and the consolidation process, which continues even after resumption of work post-rest, interferes with post-rest performance, thus producing the down-swing. (Walker (1958) has outlined a theory of consolidation and interference similar to this, but has not applied it to the learning of skilled tasks, or to PRD.) Eysenck's general theory makes possible many different tests of this hypothesis. The present experiment was in part designed to test alternative predictions made on the basis of the Ammons and the Eysenck theories.

METHOD

Subjects. Two groups of subjects were used, one being made up of prospective apprentices at a large car manufacturing plant in London, the other of apprentices employed by a large car manufacturing plant in Birmingham. The former were working under conditions of high drive as they were under the impression that their scores would count towards their acceptance or rejection for the very much sought-after training course for which they had applied. The latter were working under a condition of rather lower motivation, as they were already employed and knew that the results of the experiments would not affect them personally in any way. A more extensive discussion of this method of manipulating motivation, and a detailed analysis of experimental results obtained in a variety of measures, have been given elsewhere (Eysenck, 1964). We have found, in previous work, that performance on the pursuit rotor is not affected by motivation so manipulated, whereas reminiscence is significantly higher for the high drive groups (Eysenck & Maxwell, 1961; Eysenck & Willett, 1961; Feldman, 1964). Unfortunately in the present experiment the low drive group was somewhat older (18 yr. *v* 16 yr.) than the high drive group, and possibly for that reason performed at a higher level throughout; Ammons *et al.* (1955) have shown that pursuit rotor performance increases with age. This difference in general level of performance, fortunately, is not relevant to our hypothesis and does not affect our conclusions; it should, however, be borne in mind during our discussion of the results.

Apparatus. The pursuit rotor used, which is standard in all our published work, consists of turntable 10 in. in diameter, rotating in a clockwise direction at 60 rev./min. A target $\frac{7}{10}$ in. in diameter is set with its centre $3\frac{1}{4}$ in. from the centre of the turntable, and flush with its surface. The subject is required to keep the tip of an articulated stylus in contact with the target while the turntable rotates. The stylus, of total weight 2 oz., consists of a circular plastic handle $4\frac{1}{2}$ in. long with a guard set 1 in. from the end of the handle. An extension rod (6 in. long, $\frac{1}{10}$ in. diameter and with an 85° bend 1 in. from its end), hinged so that only its weight rests on the turntable, projects from the guard. Steady contact between stylus tip and target closes a circuit to two recording chronotrons. Time on target is integrated over 10 sec. periods, each period being termed a trial, and is registered alternately on one of the chronotrons, an automatic switching device bringing the other one into action at the end of every trial, making it possible for the experimenter to read the setting. Rotors were activated 2 sec. before the beginning of a practice period, allowing subjects to have two complete revolutions accompanied by tracking before clocks began to count; this was done so that the first 10 sec. trial should not begin 'cold' and thus be different from all the others.

Experimental design. Different groups of subjects underwent one of seven courses of distributed practice, receiving five practice periods ('trials') of respectively 20, 30, 40, 60, 80, 100 or 120 sec., with rest pauses of 1 min. each interpolated between successive practice periods. A sixth practice period of 15 min. duration of massed practice was administered to all groups after a rest in 1 min. following the last of the five periods of spaced practice. Each of these seven courses of treatment was followed by high drive and low drive groups, thus making a total of 14 separate groups. Each of these groups was made up of 30 apprentices, but through apparatus failure and for other uncontrollable reasons some groups fall short of this number by one or at most two subjects.

RESULTS

Analyses were made separately of the first five distributed practice periods, by length of practice and by drive state, and of the terminal 15 min. of massed practice. Figs. 1–7 show the results of the analysis in diagrammatic form. It will be seen that for all groups the first practice period shows performance increments, as would have been expected; none of the hypothetical causes of either PRU or PRD are active yet. For the 20 sec. groups the other four trials almost all show PRDs; much the same but with occasional but probably insignificant exceptions is true of the 30 and 40 sec. groups. The 60 sec. group shows various divergent growth curves, and some ambiguous evidence of PRU; the trend is toward a not very precipitate PRD. The 80 sec. low drive group, in the second and fourth practice periods, shows some evidence of PRU;

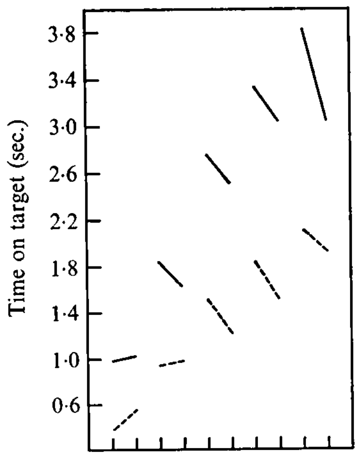

Fig. 1

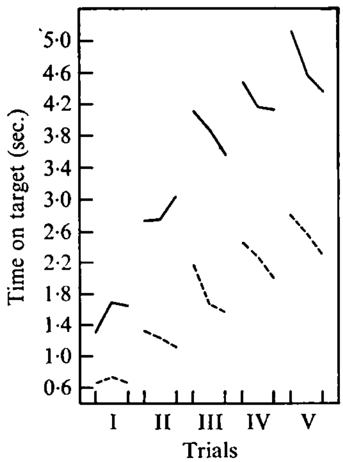

Fig. 2

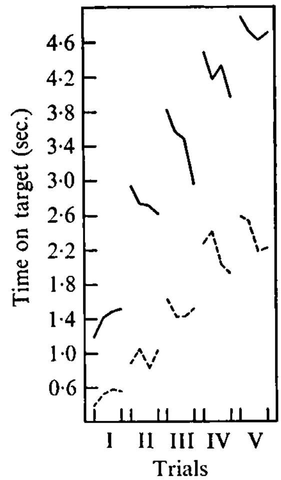

Fig. 3

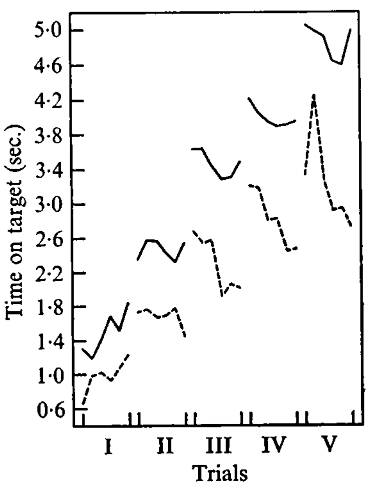

Fig. 4

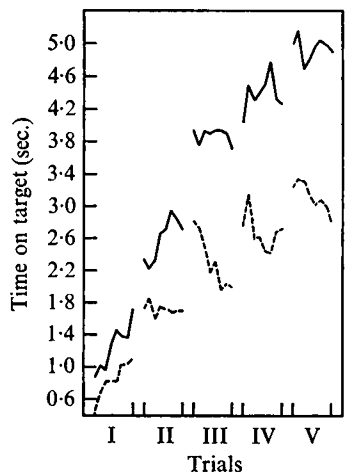

Fig. 5

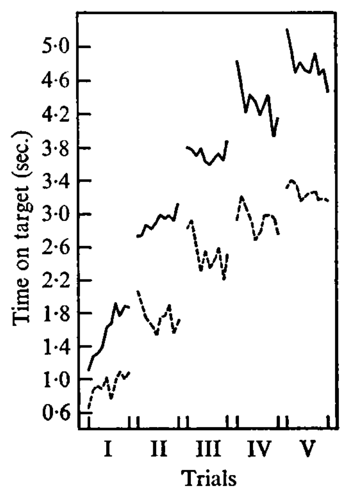

Fig. 6

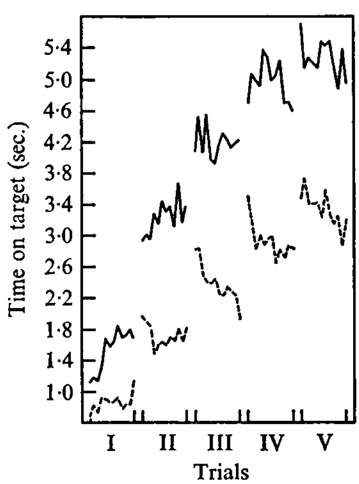

Fig. 7

Figs. 1 to 7. Performance of high and low drive groups during five practice periods of 20 sec. (Fig. 1); 30 sec. (Fig. 2); 40 sec. (Fig. 3); 60 sec. (Fig. 4); 80 sec. (Fig. 5); 100 sec. (Fig. 6); or 120 sec. (Fig. 7) separated by 1 min. rest periods. ———, low; - - - -, high.

for the rest, the picture is one of gradual PRD. The 100 sec. groups fail to show any evidence of PRU; PRD is again rather slight, and many of the curves seem to run almost parallel to the abscissa. For the 120 sec. groups, there is some evidence for PRU in the low drive group, but none in the high drive group. The general impression of these figures is that as practice periods lengthen there is the beginning of PRU in the low drive group, but not in the high drive group; the evidence for PRU is by no means very strong, and for the most part the tendency is for an unrelieved PRD, steep for the short practice periods, less steep, and occasionally quite flat, for the longer practice periods.

Quantification of these impressions is somewhat difficult, in view of the fact that the different groups vary in the number of trials per practice session from 2 to 12; this makes difficult the use of orthogonal polynomials for comparing groups across the seven different lengths of practice session. A rather simple method of analysis was finally decided upon. All seven groups have at least two 10 sec. trials for each practice session, and by subtracting the score on the first of these from the score on the second it is possible to index the direction of change (positive for upswing, negative for downswing) as well as the amount of change. These scores were computed for all 14 groups, and submitted to analysis of variance. Of the main effects, drive (high *v.* low) turned out to be below the 5 per cent level of significance. The trials (1–5) effect was significant at the 5 per cent level, and the times (20–120 sec.) effect at the 1 per cent level. There was also a significant (5 per cent) drive and trials interaction. The trials effect is characterized by a change from positive through zero to negative scores, i.e. PRD increases over successive trials. (More learned material is being consolidated.) The effect for times changes from high negative (20 sec.) through lower negative values (30 and 40 sec.) to positive, i.e. there is a suggestion that with the longer trials there is some slight evidence of PRU; however, the values are not very large. The drive × trials interaction arises because the PRD occurs on an earlier trial for the low drive group, i.e. the second rather than the third, as is the case with the high drive group; furthermore, the low drive group has a stronger overall PRD effect than the high drive group.

A second analysis was undertaken by using only the groups having three or more 10 sec. trials in each practice session; for these groups a score was derived by subtracting trial 1 from trial 3. Analysis of variance showed all main and interaction effects to be insignificant except the trials effect ($P < 0{\cdot}001$); this effect was identical with that already described in the analysis given above. A third analysis was undertaken by using scores made up by subtracting the 1st from the fourth trial for all groups working for 40 sec. or more; the results were identical with those of the previous analysis. Finally, a further analysis was done on the groups having 60 sec. of practice or more by calculating the scores by the following formula: $(5+6)-(1+2)$, i.e. by subtracting the sum of the first two 10 sec. trials from the sum of the fifth and sixth trials. This analysis is particularly relevant to our hypothesis as it is these longer trials which should produce PRU in the low drive group but not in the high drive group.

Analysis of variance disclosed two highly significant main effects ($P < 0{\cdot}001$), viz. drive and trials; all other effects and interactions were non-significant. Table 1 gives the actual scores; it will be seen that there is some evidence for PRU for the low drive group only, and that PRD is greater for the high drive group. Both results are as anticipated.

The terminal 15 min. massed practice for the various groups are graphed in Fig. 8 (high drive) and Fig. 9 (low drive). The groups in each graph differ only in terms of the total amount of practice they have had prior to the 15 min. period, ranging from 100 sec. (for the 20 sec. group) to 600 sec. (for the 120 sec. group). It will be seen that all the scores (which have been plotted in 30 sec. mean scores instead of 10 sec. trials, as plots of 7 × 90 scores become too confusing to be properly assessed by eye) show much the same pattern; they decrement for roughly the first two-thirds of the period (i.e. for 10 min.) and then increment for the remainder (i.e. for 5 min.). Roughly speaking, the groups preserve positions based on the total amount of practice received prior to the 15 min. massed practice, but this tendency is only marked when extreme values are being compared (i.e. 20 *v.* 120 sec.); with intermediate values it tends to break down.

Table 1. *PRU and PRD scores of high drive and low drive groups for five trials*

	Trials					
Drive	I	II	III	IV	V	Mean
High	4·9	−4·7	−10·1	−8·4	−7·2	−5·1
Low	9·0	5·3	− 3·2	1·1	−4·5	1·5

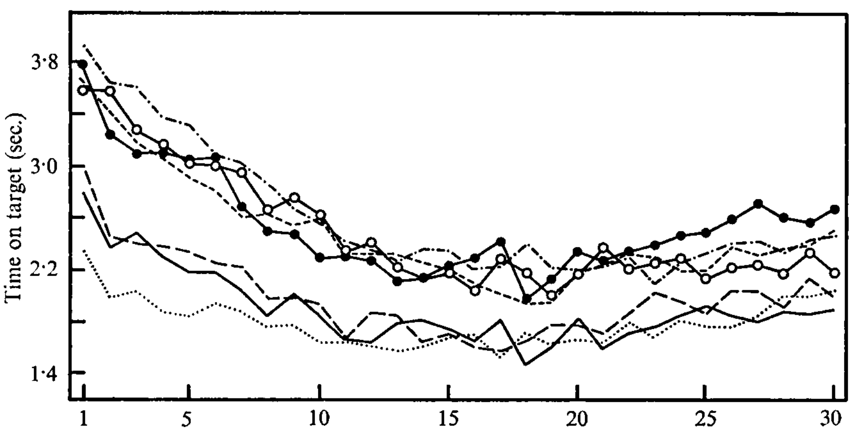

Fig. 8. Performance of high drive groups during 15 min. of massed practice preceded by varying periods of distributed practice. ....., 20 sec.; – – – –, 30 sec.; ———, 40 sec.; ●——●, 60 sec.; - - - - -, 80 sec.; ○——○, 100 sec.; ·······, 120 sec.

Analyses by means of orthogonal polynomials seemed appropriate to disclose any differences in shape between curves generated by the different drive and trials groups, and were calculated for linear, quadratic and higher order trends up to the fifth power; those above the quadratic did not show any significant results apart from a very occasional and uninterpretable positive value at the 5 per cent level, and have therefore been ignored in this discussion. For the rest, all groups except the 20 sec. one had linear trends significant at the 0·01 or more frequently the 0·001 level, and quadratic trends significant beyond the 0·001 level. In other words, all groups except the 20 sec. one (for both high and low drive) show an overall PRD, and all groups, for both drive conditions, show a U-shaped pattern of decrement followed by increment. The 20 sec. groups fail to show the overall decrement because they start so low that terminal upswing is sufficient to bring them back to roughly their starting position; all other groups start somewhat higher, and fail to return to their starting position.

The low drive groups, starting somewhat higher, show a more precipitate drop than the high drive groups; this is shown in the analysis as an interaction effect between drive and the linear component. This is significant at the 5 per cent level for the 120, 80, 60 and 30 sec. groups; significant at the 1 per cent level for the 40 sec. group, and insignificant for the 100 and 20 sec. groups. There is also a significant (5 per cent level) interaction between drive and the quadratic component; this is due to the greater curvature of the low drive group, but may only be a statistical artifact.

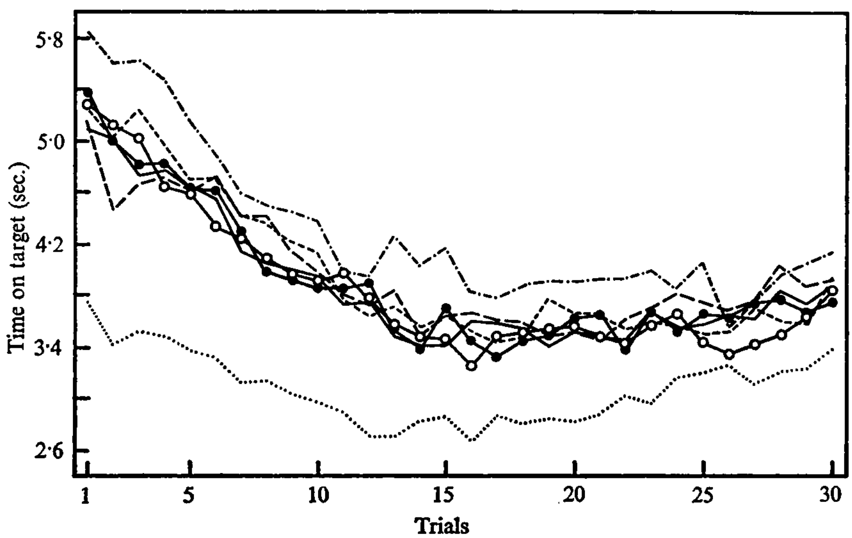

Fig. 9. Performance of low drive groups during 15 min. of massed practice preceded by varying periods of distributed practice. For key, see Fig. 8.

The actual statistics regarding the rates at which decrement and later increment proceed may be of some interest. Table 2 lists the scores over 10 sec. trials of the 14 groups; given are the first, 40th, 60th and 90th trials. It is clear from inspection of the original data that there is a linear decrement in performance over the first 40 trials, followed by a flat portion over the next 20 trials, followed by a linear increment in performance over the last 30 trials. The figures given bear this out: there is a drop of 18·1 and 14·0 per cent respectively for the low and high drive groups over the first 40 trials, a flat portion without any appreciable change, and a rising terminal section producing increments of 3·7 and 3·5 per cent respectively. For both high and low drive groups there is thus an increment of roughly 1 per cent over nine trials. The question may be asked if this is identical with the rate of incrementation which would appear during massed practice not preceded by spaced practice. Several studies from our laboratories have reported such data, for both high and low drive groups, over

90 trials, 72 trials, and 36 trials, using several hundred subjects in all; these studies showed a mean and very regular growth rate of 1 per cent for every six trials. It seems, therefore, that while superficially the post-decremental upswing appears to be proceeding at much the same rate as the pre-rest growth due to massed practice, yet the actual rates are rather different. An experiment specially designed to bring out this fact would be of some interest.

Table 2

Practice length (sec.)	1	40	60	90	1	40	60	90
120	39·6	23·0	20·7	26·0	59·8	39·4	39·1	41·7
100	36·1	21·0	21·4	22·4	53·4	33·6	35·3	34·5
80	37·0	23·3	24·0	26·1	51·3	34·1	37·8	41·0
60	37·0	20·1	22·4	28·6	55·4	36·7	34·4	37·1
40	30·4	19·6	19·7	20·5	52·9	33·0	33·8	40·0
30	32·1	16·6	16·9	19·2	54·0	34·0	35·1	42·7
20	25·0	15·7	14·1	20·7	38·2	27·6	26·6	30·9
Mean	33·9	19·9	19·9	23·4	52·2	34·1	34·6	38·3

Discussion

The results of this experiment are perhaps more successful in aiding the exploration of varying parameter values determining PRU and PRD than in deciding conclusively between the hypotheses outlined in the introductory section; nevertheless, they may serve to illustrate some of the difficulties faced by these theories in giving an acceptable account of the facts. Consider first the Ammons hypothesis according to which PRU function of 'warm-up' and PRD of the accumulation of I_R. The latter hypothesis, improbable in any case for reasons already given, loses credibility even more for the following reasons: (1) After one or two 20 sec. trials, separated by 1 min. rest pauses, there is clear evidence of PRD; yet on any reasonable assumption regarding the accumulation of I_R and its dissipation during rest this performance decrement must have taken place when at most a very small amount of I_R was present. The same argument applies to the 30 and 40 sec. groups. (2) The longer practice periods give rise to more I_R, and consequently might be thought more likely to show PRD; the evidence goes counter to this notion, however, and shows that these groups demonstrate less PRD. (3) The 15 min. of massed practice show PRDs for all groups *from the very beginning of practice*, i.e. when I_R should have been completely (or almost completely) dissipated. The theory leaves unexplained why PRD should take place when I_R was in fact absent, while later on, when I_R would have been maximally present (i.e. after 10 min. of practice) the practice curve should actually turn upwards again! We suggest that Ammons's inhibition hypothesis cannot be made to fit the facts of PRD.

Does his notion of 'warm-up' fare any better? We feel that this hypothesis would have difficulties in explaining the failure of PRU to occur in most of the groups, particularly the ones having the longer practice periods. Ammons might reply that the rest period was too short for subjects to lose 'set', so that in fact they did not require 'warm-up' afterwards to regain 'set'. However, Ammons (1947) posits that 'at the start of rest there are many "set" factors to drop out, so loss of "set" will be more rapid then than later on in rest'. Accordingly we would expect some effect of loss of set, even after 1 min. There is one feature of our results which is in line with Ammons's thinking, viz. the fact that PRU, in so far as it is present, seems to occur on early trials; as he posits, PRU 'at any given time after start of a practice session will be less, the greater the number of preceding practice sessions'. On the whole, it may be said that our data do not conclusively disprove the 'warm-up' hypothesis, but neither do they support it; the theory is probably too far removed from quantitative statement to be easily verified or disproved.

The same may perhaps be said of Eysenck's 'extinction of I_R' hypothesis to account for PRU. This hypothesis accounts for the drive effect, i.e. the occurrence of PRU in the low drive group only; there is no mention of drive in Ammons's theory. The times effect, i.e. PRU occurring with the longer practice durations, can be accounted for on both hypotheses. Ammons postulates that PRU 'increases as a negatively accelerated increasing function of total duration of previous practice'; set, he explains, 'is a function of amount of actual practice'. Eysenck would argue that ${}_SI_R$ build-up is a function of I_R build-up, which in turn is a function of length of practice and drive; the more I_R is built up, the more there is to be extinguished during post-rest practice, and the greater will be the PRU.

Can Eysenck's hypothesis account more successfully for PRD than Ammons's? If PRD is due to consolidation of the memory trace interfering with performance, then it is not surprising to find this effect occurring with even very short trials (i.e. 20 or 30 sec.), and neither is it surprising to find it occurring right at the beginning of the 15 min. massed practice session; by definition, interference should occur immediately upon resumption of work (unless the period of rest has been so long that consolidation has ceased to occur, and thus does not interfere with performance. Farley (1966) and Gray (1968) have shown that with periods of a week or so elapsing between trials, PRD is practically abolished). One finding, however, is somewhat puzzling. On a consolidation-interference hypothesis one might have expected that during the 15 min. massed practice session PRD would have been strongest (i.e. shown the steepest slope) and the longest continued for those groups having the most learning to consolidate; in other words, the 120 and 100 sec. groups should have shown most PRD, the 20 and 30 sec. groups the least. Up to a point this is true; Table 3 below gives the angles of the slopes for the decremental portion of Figs. 8 and 9 for the various groups. There is a fairly regular decrement in slope with decrease in total time spent on practice; this is particularly obvious for the extreme groups, i.e. the 120 sec. and the 20 sec. groups. (There are also obvious differences between the drive groups, which have already been commented upon. It may be surmised that these are not directly due to drive, but rather to inverted ceiling effects produced by the differences in performance level between the groups.) What makes one hesitate to accept the consolidation-interference hypothesis wholeheartedly is the fact that all groups seem to terminate PRD at the same time, enter the 'flat' portion of the performance curve at the same time, and commence the upward trend following this at the same time. Unless the length of time during which consolidation takes place, and interferes with performance, is not affected at all by the length of pre-rest practice, i.e., by the amount of learning that has taken palce, this feature of the experiment is difficult to explain. An experiment directed especially at a clarification of this point would be welcome.

It will be noted that the terminal upswing of the massed practice does not show different slopes, depending on amount of original practice. This is in line with oft-repeated findings that shifting from one condition of distribution to another does not leave permanent effects of the original distribution; as Reynolds & Adams (1953) demonstrate, all groups approximate to the same slope dependent on terminal distribution of practice. 'The implications that the level of performance following a shift in distribution and the rate at which the shift occurs are independent of the preceding number of distributed trials, have both been verified when the shift was from distributed to massed trials' (p. 144). Thus the finding of final common slopes is not surprising. Levels are not identical presumably because the groups had different amounts of practice before commencing the massed practice, although it will be noted that the terminal ranking of the groups is not identical with the amount of practice undergone.

Table 3. *Decremental slope angles of* 14 *experimental groups for initial segment of massed practice curves*

Trial length	High drive	Low drive
120	34°	40°
100	30°	35°
80	28°	33°
60	31°	34°
40	24°	34°
30	25°	30°
20	14°	23°

On the whole, the data reported here are in line with work reported previously in showing the tremendous importance of PRD, even after very short work periods; two 10 sec. trials are sufficient to produce PRD (Eysenck, 1956; Feldman, 1964). PRU, on the other hand, seems a much more reticent phenomenon, at least with the durations of practice here used; only rudimentary traces were found, and then only with the longer practice periods. This of course was as intended; our purpose was to present a micro-genetic account of the growth of these phenomena. Our experiment has taken PRU right to the threshold; practice periods of 3 min. or more are known to produce upswing under most experimental conditions. It seems to us that further parametric studies such as this are badly needed if psychology is ever going to have a more quantitative type of theory than those currently available; it is this lack of quantitative precision which makes it so difficult to disprove existing theories. Furthermore, parametric studies throw up important problems (such as the independence of length of PRD from amount of pre-rest practice) which had not been encompassed previously by any theory. This, of course, is the main justification for the functional approach; experiments of this type teach us the precise manner in which the phenomena under investigation are a function of independent variables which can be experimentally manipulated.

We are indebted to the Maudsley and Bethlem Royal Research Fund for a grant which made this study possible.

REFERENCES

ADAMS, J. A. (1961). The second facet of forgetting: a review of warm-up decrement. *Psychol. Bull.* **58**, 257–273.

ADAMS, J. A. (1963). Comment on Feldman's 'reconsiderations of the extinction hypothesis of warm-up in motor behaviour'. *Psychol. Bull.* **60**, 460–463.

AMMONS, R. B. (1947). Acquisition of motor skill: I. Quantitative analysis and theoretical formulation. *Psychol. Rev.* **54**, 263–281.

AMMONS, R. B. (1952). Relationship of motivation and method of testing to distribution of practice phenomena in rotary pursuit *Q. J. exp. Psychol.* **4**, 155–164.

AMMONS, R. B., ALPRIN, S. I. & AMMONS, C. H. (1955). Rotary pursuit performance as related to sex and age of pre-adult subjects. *J. exp. Psychol.* **49**, 127–133.

DENNY, M. R. (1951). The shape of the post-rest performance curve for the continuous rotary pursuit task. *Motor Skills Res. Exch.* **3**, 103–105.

DENNY, M. R., FRISBEY, N. & WEAVER, J. (1955). Rotary pursuit performance under alternate conditioned and massed practice. *J. exp. Psychol.* **49**, 48–54.

EYSENCK, H. J. (1956). 'Warm-up' in pursuit rotor learning as a function of the extinction of conditioned inhibition. *Acta psychol.* **12**, 349–370.

EYSENCK, H. J. (1960). Reminiscence and post-rest increment after massed practice. *Percept. mot. Skills* **11**, 221–222.

EYSENCK, H. J. (ed.) (1964). *Experiments in Motivation.* Oxford: Pergamon Press.

EYSENCK, H. J. (1965). A three-factor theory of reminiscence. *Br. J. Psychol.* **56**, 163–181.

EYSENCK, H. J. & MAXWELL, A. E. (1961). Reminiscence as a function of drive. *Br. J. Psychol.* **52**, 43–52.

EYSENCK, H. J. & WILLETT, R. A. (1961). The measurement of motivation through the use of objective indices. *J. ment. Sci.* **107**, 961–968.

FARLEY, F. H. (1966). Reminiscence and post-rest performance as a function of length of rest, drive and personality. (Unpublished Ph.D. thesis, London.)

FELDMAN, M. P. (1963). A reconsideration of the extinction hypothesis of warm-up in motor behaviour. *Psychol. Bull.* **60**, 452–459.

FELDMAN, M. P. (1964). Pursuit rotor performance and reminiscence as a function of drive level. In H. J. Eysenck (ed.), *Experiments in Motivation.* Oxford: Pergamon Press.

GRAY, J. E. (1968). Level of arousal and length of rest as determinants of pursuit rotor performance. (Unpublished Ph.D. thesis, London.)

HULL, C. L. (1943). *Principles of Behaviour.* New York: Appleton-Century.

HUNTER, I. A. (1955). The warming-up effect in recall performance. *Q. J. exp. Psychol.* **7**, 166–175.

IRION, A. L. (1949). Retention and warming-up effects in paired associate learning. *J. exp. Psychol.* **39**, 669–675.

IRION, A. L. & WHAM, D. S. (1951). Recovery from retention loss of a function of amount of prerecall warming-up. *J. exp. Psychol.* **41**, 242–246.

KIMBLE, G A. (1949). An experimental test of two-factor theory of inhibition. *J. exp. Psychol.* **39**, 15–23.

MCGEOCH, J. A. & IRION, A. L. (1952). *The Psychology of Human Learning.* New York: Longmans.

REYNOLDS, B. & ADAMS, J. A. (1953). Effect of distribution and shift in distribution of practice within a single training session. *J. exp. Psychol.* **46**, 137–145.

STAR, K. (1957). An experimental study of 'reactive inhibition' and its relation to certain personality traits. (Unpublished Ph.D. thesis, London.)

WALKER, E. L. (1958). Action decrement and its relation to learning. *Psychol. Rev.* **65**, 129–142.

(*Manuscript received* 10 *January* 1969)