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REMINISCENCE AND THE SHAPE OF THE LEARNING CURVE AS A FUNCTION OF SUBJECTS' ABILITY LEVEL ON THE PURSUIT ROTOR

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Two experiments are reported in which the shape of the learning curve pre-rest and post-rest, and the reminiscence phenomenon, are studied as a function of the ability of the subjects to perform on the pursuit rotor under conditions of massed practice. The experiments differ in the choice of subjects and the choice of practice and rest periods involved. Both experiments demonstrate unequivocal differences in the performance curves of high- and low-ability subjects, both before and after the rest pause; these differences are in part also a function of the length of the rest pause. Reminiscence was also found to depend on ability level, high reminiscence being found in high-ability subjects. The applicability of several different hypotheses to the phenomena in question is discussed and a theory suggested which combines features from several earlier theories.

Some of the parameters determining reminiscence on the pursuit rotor are reasonably well known; examples are length of massed pre-rest practice, length of rest pause, and level of motivation (Eysenck, 1964*a*). Much less is known about other phenomena closely associated with reminiscence, e.g. post-rest upswing (PRU), also sometimes called warm-up decrement (Ammons, 1947) and post-rest downswing (PRD). There are also very marked individual differences in the occurrence of these phenomena; these usually appear in the analyses in the form of unduly large error variances. Some of these individual differences have been shown to be associated with personality variables such as extraversion–introversion (Eysenck, 1962; Farley, 1966; Gray, 1968), but most of the variance is still unaccounted for. Under these circumstances it seemed worth while to look at a variable which produces tremendous differences between subjects, namely their level of ability. From the very beginning of practice some subjects perform at a level several hundred or even thousand per cent above that of other subjects of similar background and intelligence, and these differences tend to persist over hours of continued practice (Jones, 1966), whether massed or distributed. The possibility that ability differences may affect the shape of the learning curve cannot be dismissed without close examination, and we have attempted in this paper to demonstrate certain phenomena associated with high and low ability (defined in terms of initial performance) respectively.

There is little information in the literature on this point, and what there is is somewhat contradictory (Buxton & Grant, 1939; Leavitt, 1945; Leavitt & Schlosberg, 1944; Reynolds & Adams, 1954; Zeaman & Kaufman, 1955; Cieutat & Noble, 1958; Locke, 1965; Jahnke, 1961; Eysenck, 1964*b*; Clark, 1967). Some of these studies are only marginally relevant, and in only few of them has the problem been attacked directly. Reynolds & Adams (1954) report the only major study in this field, comparing subjects trained 'one group of subjects with massed and a second group with distributed practice' (p. 269) and subdivided according to initial level of ability. They concluded that 'with the exception of slope characteristics of first-session curves no evidence has been found for the interaction of ability-level and learning variables' (p. 276). This finding, however, is suspect in so far as the 'massed' practice is concerned; it seems that each practice period of 20 sec. was followed by a rest period of 5 sec. in the so-called 'massed' practice, thus effectively converting it into a 'spaced' type of practice. Eysenck (1964*b*) reported data on 300 high-drive apprentices, divided into five ability groups. Results showed (1) that in the pre-rest practice session the high-ability group showed a marked initial upswing which after 2 min. turned

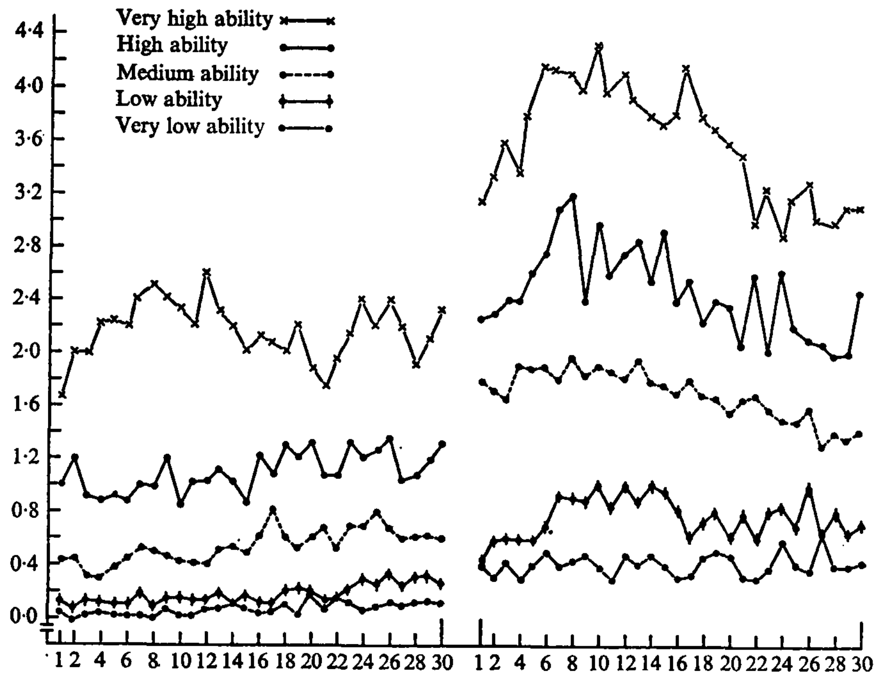

Fig. 1. Pre-rest and post-rest performance of different ability groups on the pursuit rotor. A 10 min. rest pause is interpolated between practice periods.

into a downswing. (2) Reminiscence scores did not differ significantly between ability groups. (3) PRU and PRD were clearly related to ability level, being stronger in the higher scoring groups, and in fact inverted in the lowest scoring group, where post-rest upswing is absent and a marked post-rest downswing present instead (Eysenck, 1964*a*, fig. 2). It should be noted that these data are derived from a high-drive group, in which motivation was produced in the manner described by Eysenck (1964*a*); it does not follow that low-drive groups would show similar patterns of reaction.

Clark (1967), in an unpublished study, repeated Eysenck's study on five pursuit-rotor ability groups, each of 25 subjects, defined by rank ordered performance level of the first 10 massed practice levels; subjects were hospitalized schizophrenics. Fig. 1 shows his main results, which are very similar to those reported by Eysenck (1964*b*); note the initial upswing of the high-ability group during pre-rest practice, and the PRU and PRD characteristically diminishing from high- to low-ability groups. Neither age nor duration of illness had any association with ability on the rotor. Unlike the

Eysenck study, however, there were very marked differences in reminiscence between the groups, which by analysis of variance exceeded a $P = 0{\cdot}001$ level; 'mean reminiscence scores of the very high, high, and medium ability groups are significantly greater than the mean scores of each of the low and very low ability groups' (Clark, 1967, p. 182). This effect may be an artifact due to the very low level of performance of the worst two groups; with normal groups many of these subjects would have been rejected according to the rules imposed by Eysenck (1964*b*), namely that '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 1 sec. on target during at least one of the 30 10-sec. periods which constituted the pre-rest practice period' (p. 180). However, the data may also be interpreted as suggesting that with low-drive groups there is a tendency for high-ability subjects to show more reminiscence than low-ability subjects. It was part of the purpose of the experiment to be reported to furnish further information on this point.

Experiment I

Two experiments were in fact performed, using rather different designs, in order to investigate various parametric determinants of the phenomena in question. The theoretical relevance of these parametric investigations will be discussed in a later section. In the first experiment, eight groups of low-drive industrial apprentices were given massed practice on the pursuit rotor for either 3 min. or 8 min., scored in terms of 10 sec. periods time-on-target; rest periods of either 30 sec., 2 min., 6 min. or 20 min. followed pre-rest practice, and the rest periods in turn were followed by another 4 min. of practice for all groups. Reminiscence scores were derived by subtracting the mean of the last three pre-rest trials from the first post-rest trial; using the mean of three trials makes the score more reliable, and inspection shows little systematic change in performance at this stage. A single post-rest trial has to be used because of PRU which produces marked and systematic changes in performance.

Each of the eight groups contained 30 subjects; of these the top 12 and the bottom 12 in ability were chosen for purposes of analysis. Ability was defined in terms of total performance over the first 12 trials, and analysis of variance showed no significant differences in performance between groups either for the high-ability or for the low-ability subjects; in other words, we can compare our two sets of performance groups without having to control for initial differences in level of ability within sets. No detailed description is here given of either the type of population or the instrument used; details regarding both have been given elsewhere (Eysenck, 1964*a*). The subjects were also administered the Maudsley Personality Inventory, but scores of this merely confirmed that allocation to groups had indeed been random, and that ability did not correlate with personality, at least in so far as this is measured by the inventory.

Pre-rest performances of the 96 subjects who practised for 3 min. are diagrammed in Fig. 2; those of the 96 subjects who practised for 8 min. are diagrammed in Fig. 3. Inspection suggests a simple linear increase in performance for the low-ability groups, whilst the high-ability group shows a marked upswing to begin with, followed by a plateau; for the 8 min. group there is no improvement from the 10th trial to the

48th. (The 3 min. group does not appear to have settled down sufficiently to make it possible to assess the applicability of the plateau notion.) Analysis by orthogonal polynomials was performed on the data for both groups, to give statistical background to the results of the visual inspection. For the 8 min. group the linear component was significant at the $P < 0{\cdot}001$ level for both high- and low-ability subjects; the quadratic component was also significant for both groups ($P < 0{\cdot}01$). Cubic and quartic components were insignificant in the low-ability group, but significant at the $P < 0{\cdot}01$ and $< 0{\cdot}05$ levels respectively for the high-ability group. Thus for all intents and purposes the low-ability group shows a linear increment with some evidence of a bend, while the high-ability group, in addition to the linear component,

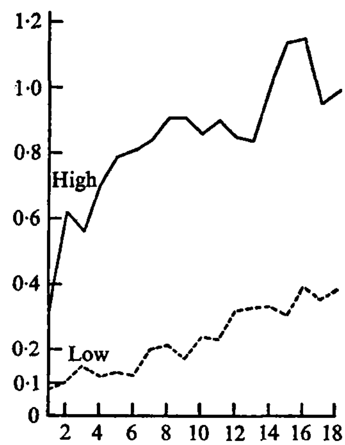

Fig. 2

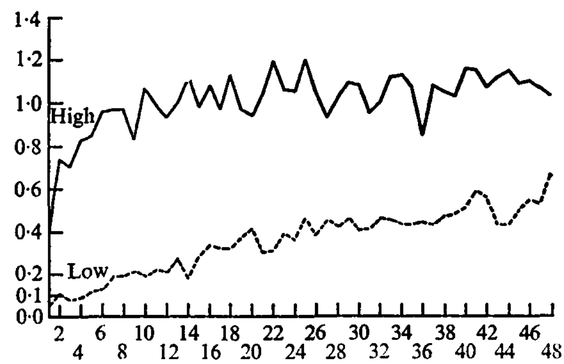

Fig. 3

Fig. 2. Pre-rest performance of high-ability and low-ability subjects during 3 min. practice period.
Fig. 3. Pre-rest performance of high-ability and low-ability subjects during 8 min. practice period.

shows higher-order variations up to the 4th power. Analysis of the combined high- *v.* low-ability groups show linear, cubic and quartic components to give rise to significant differences ($P < 0{\cdot}05$, 0·05 and 0·01 respectively). Analysis of the 3 min. groups shows a highly significant linear component for both high- and low-ability subjects ($P < 0{\cdot}001$); the only other significant value is the quadratic for the high-ability group ($P < 0{\cdot}01$). Analysis for the combined groups (high or low ability) confirms that it is in this component that the two groups differ most significantly ($P < 0{\cdot}01$); however, linear and cubic trends also show significance at the 0·05 level. Visual inspection therefore is largely vindicated by the analysis, except that the high-ability groups show a record even more complex than suggested, including cubic and quartic trends.

Post-rest data are given for the 30 sec. rest groups in Figs. 4 and 5; these show PRD but no sign of PRU. Furthermore, the high-ability group shows greater reminiscence than does the low-ability group. Analysis by orthogonal polynomials shows that the linear decrement is significant ($P < 0{\cdot}05$) for the high-ability group, but not for the low-ability group; no other powers are significant. Analysis for the combined groups shows them to be performing at significantly different levels

($P < 0{\cdot}001$) with the linear element differentiating significantly between their rates of decline ($P < 0{\cdot}05$).

Post-rest data are given for the 2 min. rest groups in Figs. 6 and 7; these show PRD (Fig. 6) but no sign of PRU. The high-ability group again shows greater reminiscence than does the low-ability group. Analysis by orthogonal polynomials fails to show statistical significance for any sequence effect, so that the visual appearance of decrement is not supported.

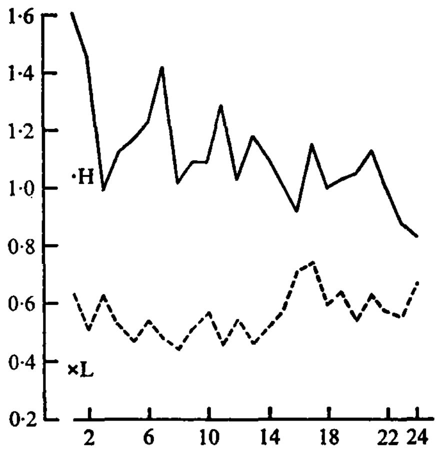

Fig. 4

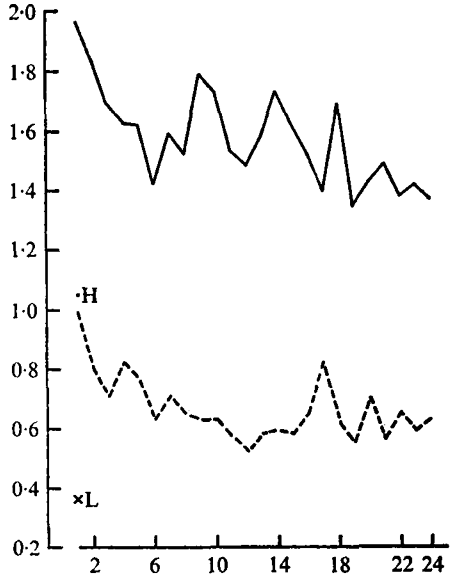

Fig. 5

Fig. 4. Post-rest performance for 30 sec. rest group, after 3 min. of pre-rest practice. (In Figs. 4–11 the pre-rest performances of the high-ability and low-ability groups are marked with an H or an L respectively to enable the reminiscence score to be estimated visually from the figure.)

Fig. 5. Post-rest performance for 30 sec. rest group, after 8 min. pre-rest practice.

Post-rest data are given for the 6 min. rest groups in Figs. 8 and 9. The high-ability group shows significant decrement for both the 8 min. practice group ($P < 0{\cdot}01$) and the 3 min. practice group ($P < 0{\cdot}001$). An analysis of the combined groups shows the decrement difference to be significant ($P < 0{\cdot}05$) for the 3 min. group only. For the 8 min. group there is also a significant difference in the quartic ($P < 0{\cdot}05$). Reminiscence scores are again higher for the high-ability group.

Post-rest data are given for the 20 min. rest groups in Figs. 10 and 11; these show both PRU and PRD. The high-ability group again shows greater reminiscence than does the low-ability group. Analysis by orthogonal polynomials shows both PRU and PRD to be present in the high-ability group with 3 min. practice, but not in the low-ability group; linear and quadratic components are significant for the former ($P < 0{\cdot}05$), but not for the latter. No other components are significant. For the 8 min. groups only the quadratic component is significant in the high-ability subjects; neither component is significant for the low-ability group. Visual inspection suggests that for the high-ability group 8 min. of pre-rest practice produces a stronger PRU which cancels in extent the PRD, resulting in a non-significant linear component; for the low-ability group neither PRU nor PRD are strong enough to produce statistically significant results, possibly due to the relatively small number of subjects in each group.

Fig. 6

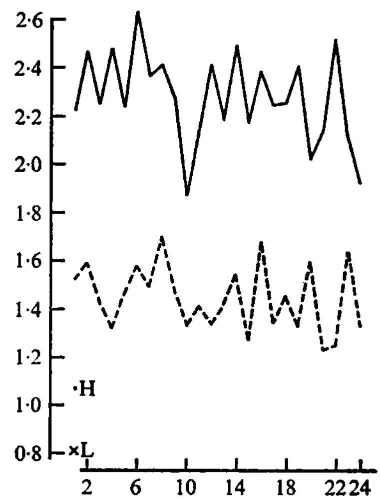

Fig. 7

Fig. 6. Post-rest performance for 2 min. rest group, after 3 min. of pre-rest practice.
Fig. 7. Post-rest performance for 2 min. rest group, after 8 min. of pre-rest practice.

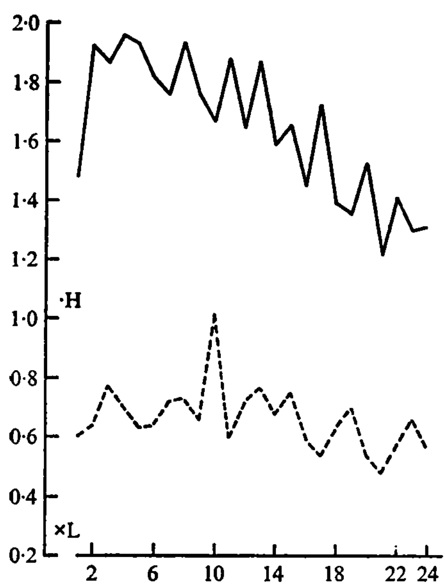

Fig. 8

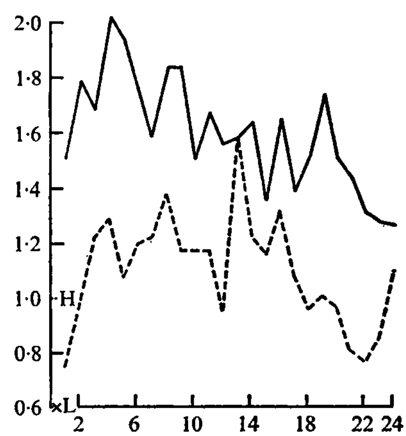

Fig. 9

Fig. 8. Post-rest performance for 6 min. rest group, after 3 min. of pre-rest practice.
Fig. 9. Post-rest performance for 6 min. rest group, after 8 min. of pre-rest practice.

In the combined high- and low-ability groups' analysis for 3 min. pre-rest practice, the linear component gives a significant differentiation ($P < 0{\cdot}05$), while for the combined 8 min. groups none of the polynomials results in significant differences. This suggests that subjects in the low-ability groups show a trend in the same direction as those in the high-ability groups, but much weaker; thus these trends are not themselves significant, but they are sufficiently strong to prevent differences between the groups from becoming significant.

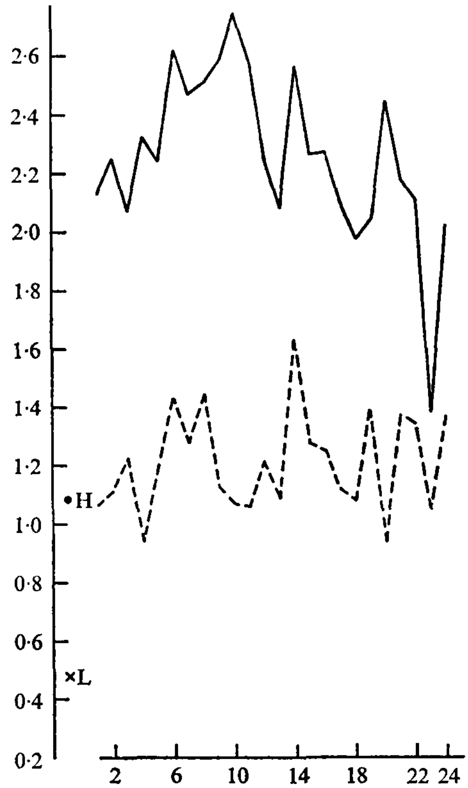

Fig. 10

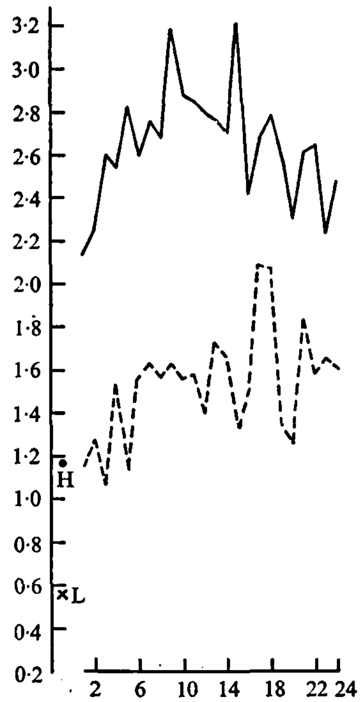

Fig. 11

Fig. 10. Post-rest performance for 20 min. rest group, after 3 min. of pre-rest practice.
Fig. 11. Post-rest performance for 20 min. rest group, after 8 min of pre-rest practice.

Differences in reminiscence scores have been mentioned, but not analysed so far. Analysis of variance was carried out on reminiscence as a function of high and low ability, long and short pre-rest practice, and length of rest period. High-ability groups in each case showed greater reminiscence; longer pre-rest practice produces greater reminiscence; and longer rest pauses produce greater reminiscence. Ability level produces statistical significance ($P < 0{\cdot}001$); rest reaches a significance level of $P < 0{\cdot}05$, while length of pre-rest practice was not significant. It is notable that ability level is a much more significant determiner of reminiscence than either of the other two factors in the genesis of reminiscence. None of the interactions were significant (cf. Buxton, 1943).

Results reported so far suggest the following conclusions. Pre-rest practice produces mainly linear trends in low-ability subjects and complex non-linear trends in high-ability subjects. Post-rest results show PRD, which is stronger in high-ability subjects than in low-ability subjects. Post-rest results show PRU only with long rest periods; PRU is more apparent in the high-ability groups than in the low-ability groups. Reminiscence under all circumstances is greater in high-ability than in low-ability subjects. These results demonstrate that all parts of the learning curve are vitally affected by ability level, and suggest that simple averaging of combined data may simply confuse proper determination of learning curves.

EXPERIMENT II

In this experiment all subjects did 6 min. of massed practice, followed by a rest of 30 sec., 10 min. or 1 week; post-rest practice consisted of a further 7 min. of practice. Two concentric targets were used in order to study effects of ease or difficulty of the task. (Bahrick *et al.*, 1957, have drawn attention to the fact that marked differences in the shape of learning curves may result from such differences.) The smaller target was 0·5 in. in diameter, the larger 1·61 in.; details of the apparatus are given in Gray (1968). Subjects in each rest group were divided into three subgroups of equal number on the basis of their cumulative time on target (0·5 in. target) over the first 120 sec. of practice. The Maudsley Personality Inventory was given to all subjects, but only served to confirm the random allocation of subjects to ability groups. There were approximately 70 subjects in each of the three different rest groups (72 in the 30 sec. group, 70 in the 10 min. group, and 68 in the 1-week group.) Subjects were low-drive student volunteers, i.e. subjects who had no special and extraneous motivation to do well on the task.

Pre-rest scores of the three ability groups are shown in Figs. 12 and 13 for the difficult and easy targets respectively. Visually it seems that on the small target the high-ability group shows a distinct upswing followed by a distinct downswing, while the average ability group shows a straight but slow increase in performance, and the low-ability group an initial slight downswing followed by an increase in performance slightly faster than that of the average ability group. Analysis by orthogonal polynomials gave the following results. The high-ability group shows no significant linear trend, but highly significant quadratic and cubic trends ($P < 0{\cdot}001$). The average ability group has a very significant linear trend ($P < 0{\cdot}001$), and a significant quadratic trend ($P < 0{\cdot}01$), but no cubic. The low-ability group only has a linear trend ($P < 0{\cdot}05$). Combined analysis of all groups discloses, in addition to the obvious level difference ($P < 0{\cdot}001$), significant differences at the $P < 0{\cdot}01$ level for linear, quadratic and cubic trends.

For the easy target, the linear component is not significant; quadratic and cubic components are significant at the 0·001 level for the high-ability group. For the average ability group the linear component is highly significant, as is the quadratic ($P < 0{\cdot}001$); the cubic is barely significant ($P < 0{\cdot}05$). For the low-ability group the linear trend is highly significant ($P < 0{\cdot}001$), and the quadratic is barely so ($P < 0{\cdot}05$). The combined groups are differentiated, apart from the obvious differences in level ($P < 0{\cdot}001$), on the linear ($P < 0{\cdot}001$) and the cubic ($P < 0{\cdot}05$) trends. Taking these results together with visual inspection of Fig. 12, we may say that the high-ability group shows marked upswing and downswing; the average-ability group less marked upswing followed by a plateau; and the low-ability group downswing followed by rapid increment. Change in target size may thus be said to have brought out and emphasized trends already present in the results of the difficult target; there are no marked changes in general shape of the learning curve. The initial decrement in the low-ability group, already suggested in the analysis of the results from the difficult

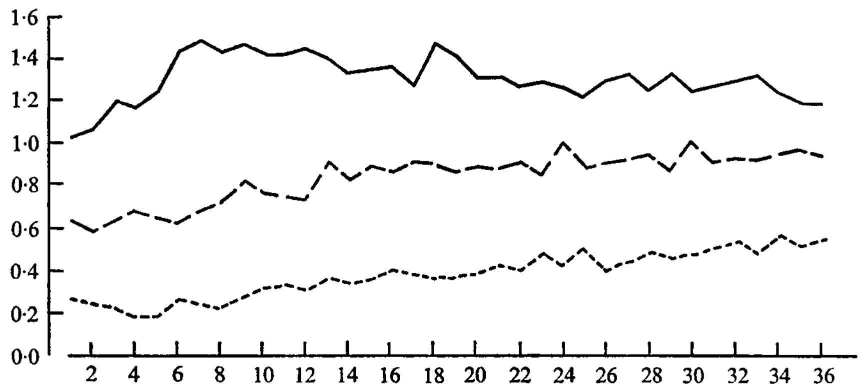

Fig. 12. Pre-rest scores of high-, medium- and low-ability groups, using the difficult target.

task, is clear and significant here; its causes are difficult to guess at and do not seem predictable from any existing theory. The high-ability group shows a learning curve surprisingly similar to that often found post-rest in massed practice groups; PRU and PRD are here in evidence as pre-rest upswing and pre-rest downswing. The possibility that both phenomena have the same or similar causes will be discussed later on.

Post-rest curves of practice are given below; Fig. 14 gives data for the 30 sec. rest groups, Fig. 15 for the 10 min. rest groups and Fig. 16 for the 1-week rest groups. Analysis by orthogonal polynomials was carried out, and the results for linear, quadratic and cubic components are shown in Table 1. It will be seen that length of rest pause is a very important factor. For the 30 sec. rest pause groups none of the results are significant; all groups proceed on a level without significant rises or decrements in performance. The 10 min. rest pause produces very marked effects, with linear, quadratic and cubic components all significant for all groups. For the combined groups only the linear trend is significant, apparently because of the PRD depressing the high-ability group's performance below its starting-point. For the 1-week group linear components are insignificant, quadratics very significant for the high-ability subjects, and insignificant for the low-ability subjects. Cubics are significant only for the high- and average-ability groups. On the combined groups analysis, both quadratic and cubic components are significant. These data leave no doubt that groups of different ability levels show highly significant post-rest performance curves provided the rest is long enough to permit consolidation (or dissipation of inhibition) to take place to a sufficient degree.

Reminiscence was calculated as before; the data show a significant interaction effect. The low-ability group shows a continued increment in reminiscence over the three rest periods; the other two groups show a rise from 30 sec. to 10 min. followed by a fall. These results are in good agreement with what one might have expected from Leavitt's findings – a positive correlation between ability and reminiscence for short rest pauses, and a negative one for long rest pauses.

A slightly more analytic way of presenting the data is the following. A linear regression coefficient 'b' was computed for the final $4\frac{1}{2}$ min. of the pre-rest practice period to indicate depression of performance during this time, i.e. following any initial upswing. A regression coefficient 'a' was calculated to represent the level of ability measured $1\frac{1}{2}$ min. after performance started. These coefficients were corre-

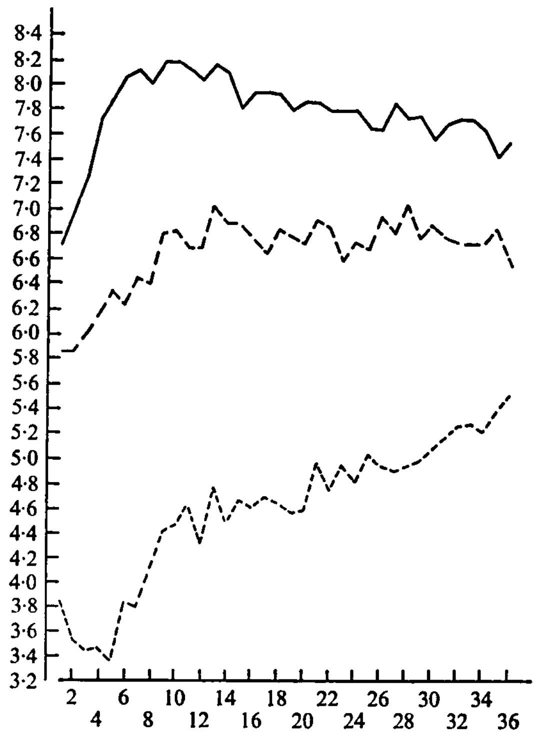

Fig. 13. Pre-rest scores of high-, medium- and low-ability groups, using the easy target.

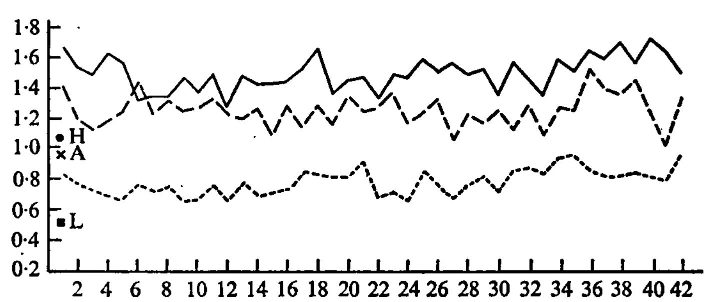

Fig. 14. Post-rest scores for high-, medium- and low-ability groups after 30 sec. rest pause.

lated with reminiscence scores, determined as before, and also with a new coefficient, called rem. max. This coefficient uses the same pre-rest measure of reminiscence, i.e. the mean of the final three pre-rest trials; however, the post-rest measure used is the mean of the two highest trials occurring at any time within the first 2 min. of post-rest practice. This index is designed to measure reminiscence to the top of each

Fig. 15. Post-rest scores for high-, medium- and low-ability groups after 10 min. rest pause.

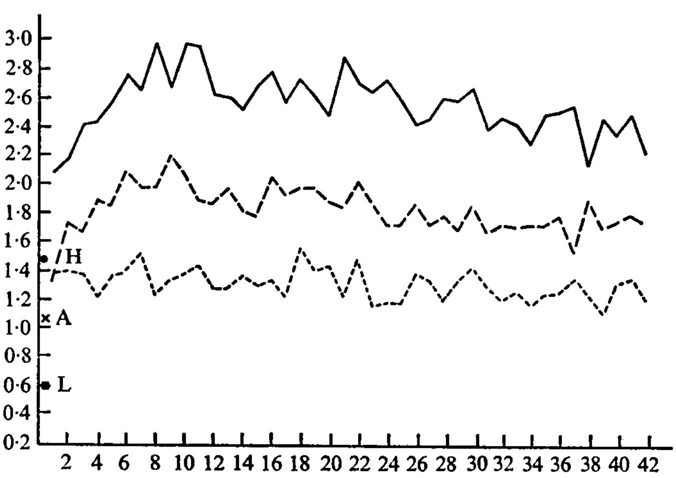

Fig. 16. Post-rest scores for high-, medium- and low-ability groups after 1-week rest pause.

subject's post-rest upswing; it has some resemblance to Ammons's (1947) index, but does not use his method of backward extrapolation. The correlations between reminiscence and rem. max. on the one hand, and '*a*' and '*b*' on the other, are given in Table 2; there is a gradual decrease in the correlations between reminiscence and '*a*' with increasing length of rest, but this change is not significant. Neither is the increasing correlation with '*b*', and the changes in size of correlation with rem. max.

are neither systematic nor significant. These data suggest that level of ability in this study is importantly correlated only with rem. max., i.e. an index which combines the twin effects of the slight correlation of reminiscence with ability with the strong PRU characteristic of high-ability subjects.

Table 1. *Significance of linear, quadratic and cubic orthogonal polynomials for groups of high, average and low ability, and all groups combined, when tested with rest pauses of* 30 *sec.*, 10 *min. or* 1 *week respectively*

	30 sec.	10 min.	1 week	
High ability	n.s.	0·001	n.s.	Linear
	n.s.	0·001	0·01	Quadratic
	n.s.	0·001	0·01	Cubic
Average ability	n.s.	0·01	n.s.	Linear
	n.s.	0·001	0·05	Quadratic
	n.s.	0·05	0·001	Cubic
Low ability	n.s.	0·01	n.s.	Linear
	n.s.	0·001	n.s.	Quadratic
	n.s.	0·001	n.s.	Cubic
Combined	n.s.	0·05	n.s.	Linear
	n.s.	n.s.	0·05	Quadratic
	n.s.	n.s.	0·05	Cubic

Table 2. *Correlations between reminiscence and 'maximum reminiscence' scores and regression coefficients 'a' and 'b', representing pre-rest performance level and decrement*

		Reminiscence	Rem. max.
30 sec. group	'*a*'	0·153	0·469**
	'*b*'	−0·261**	−0·239*
10 min. group	'*a*'	0·082	0·338**
	'*b*'	−0·210	−0·265*
1 week group	'*a*'	0·032	0·413**
	'*b*'	−0·416**	−0·245*

* $P < 0·05$. ** $P < 0·01$.

Results from this study, using older, brighter and possibly more highly motivated subjects than the previous one, confirm in most respects the conclusions already reached. Pre-rest performance shows high ability giving rise to upswing followed by downswing, while low ability shows the opposite pattern. Post-rest performance shows PRU and PRD to be phenomena peculiar to subjects in the higher-ability groups, and missing in the lower-ability groups; length of rest pause was also found to be an important factor in this connexion. Reminiscence was not found to be determined by ability level to anything like the extent suggested by the first experiment, or that of Clark (1967); it is possible that this may be due to greater motivation, making this group more comparable to Eysenck's (1964*b*) high-drive group, where no relation was found between ability and reminiscence. The apprentice group used in the first experiment was on the whole rather poorly motivated if one may use personal judgement based on observation, whereas the university students used in the present experiment seemed to be more ego-involved (Alper, 1948). Clearly motivation is an important variable in untangling the relationship between ability and reminiscence, and equally clearly our data do not provide the required independent measure of motivation without which these suggestions cannot be regarded as anything but speculation.

Experiment III

In the Reynolds & Adams (1954) study it seems possible that their failure to observe post-rest differences between their different ability groups was due to the fact that they used distributed rather than massed practice. If this were true, then it should be possible to compare groups of low-drive apprentices, similar to those used in Expt. I, engaged on distributed learning of pursuit rotor; if distribution of practice is responsible for the failure of ability differences to mark differences in the shape of the learning curve, then such an experiment should result in essentially similar curves, excepting of course the course of learning preceding the first imposed rest.

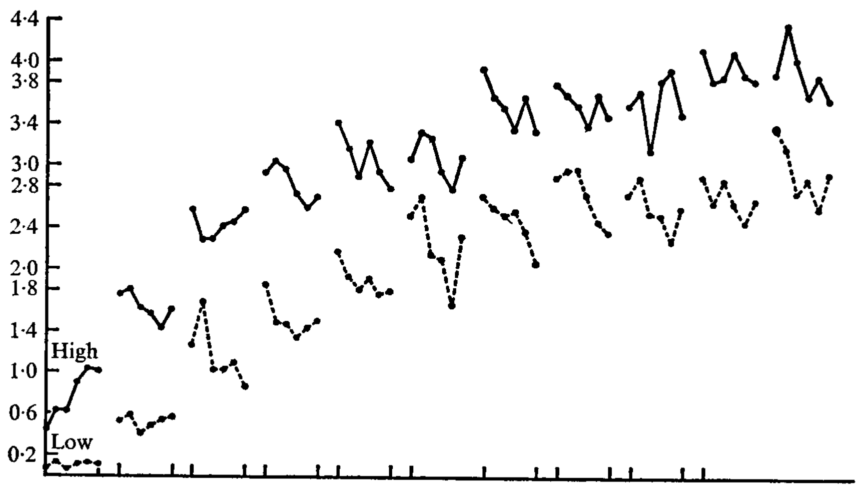

Fig. 17. Scores of high- and low-ability groups during 11 1 min. practice periods, separated by 5 min. rest pauses.

Fifteen high-ability and 15 low-ability subjects were chosen from 45 subjects who had practised on the pursuit rotor for 11 1 min. periods, separated by 5 min. rest pauses. Fig. 17 shows the results. It will be seen that PRU is universally missing in both groups, as would be expected from Eysenck's (1956) theory, on the basis that not enough practice time had been allowed for the accumulation of I_R and $_SI_R$. PRD's are observed equally in both groups; in Eysenck's (1965) theory this could be due to consolidation effects depressing performance post-rest. The only trial on which the groups differ significantly (by orthogonal polynomial analysis) is the first; as previously observed, the high-ability group shows a rapid upswing while the low-ability group shows no change at all. (A medium-ability group, formed from the remaining 15 subjects but not shown in the figure because it interferes with the clarity of presentation without adding anything to the argument, showed intermediate upswing, followed by a plateau.) These results support the view that massing is responsible for the major differences between high-ability and low-ability groups.

DISCUSSION

The term 'ability' has hitherto been used as simply a descriptive label referring to the initial performance level of the subjects; as it happens initial performance levels tend to be preserved throughout the course of experiments like this, correlating reasonably highly with terminal performance levels, so that 'ability' so defined characterizes an individual's performance throughout the experiment. But clearly the effects of ability level on the shape of the learning curve cannot be discussed without some more analytic dissection of this concept of ability, which may be looked upon as either an innate property of the organism or an acquired skill, or a combination of both. Twin studies by McNemar (1933) demonstrated a heritability coefficient of 0·9 for pursuit-rotor performance (decreasing with increasing practice), and Vandenberg (1962) reported somewhat lower but still significant values. Environmental influences are less well documented, but it does not seem unreasonable to postulate that practice in such tasks as watching gramophone records go round, writing, drawing and tracing with pen or pencil, and turning the steering wheel of a motor car may produce practice increments in those fundamental abilities which underlie pursuit-rotor practice (Fleishman, 1960). It seems reasonable to assume that the phenotype of pursuit-rotor skill at the beginning of practice is in part a reflexion of genuine genotype differences, and in part the outcome of specific environmental histories. Can either or both of these components help us understand the phenomena connected with individual differences in (phenotypic) ability?

Reynolds & Adams (1954) suggest an interesting hypothesis. Drawing attention to the similarities between the pre-rest performance curves of high-ability subjects and the well-known PRU phenomenon, which they would explain in terms of warm-up or the regaining of some physical or mental set, they say: 'If the warm-up period can be regarded as a period of recruitment of previously acquired responses, then subjects in massed decile 10 (i.e. their highest ability group) would appear to be activating a pool of previously acquired relevant responses, carried over, perhaps, from psychomotor tasks encountered in everyday situations' (p. 276). The similarity on which they base this suggestion is even closer in our experiments, as we find PRD as well as PRU effects in our pre-rest practice of high-ability subjects, due no doubt to the fact that we used proper massing of trials, whereas Reynolds & Adams did not.

This additional feature, however, rather spoils the appeal of their theory as nothing in warm-up theory accounts for PRD, or for the downswing found here pre-rest. Furthermore, there are many arguments against the application of warm-up theory in relation to pursuit-rotor learning (Feldman, 1963) which apply equally cogently to pre-rest practice as to post-rest practice. The alternative hypothesis suggested by Eysenck (1956) for PRU, i.e. the extinction of $_{S}I_{R}$ through non-reinforcement, might be thought to fit the case rather better as all that is required is the assumption that higher-ability subjects have in the past practised components of the task more assiduously (massed practice) than low-ability subjects. Such an explanation, however, would leave out entirely the possibility of genetic differences between high- and low-ability subjects, and would appeal, as does Reynolds & Adams's explanation, entirely to unobserved and speculative events in the past lives of the subjects.

Both the 'warm-up' or 'set' theory and the extinction of $_{S}I_{R}$ hypothesis fail to account for the non-existence of PRU in the case of the low-ability subjects. It would need some special *ad hoc* assumptions to explain why low-ability subjects do not show 'warm-up' while high-ability subjects do; there is nothing in the literature to suggest anything of the kind (Ammons, 1947; Adams, 1961). The conditioned inhibition hypothesis might argue that high-ability subjects have worked harder than low-ability subjects during the pre-rest practice period, have accordingly accumulated more I_R, and have hence more $_{S}I_{R}$ to extinguish. This is not impossible, but there is of course no direct evidence to support such a long chain of arguments.

A consideration of PRD might be of assistance. Frith (1969) has suggested a possible cause for PRD in his work on strategies in skilled motor performance. Working with simple tapping tasks, Frith found that some subjects choose a strategy which results in maximum performance, leading to the accumulation of I_R and the occurrence of involuntary rest pauses (IRP's). Others prefer to work at submaximal levels, avoiding the build-up of I_R and the occurrence of IRP's; in consequence they may also, according to theory, avoid the growth of $_{S}I_{R}$ to any significant degree. If we can assume that subjects high in ability (whether due to innate or environmental factors) may be motivated to try harder for maximum performance from the beginning, they might accumulate sufficient I_R to lead to performance decrement even during pre-rest practice; having accumulated I_R and having experienced a series or IRP's they would also accumulate $_{S}I_{R}$ which could then be extinguished post-rest, giving rise to PRU as in Eysenck's theory. PRD would follow as a consequence of continued maximum performance strategy. Low-ability subjects, on this account, would choose a different strategy, i.e. one of submaximum effort, thus avoiding I_R build-up, the occurrence of IRP's, and the genesis of $_{S}I_{R}$. Hence for this group there would be no PRU or PRD. If these strategies are characteristic of high- and low-ability subjects respectively, then they would also characterize their practice on the component tasks which Reynolds & Adams have suggested would lead to ability differences at the beginning of the pursuit-rotor learning; hence a differential build-up of $_{S}I_{R}$ becomes a possibility and equally its extinction during the first minute or two of practice, giving rise to the upswing phenomenon pre-rest. This account is of course highly speculative, but it would account for the phenomena observed.

It might also be hypothesized that the higher-ability groups, by and large, would be more highly motivated; motivation and success are unlikely to be entirely separated. Hence in groups not specifically motivated for pursuit-rotor performance reminiscence, which is known to be a function of motivation (Eysenck, 1964*a*), would be greater in high-ability subjects; this differential would be wiped out when an external motivating factor is introduced, bringing the low-drive subjects up to the level of the most highly (internally) motivated subjects. This additional hypothesis would explain the observed relationship between ability level and reminiscence in low-drive groups, and its failure to be observed in high-drive groups. Again the hypothesis appeals to characteristics in task and subject which are difficult to observe and measure, and which certainly have not so far been measured; the main point in proposing such a highly speculative theory is of course that it may lead to further investigations geared more specifically than the present one to testing the various parts of the theory in question.

One final hypothesis to be considered is concerned with the vexed problem of measurement of reminiscence and performance. Bahrick *et al.* (1957) have shown how the size of target may affect scores, and how the use of any particular size of target may produce measurement artifacts. In this connexion the work of Humphries (1961) is very relevant; he used a rotor in which circular target areas, insulated from each other, surrounded a very small central disc; recording from each of these target areas was separate, thus enabling scores to be obtained simultaneously from target areas differing in size. In his fig. 5 (p. 217) he has plotted results for 5 min. of massed practice, and 2 min. of practice following upon a 5 min. rest pause. It is clear that the larger target sizes give results similar to those obtained by our high-ability subjects, while the smaller targets give results similar to those obtained by our low-ability subjects. The former show pre-rest upswing, pre-rest downswing, and marked reminiscence, while the latter show neither pre-rest upswing nor downswing, and no reminiscence – although the scores are derived from the same subjects on the same occasion! This similarity is striking, but it does not prove that the phenomenon is an artifact when observed in high- and low-ability subjects respectively. Our second experiment has shown that shifting from a small target to a large one does not obliterate or change the observed phenomena; they are more dramatic in the case of the larger target, but they are identical with those produced by the smaller target. Neither can it be said that much larger or much smaller targets would eliminate our findings; it would seem impossible to enlarge the target much beyond the larger one used by us, as with such a target the subjects would be on target almost 100 per cent of the time. The target could of course be reduced, but in that case very little in the way of scoring would be possible – even with our small target scores were very low. Our two targets seem to span a large part of the area likely to give any reasonable learning data, and hence we feel that the similarity of results may serve to reassure readers worried by the arguments of Bahrick *et al.* or the data furnished by Humphries. Future work will undoubtedly benefit from incorporating multiple targets into the design, as in the Humphries experiment; we doubt if such innovations will alter the main conclusions drawn from our results.

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