Perceptual and Motor Skills, 1969, 28, 992-994.

A NEW THEORY OF POST-REST UPSWING OR "WARM-UP" IN MOTOR LEARNING

H. J. EYSENCK[1]

Institute of Psychiatry, University of London

Summary.—Post-rest upswing in motor learning is traditionally explained in psychological terms, i.e., either as a regaining of "set" or as extinction of $_{S}I_{R}$. It is suggested that physiological evidence points to an alternative, namely a true "warming-up" of the muscles involved in the work under consideration. The hypothesis is shown to explain certain otherwise puzzling features of "warm-up" in pursuit rotor performance.

Post-rest upswing in work on the learning of motor skills, e.g., the pursuit rotor, has usually been explained in terms of the need to regain "set" (by analogy with similar phenomena in verbal learning) or by reference to the extinction of conditioned inhibition (Adams, 1961). The term "warm-up" often used to describe the phenomenon suggests an alternative interpretation, i.e., the actual increase in temperature of the muscle groups involved in the work under consideration. As Asmussen (1965) points out, higher temperatures may be assumed to be beneficial to the organism; all chemical processes take place at a faster rate, internal frictional resistance in muscles and joints decreases as the viscosity of extracellular and synovial fluids decreases, and the shape of the oxygen-dissociation curve of the blood changes so as to enhance the delivery of oxygen to the tissues. (There is, of course, an upper limit to the beneficial effects of heat; at high levels the need to dissipate body heat alters the pattern of blood supply so as to decrease oxygen supply to the muscles.) Experimental studies, dating from the classical work of Asmussen and Boje (1945) and the investigations of Munido (1947) and Hoegberg and Lunggren (1947), support this view. Performance on the bicycle ergometer has been found consistently superior in the warm, as opposed to the cold state, and this superiority was present even when the change in temperature was effected by short wave diathermy or by means of a hot shower (Asmussen & Boje, 1945). Munido (1947) found proficiency in swimming increased by increases in temperature, whether actively or passively produced. The evidence suggests that it is the temperature in the muscles involved in the work which is the crucial factor, rather than over-all body temperature, as measured in the rectum; Asmussen and Boje found that, when performance time for sprint on the bicycle ergometer was plotted against the temperature of the lateral vastus muscle, and against rectal temperature, the plot for muscle temperature was a precise mirror image of that for performance, whereas rectal temperature increased much more slowly than muscle temperature and limped badly behind improvement in performance. In more purely psychological work, too, high temperature has usually been associated with good performance (Kleitman, 1963); much of the more recent work on this topic has been published from the Cambridge Psychology Unit (Colquhoun, *et al.*, 1968a, 1968b; Blake, 1967a), who have also established a correlation between circadian rhythms of body temperature and introversion-extraversion (Blake, 1967b).

It is suggested that performance on the pursuit rotor or other motor skills apparatus improves with increases in the temperature of the muscles involved in the work; that during rest pauses, particularly prolonged rest pauses, a drop occurs in the temperature of these

[1]The writer is indebted to the Maudsley and Bethlem Royal Research Fund for the support of this investigation.

muscles, and that resumption of work leads to an increase in temperature which is paralleled by an improvement in performance (independent of learning or reminiscence) which is registered as post-rest upswing or "warm-up." This rapid movement is superimposed on whatever other trends may be present; in the case of post-rest practice on the pursuit rotor, these trends seem to be negative, i.e., to lead to continually worsening performance (Ammons, 1947; Eysenck, 1965). The duration of the warming-up improvement is limited; it ceases when the muscles have regained their previous level of heat. The amount of temperature change involved is not assumed to be great, and the time elements involved are unlikely to be in excess of 1 min. or so, and may well be less. The theory predicts, among other things, the following: (1) Upswing phenomena should be observable pre-rest as well as post-rest; this follows from the view that irrespective of learning, performance increases temperature level, and higher temperature levels facilitate performance. (2) This upswing, whether pre-rest or post-rest, should be greatest in those *Ss* who make the greatest effort and consequently accumulate more heat; in other words, *Ss* of greater ability, who keep the stylus on target for a greater proportion of the time, should show greater warm-up. (3) Exercise of the muscles involved in the work, undertaken during the rest pause, should improve performance post-rest, thus leading to apparently greater reminiscence scores; reminiscence of the exercised groups would include part or all of what in the non-exercised groups would be considered warm-up decrement. (This exercise would, of course, have to be non-specific, i.e., not similar in any way to pursuit tracking or whatever the task involved.) (4) Exercise with the hand not used in the tracking task would generate less heat in the muscles involved in the tracking and thus lead to lower reminiscence scores than exercise with the hand involved in the tracking task.

Evidence supports all four predictions. Reynolds and Adams (1954) have demonstrated pre-rest upswing in pursuit rotor learning and have shown this to be a direct function of ability level, so have Eysenck and Gray.[3] Eysenck (1964) has shown post-rest upswing to be a function of ability level. Catalano (1967) has demonstrated higher reminiscence on the pursuit rotor as a function of dynamometer pressing during the rest pause and has shown also that this gain in reminiscence is significantly greater when the exercise is done with the task-involved hand than when it is done with the non-involved hand. This finding is difficult to reconcile with his own hypothesis of dynamometer-pressing increasing degree of cortical arousal. Catalano's Fig. 1 illustrates very well the hypothesized course of events, particularly that part of the graph showing the differential performance post-rest vs post-squeeze when the dynamometer pull is three-fourths of capacity. There is no difference between groups during the second, third and fourth trials; there is a marked difference on the first trial, such that the rest group shows warm-up, the squeeze group does not. Many other consequences can, of course, be derived from this view, apart from the obvious ones regarding direct measurement of muscle temperature; future publications will report on efforts to support or disprove these hypotheses. It may be noted, however, that even if these experiments should support the theory, this does not necessarily invalidate alternative theories; post-rest upswing may have more than one source, and true physiological "warm-up" may be only one of them.

REFERENCES

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

AMMONS, R. B. Acquisition of motor skill: I. Qualitative analysis and theoretical formulation. *Psychol. Rev.*, 1947, 54, 263-281.

[3]H. J. Eysenck & J. Gray. Reminiscence and the shape of learning curve as a function of subjects' ability level on the pursuit rotor. (Unpublished manuscript, 1969)

ASMUSSEN, E. Muscular exercise. In W. O. Fenn & H. Rahn (Eds.), *Handbook of physiology.* Sect. 3. *Respiration.* Vol. 2. Baltimore: Williams & Wilkins, 1965. Pp. 939-978.

ASMUSSEN, E., & BOJE, O. Body temperature and capacity for work. *Acta physiol. Scand.*, 1945, 10, 1-22.

BLAKE, M. J. F. Relationship between circadian rhythm of body temperature and introversion-extraversion. *Nature*, 1967, 215, 896-897. (a)

BLAKE, M. J. F. Time of day effects on performance in a range of tasks. *Psychonom. Sci.*, 1967, 9, 349-350. (b)

CATALANO, J. F. Arousal as a factor in reminiscence. *Percept. mot. Skills*, 1967, 24, 1171-1180.

COLQUHOUN, W. P., BLAKE, M. J. F., & EDWARDS, R. S. Experimental studies of shift work: I. A comparison of 'rotating' and 'stabilized' 4-hour shift systems. *Ergonomics*, 1968, 11, 437-453. (a)

COLQUHOUN, W. P., BLAKE, M. J. F., & EDWARDS, R. S. Experimental studies of shift work: II. Stabilized 8-hour shift systems. *Ergonomics*, 1968, 11, 527-546. (b)

EYSENCK, H. J. An experimental test of the "inhibition" and "consolidation" theories of reminiscence. *Life Sci.*, 1964, 3, 175-188.

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

HOEGBERG, P., & LUNDGREN, O. Uppvärmninjen inver Kon på loppprestationeruc. *Svensk. Idrott*, 1947, 40, 480.

KLEITMAN, N. *Sleep and wakefulness.* Chicago: Chicago Univer. Press, 1963.

MUNIDO, L. The influence of body temperature on performance in swimming. *Acta physiol. Scand.*, 1947, 12, 102-109.

REYNOLDS, B., & ADAMS, J. A. Psychomotor performance as a function of initial level of ability. *Amer. J. Psychol.*, 1954, 67, 268-277.

Accepted May 26, 1969.