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AN EXAMINATION OF THE INVERTED-U CURVE: A BEHAVIOURAL
AND A PHYSIOLOGICAL APPROACH

A thesis submitted in partial fulfilment of the requirements for the
degree of Doctor of Philosophy.

by

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This thesis describes original research carried out by the author in the Department of Psychology of the Australian National University from March 1973 to March 1976.

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PREFACE

A portion of this research is being published in the following paper:

Lind, P. The behavioural effects of single and combined stressors: a test of arousal theory. *British Journal of Psychology*, 1976, in press.

ABSTRACT

According to activation theory, there is a continuum of "activation", i.e. greater and lesser degrees of neural activity extending from the reticular formation to the cortex, to the spinal cord and to the periphery, e.g. the autonomic nervous system. Increases in activation produce an inverted-U change, i.e. a sequence of improvement and impairment, in behaviour.

Chapter 1 reviews the evidence in support of activation theory.

In infra-human species, physiological studies tend to substantiate activation theory. In particular, Wayner's (1974) work suggests that there is a continuum of spinal reflex discharges in the brain stem motor control system.

In infra-human species, behavioural studies have not adequately tested activation theory. Nevertheless, inverted-U changes in behaviour as a function of the intensity of stimulation have occasionally, but reliably, been reported (Yerkes and Dodson, 1908; Broadhurst, 1957; Moyer and Korn, 1964).

The aim of the present thesis is to determine whether activation theory can predict the physiological and the behavioural functioning of intact, unanaesthetized rats which have not been chemically altered or lesioned.

Chapter 2 considers the type of paradigm in which activation theory may be evaluated. The common approach of correlating different indices of nervous system responses to external stimuli (Malmö, 1959)

appears to be unsatisfactory. Another approach, derived from investigations of the summation of "drives" (Bolles, 1967) and of the interaction of "stresses" (Wilkinson, 1969), allows more control over the sources of variance which influence nervous system responses.

Two predictions of activation theory are tested:

- (i) that stimuli combine to heighten activation, as indexed by nervous system increases, and,
- (ii) that stimuli combine to heighten activation, as indexed by either improvement or impairment in behaviour, depending on the intensity of stimulation; at low intensities, combinations alter activation from low to moderate levels and, thereby, improve behaviour and, at higher intensities, combinations alter activation from moderate to high levels and, thereby, impair behaviour.

The physiological prediction was considered in Chapter 4. Consistent with the expectations of activation theory, a loud burst of white noise plus a moderate shock elicited greater conditioned increases in skin conductance than a weak burst of white noise plus a moderate shock.

The behavioural prediction was considered in Chapter 3. An inverted-U trend in shuttleavoidance as a function of the intensity of either white noise or shock was obtained. Contrary to the expectations of activation theory, however, a decreasing monotonic trend in shuttleavoidance as a function of the intensity of white noise plus shock did not eventuate.

While there seems to be support for the possibility of a continuum of activation in the nervous system, then, increases in activation are not sufficient to produce a sequence of improvement and

impairment in shuttling. Accordingly, Chapter 5 appraises other ways of explaining this sequence (the so-called "inverted-U curve"). Most explanations, except those which contain postulates about competing responses, can be rejected.

Chapter 6 evaluates postulates about competing responses by means of the following assumptions: competing responses develop when subjects are required to approach shock-related cues and these responses do not develop when subjects are allowed to approach shock-unrelated cues; therefore, the supposed consequence of competing responses, *viz.* inverted-U curves, should occur in the former case but not in the latter case. Compared with subjects which approached shock-related cues, subjects approaching shock-unrelated cues evidenced better shuttling at a high intensity of shock as well as, inexplicably, at low intensities of shock.

An attempt to account for these data prompted the manipulation of two variables, i.e. the number and the type of CSs. This manipulation is reported in Chapter 7, where the effects on shuttle-avoidance of one CS and of two CSs were compared under three conditions:

- (a) the presentation of a visual CS (light or darkness) in the occupied compartment and/or the presentation of a tone CS;
- (b) the presentation of a visual CS (light or darkness) in both compartments either alone or together with a tone CS; and,
- (c) the presentation of a visual CS (light or darkness) in the to-be-entered compartment either alone or together with a tone CS.

At high intensities of shock, a CS, presented in the occupied compartment only, appeared to eliminate competing responses and, thus, to enhance shuttling. At low intensities of shock, a CS, involving a

dark-to-light change only, combined with a tone CS to facilitate shuttling. This facilitation appeared to represent a "sensitization" (Duffy, 1972; Hinde, 1966, 1970) of the tone by a sensory change of particular relevance to albino rats.

On the basis of these results, Chapter 8 argues that the inverted-U relationship between shuttleavoidance and shock is due to the antagonistic operation of incremental and of decremental influences, or reinforcements. In particular, inverted-U relations occur with the combination of these influences in the same situation; also, inverted-U relations seem to be predictable from an addition of the effects of the operation of these influences in separate situations.

The foregoing argument suggests a possible inadequacy in the experiments of Chapter 3 where white noise and shock were combined in a situation which confounded incremental and decremental influences. These stimuli may have heightened activation and, in consequence, may have simultaneously altered shuttling in opposite directions, so that shuttling appeared to be unaffected. Consequently, it seemed necessary to isolate incremental and decremental influences and, then, to re-examine combined and separate presentations of white noise and of shock. In accord with activation theory, white noise plus shock might be expected to improve shuttleavoidance compared to shock alone in the presence of the incremental influence and, in contrast, white noise plus shock might be expected to impair shuttleavoidance compared to shock alone in the presence of the decremental influence. These predictions were not confirmed in Chapter 9.

In general, there is evidence in support of the possibility of a continuum of activation in the nervous system. However, there is

no evidence to suggest that increases in activation *per se* are related to the incremental and decremental influences which are responsible for sequences of improvements and impairments in behaviour.

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