

SOME RESEARCH ISSUES CONCERNING HUMAN PERFORMANCE IN COMPLEX SYSTEMS

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In the study of human performance, a topic which has received widespread attention is known as the Yerkes-Dodson Law. This law states that the quality of performance on any task is an inverted-U-shaped function of the level of arousal of the performing human, and that the range over which performance improves with increasing arousal varies with task complexity (Yerkes and Dodson, 1908). Thus, according to this proposition, as arousal (stress) is shown to increase, performance also appears to increase in linear fashion until a critical point is reached when further increases in stress result in rapid performance deterioration.

This law, although originally based on somewhat crude experimental procedures, has been demonstrated to be valid in a wide range of situations. (Duffy, 1957; Malmo, 1958; Hebb, 1949; Schlosberg, 1954; Stennett, 1957). An example of the validity of the Yerkes-Dodson Law is provided by the work of Stennett (1957). He investigated the relationship between performance on a tracking task and levels of GSR and muscle tension. He also introduced a new variable by manipulating the motivational level of his subjects with changing instructions. Presumably, instructions which demanded more effort of the subjects would result in higher levels of arousal and this would be reflected in the GSR and muscle tension measures. Stennett found that performance on the auditory tracking task was related to level of motivation by an inverted-U-shaped function. The finding held regardless of the measure used to indicate arousal. Figure 1 shows the classical Yerkes-Dodson relationship.

It has also been hypotehsized (Hebb, 1949) that sensory events are composed of cue functions (which guide behavior into a particular type of activity such as eating, drinking, etc.) and arousal functions which elicit the basic energy to propel the organism in a goal-oriented direction. According to this theory, without arousal, no cue function can exist.

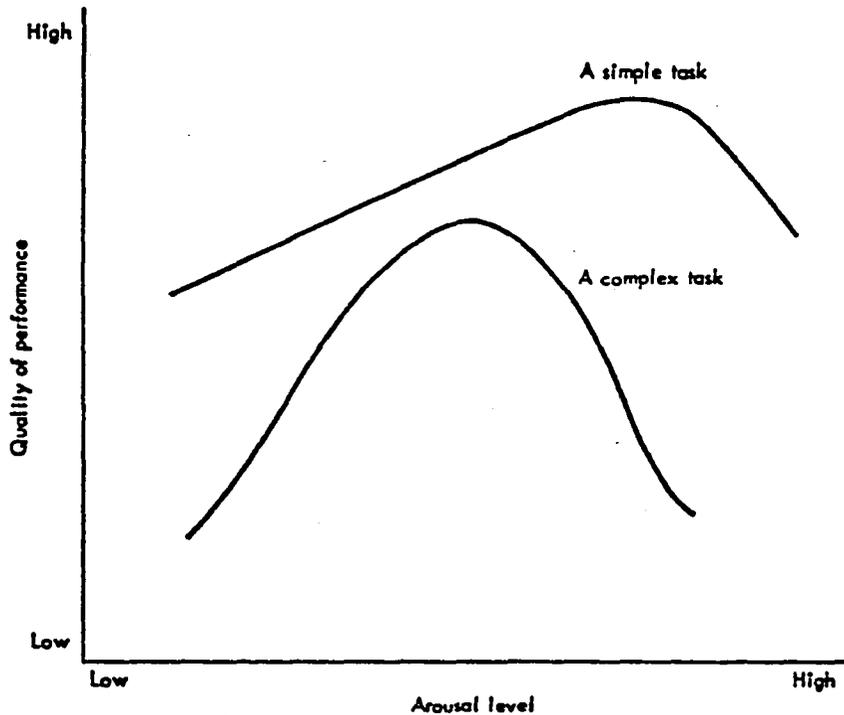


Figure 1 - The Yerkes-Dodson Law as pictured by Kaneman (1973)

Hebb's concept of arousal is synonymous with the concept of general drive state and is also related to cue function via the inverted-U-shaped function. Hebb's conception is shown in Figure 2.

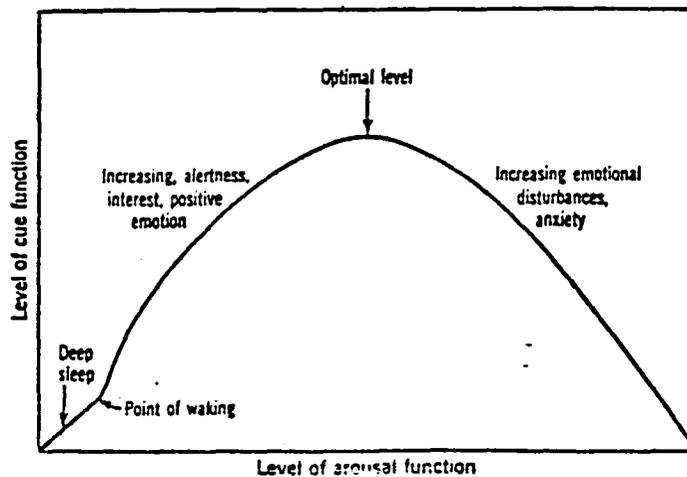


Figure 2 - Hypothetical "inverted U-shaped" relationship between behavioral efficiency or level of cue function and level of arousal as pictured by Hebb (1949).

More recently, Fineberg (1975) has shown that this function also describes aviator performance (reaction time and response accuracy) in a series of complex tasks involving manipulations of aircraft closing velocity and target distance.

Welford (1968) has postulated two explanations for such phenomena. One assumes that an individual's level of arousal varies with the strength of an incentive, such that a high level of incentive would have little effect on the performance of an easy task, but would have a much greater effect as the requirement for capacity increased. The second explanation presumes that tasks themselves induce a degree of arousal, and that this arousal rises with increasing task difficulty. This arousal is then added to the arousal produced by an incentive. If the optimum arousal level is the same for most degrees of task difficulty, the addition due to incentive that would produce this optimum, would fall as a task becomes more difficult.

The Yerkes-Dodson Law has been widely studied in the areas of stress and performance (c.f. Freeman, 1938; Stabler and Dyal, 1963; Anderson, 1976). It appears to have been adequately demonstrated, and exists as a respected component of the scientific literature.

Cognitive Tasks

Additionally, work has focused upon expanding the variable domain in this area. A series of studies by Swezey (summarized in a forthcoming book; Easterby and Zwaga, in press) have suggested that the inverted-U-shaped phenomenon can legitimately be extended to the cognitive domain. That is, when a variety of stimulus manipulations in several different contexts (primarily legibility studies) addressed the cognitive tasks of recalling and retaining presented alphanumeric data, an inverted-U-shaped function similar to the Yerkes-Dodson type effect, resulted. A cognitive processing explanation for this phenomenon was offered (Swezey, 1978) which suggested that as stimuli were degraded the effective result of the degradations was to force the user to concentrate harder on the presented material in order to compensate for the rapidly degrading stimulus conditions. This increased

concentration resulted in improved recall and retention performance up to a point beyond which no amount of increased concentration on the user's part could compensate for the extreme stimulus degradation, and recall and retention thus deteriorated.

Interactive Complexity Theory

In a somewhat different domain, work by Streufert and associates (summarized in Streufert and Streufert, 1978) have postulated an interactive theory of cognitive complexity which, briefly stated, suggests that as the environmental complexity of a situation increases, the ability of individuals to demonstrate flexible differentiative and integrative performance in complex decision making tasks follows (you guessed it) a series of inverted-U-shaped curves.

According to Streufert (1982), the potential for multidimensional (differentiative/integrative) behavior is considered to be optimal at some intermediate level of environmental load. However, differential maximum elevations of the U-shaped curves at that optimal point reflect differential styles of information processing. That is, Streufert's theory postulates the existence of various styles of information processing. Current theory specifies nine such styles as follows: low unidimensional, normal unidimensional, general differentiative, closed-hierarchical differentiative, excessive differentiative, low integrative, high integrative, closed-hierarchical integrative, and non-closing integrative (Streufert and Swezey, 1982). Individuals employing such styles presumably show differently constructed inverted-U-shaped curves (c.f. Figure 3).

Complexity theory has been tested in basic laboratory experiments (e.g., Streufert, 1966), in organizational manned simulations (e.g., Streufert, 1970), and in a large number of real-world settings (summarized in Streufert and Streufert, 1978). The predictions of the theory have been confirmed for perceptual (e.g., Streufert and Driver, 1965), and complex decision-making tasks (e.g., Streufert and Schroder, 1965) among others.

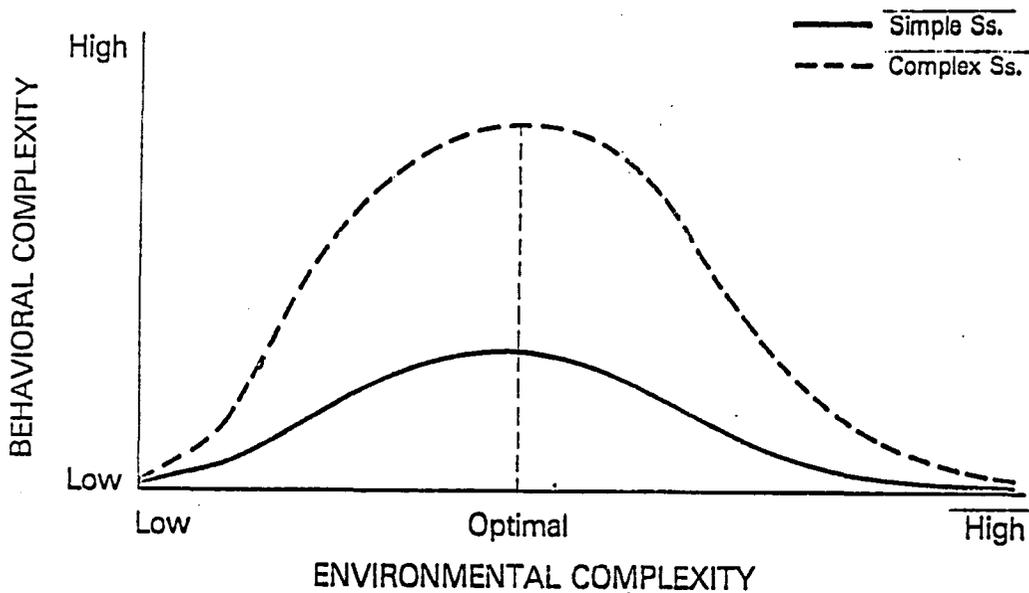


Figure 3 - Degree of flexible differentiation and integration in perception and performance as a function of environmental complexity (Revised theory: Streufert and Streufert, 1978)

Complex Systems Design

The previous discussion has introduced the notion that an inverted-U-shaped function applies widely to perceptual, retention, and decision-making tasks; and further, that individual decision styles may effect the specific shape and height of that function. Such a notion would argue that complex systems should be designed with these data in mind (i.e., should be designed to maximize user performance by employing optimal stressor levels). Here the term "stressor" is used generically to refer to such concepts as load, environmental complexity, stimulus degradation, etc. The point is that research may be conducted to determine ways to manipulate system design parameters in order to maintain the optimal (asymptotic) performance level on the inverted-U-shaped curves (c.f. Figure 4) for various individual cognitive styles (i.e., simple, complex, etc.).

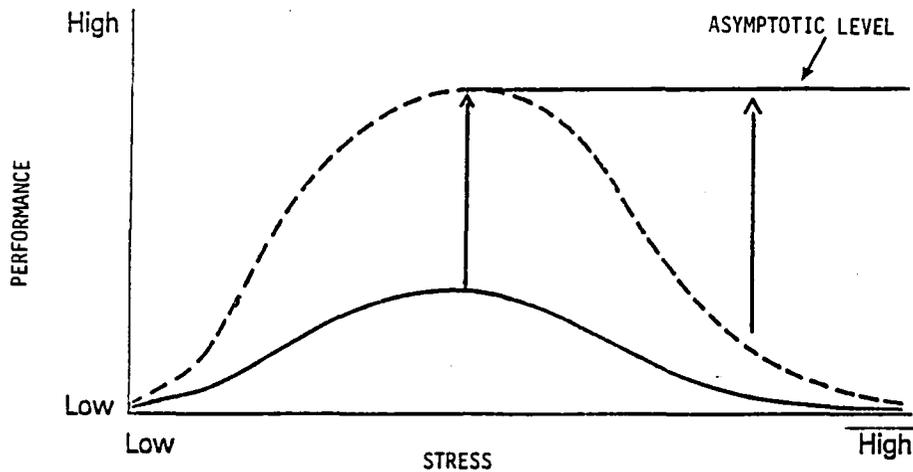


Figure 4 - Asymptotic level

One of the major human factors findings of the 1981 Air Force Studies Board panel on Automation in Combat Aircraft (AFSB, 1981) was that..."The effectiveness of automation depends (in large part) on matching the designs of automated systems to (users' cognitive) representations of their tasks. This requires an understanding of how (users) think about their tasks, as well as an understanding of the performance characteristics of the control and display components through which the (users) and the automated systems interact...(p. 59)."

"Further that panel issued the following recommendation..." Develop models of (user) behavior, for example, specific models of workload and menu selection, as well as general models of how (users) process information and make decisions...(p. 59)."

Recent studies in cognitive psychology appear promising but need to be codified into practical handbooks and models. Such an attempt has recently been made, for example, by Davis and Swezey (in press) in the area of human factors guidelines for computer graphics displays.

Practical research efforts are needed in these areas as follows:

- Determining and quantifying optimum stressor levels for various tasks and display parameters,
- Manipulating system designs and display parameters to achieve optimum stressor levels (and thereby determining ways to maintain asymptotic performance),
- Determining the effects of various individual cognitive styles on system performance,
- Studying cognitive models and expectations of system users,
- Synthesizing guidelines for complex system design,
- Employing Hunter, Schmidt, and Jackson (1981) type meta-analytic procedures to establish the current state of knowledge in the area of complex display design.

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