16: STRESS AND ADAPTABILITY

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One of the mandates given to Workshop C (see preface) was the exploration of definitions of the concept of stress and how stress may act to impact various human capabilities. Due to time contraints, it was not possible to address this important and broad issue in detail, although an initial consensus was found in support of the position adopted by Lazarus (see Lazarus, 1966; Lazarus & Folkman, 1984). The purpose of the present paper is to elaborate upon this little explored theme through examination of a recent position which bears upon this problem (Hancock & Chignell, 1985) and, specifically, to indicate how insights gained during the meeting have acted to enhance this latter perspective.

THE TRINITY OF STRESS

Input Stress

As with other ubiquitous phenomena (eg time), stress may be regarded as possessing three loci with respect to observer/environment interaction. These are illustrated in Figure 1. Stress may be a specific metric of the physical surround, often referred to as a "stressor" following the nomenclature of Selye. Stress is usually employed as a relative term, in the sense that it requires an object or observer upon which to act. Wthout this, the function of input stress remains largely unknown and although it may provide an interesting source of speculation, it has been claimed that it is not amenable to examination through the scientific method (Medawar, 1984).

Adaptability

The second locus of stress is the compensation undertaken by an object or observer, to mitigate the perturbing effect of the input stress. Ursin (this volume) emphasises the notion that the constituents of the input stress do not strike a static individual. Rather, previous experience with the stress, the task at hand (eg Hancock, 1985a; Wilkinson, 1969), or intrinsic variation such as circadian phase can all act to affect the ability to compensate to a constant input stress (See also Gopher, this volume). It is this comensatory property, which is known as adaptability, that characterises the second locus of stress. In addition to the above mentioned macro-factors which clearly affect reaction to input stress, a variety of micro-factors also influence response. Simple changes due to intrinsic random variation and the passage of time between successive exposures mean that any constant input stress which is presented repetitively will not impact the active nervous system of the respondent in the same state. Consequently, consistent response to equivalent stress inputs should not be expected. This observation introduces considerable difficulty into the understanding of overall stress effects

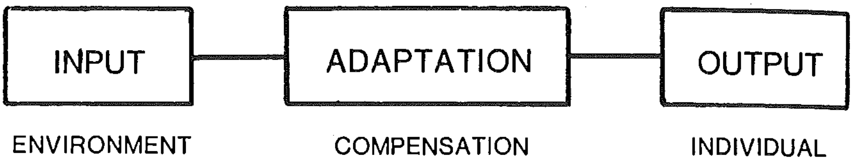

Figure 1 Three loci of stress. Stress may be considered in terms of changes in the physical environment (input), the compensatory activity carried out by the individual (adaptation), or as individual behavourial characteristics (output). The three loci are inter-dependent and overlapping, and may be described at different levels of analysis.

Output Stress

The third locus of stress is in output and, just as input can be solely described in terms of physical characteristics of the environment, so output is a function of the respondent. For the purpose of subsequent discussion, the response of the human performer is considered, although in principle the notions may also be applied to any responsive organism. Behaviour, in the present locus is concerned with on-going task performance and is not equivalent to the adaptive behaviour associated with the second locus. It should be recognised that the three loci of stress are co-existent and are strictly speaking, non-exclusive in that they may overlap each other. The manner in which such overlap can occur is addressed briefly below.

This trinity of stress can be described at several levels of analysis, including the physical, physiological, psychological and social. In the case of human exposure to stress, it is clear that effects are pervasive and while they are most clearly observed at their own level of analysis (ie physiological input stress is most clearly reflected in physiological adaptability and physiological output), there is an effect at each alternate level. The severity of action at each alternative level is probably related to the "distance" from the site or level of major impact.

PRINCIPLES OF ADAPTABILITY

Any input stress may be regarded as either an excess or an insufficiency of some environmental component and this hypo/hyperstress continuum is represented along the abscissa in Figure 2. With the present concern for the integration of human physiological and behavioural action the two ordinates are labelled physiological and psychological adaptability respectively. They range from a maximal level of adaptability as indicative of the complete readiness of the performer to respond to adverse input, to minimal adaptability where the ability to undertake compensatory action is almost completely depleted.

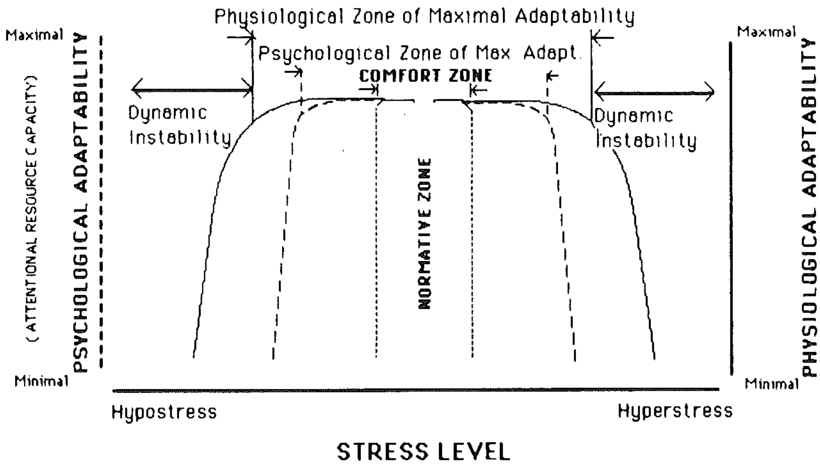

Figure 2 Change in physiological adaptability (solid line) and psychological adaptability (dashed line) as a function of stress level. Embedded are comfort and normative zone. Zones of adaptability surrounding these areas represent regions where negative feedback predominates. Beyond these limits are dynamically unstable conditions typified by positive feedback.

Normative and Comfort Zones

At the centre of this continuum is a normative zone, where the demands of the environment, which in real life are always multi-levelled and multivariate, exercise little impact on the performer. However, due to the numerosity and complexity of environmental demands, the stable presence of the performer in this zone is considered an infrequent event. Surrounding the normative zone is a region of perceived comfort. While this concept is not amenable to description in certain domains, it has precise and quantifiable limits in relation to several environmental input stress metrics. At the level of psychological adaptability it is essentially a subjective reaction of the performer to the multivariate task array presented by the impinging sensory display. This region or zone is considered important in that it is assumed that the performer is consistently attempting to maintain placement whithin this zone and that violation of the boundaries initiates explicit adaptive compensation. This is indicated in Figure 2 by the origin of the adaptability functions at the cessation of the comfort zone.

Zones of Adaptability

Outside of the comfort zone is a region of adaptability. Within the region of maximal adaptability, which it should be noted is larger for physiological compared to psychological functioning, stability is maintained. In terms of psychological adaptability this maintenance cost is represented by attentional resource capacity expenditure. As will be elaborated below, it is possible that the regference normative zone and associated surrounding zones can vary with respect to their location along the stress continnum particularly for different individuals. Thus it is common to conceptualise resource capacity expenditure as being associated with the excessive demands or overload of some task or group of tasks, ie hyperstressful conditions. Previously, we have suggested that stress acts to drain attentional resources (Hancock & Pierce, 1984) and that overload results in the function as expressed on the right-hand side of Figure 2. However, exteme underload, as typified by vigilance conditions can also act to reduce adaptability (see Hancock, 1985b).

This reduction under hypostressful conditions may take two forms. First, it may be that the supply of attentional resources are servomechanistic in nature such that demand begets supply while the absence of demand acts to reduce overall resource level. The notice that rate of demand is an influential factor also has an equivalent in physiological adaptability to any input stress. The second alternative concerning the failure of psychological adaptability in underloaded situations is related to the strategy employed by the performer. It is assumed that the performer devotes attentional resources as externally dictated by the salience of tasks at hand. It is possible to attempt to increase the salience of a specific task for the performer by, for example, isolating the performer from the rest of the environment. However, the performer may adopt covert resource utilisation strategies that result in apparent progressive failure as measured by performance on the task. This performance decrement may occur while the actual level of resource availability remains relatively constant but is devoted to alternate sources of information. This is commonly seen with underload in children whose tolerance to repetitive and inherently uninteresting environmental displays is particularly poor.

The original work of Mackworth (1950) can shed some light on this issue. He noted that after a brief interruption in a vigil, whether a purposive or accidental interruption, performance level of the observer improved. In terms of attentional resources, the demand initiated by the interrupion may be allowed greater availability upon return to the task. Alternatively, the break may have served to refocus those resources still available back to the imposed task. While these suggestions are difficult to test, it is probable that some composite of these actions is occuring both in laboratory and real world tasks, although in different proportions depending upon the actual situational constraints.

Determinants of Adaptability

The nature, severity and time course of the input stress array directly impacts five components which determine the level of adaptability. The first of these (1) is the current location on the adaptability function which depends on the previous history of exposure. While this location may be informative with respect to the presence or absence of comfort and/or stability, it is of limited use without more information about dynamic determinants. Thus, the second overall factor (2) is the change induced by prevailing conditions and, as suggested above, is central to the determination of adaptive response. It is also necessary to establish (3) the direction of current change and whether prevailing inputs are acting to induce or violate stability. In most circumstances, stress is perceived as an agent that acts to reduce adaptability. However, in the case of an input stress which interacts antogonistically with existing conditions this reduction of adaptability may be reversed. An example is the antagonistic effect that noise exerts when the performer is stressed through sleep loss (Wilkinson, 1969).

As change is an important component, so (4) the rate of the prevailing change or acceleration, also acts to affect adaptability. In work dealing with the impact of temperature upon performance it has been suggested that change and acceleration away from a steady, but not necessarily normative state, are the two key determinants of adaptability. These components, as expressed in terms of a physiological change, subsequently affect psychological adaptability as expressed in performance level (see Hancock, 1985b).

The final component (5) is the integral, which in a general way represents the overall amount of stress experienced in a particular epoch. Of course the time over which such an integration occurs vry much depends upon the situational demands. Some events, eg a flight mission, may be easily marked in time, whereas other conditions may be much more equivocal concerning the onset and offset of multivariate input stress exposure. The exact weighting of these five determinants remain at present unknown and it is tempting to suggest that such weighting is solely situational specific. However, evidence from performance under the impact of a variety of input stress would indicate the primacy of the two factors, change and acceleration, under most conditions.

Relationship Between Adaptive Mechanisms

Figure 2 indicates that psychological adaptability fails prior to physiological adaptability but it makes no direct assertions concerning the inter-relationship between these functions. In work on the effects of temperature (eg Hancock, 1985b) it has been suggested that the point of transition from dynamic stability to dynamic instability in the psychological realm is also the point where complete physiological adaptability to the input stress begins to fail. This is illustrated in Figure 2 as the deviation of the solid curve from the horizontal and is equated via a vertical dotted line to change in psychological adaptability. There is at present no definitive evidence to suggest the presence of such a direct relationship for other forms of input stress, although it is possible that such a link exists. The evidence for the breakdown in physiological adaptability is considerable and the increasing exponential form taken is consistent with findings from several differing areas of investigation.

Initially, it appears as though regions of dynamic stability may be characterised by negative feedback which, in physiological systems, represents homeostatic action (Barnard, 1865; Cannon, 1932). The breakdown of such control results in positive feedback which is typified by the increasing exponential functions shown in regions of dynamic instability. However, while it may prove convenient to use this characterisation for modelling purposes, it is most probably not the way in which such systems are actually controlled (see Prigogine, 1980). The approach toward transition from the stable to unstable mode of control appears directly related to the combination of exposure time and severity of the input stress. These factors dictate the rate of change of adaptability away from the normative, steady state. It is the transition across these states, particularly from relatively stable to unstable modes that can be revealed by a time-line analysis of performance.

There are serveral other aspects of Figure 2 that are of interest. First, it preserves the inverted-U shaped function between stress and capability as expressed in adaptability scales. While the peak is no longer represented by a single optimal point, it retains the intuitive notion that for some scales of input stress increase from an initial level is a beneficial intrusion. However, it also suggests that normative and confortable levels of stress present the best opportunity to maintain maximum adaptability and therefore optimal performance. Support for such a position is provided by Sparrow (1983) who presented convincing evidence that optimal rates in a variety of mostly rhythmic performance tasks coincide with the rate that is freely chosen by the performer.

Also, it is the case that the absence of many types of input stress does not require adaptive response. For example, a zero level of material-born vibration falls within the normative zone for the exposed human performer. This unipolarity of some inputs may be responsible for the failure to find the ascending arm of the inverted-U under some experimental conditions. For other varieties of input stress, the normative zone of the human does not coincide with the zero value of the input, and temperature is a good example of such a case.

There are two factors which may influence this overall perspective. First, the picture presented in Figure 2 is two dimensional and therefore omits two important components. The first of these components is time. In order to allow prediction of response, it is necessary to represent the time course of events as they progress under input stress. The second missing component is the multiplicity of input stress that is intrinsic to actual exposures. A single stress continuum as presented in Figure 2 is unable to capture the complexities involved, especially when inputs either act to retard or accelerate joint impact. These interactive aspects are of particular importance in controlling adaptability and point to the need for multi-dimensional representation (See Hancock & Chignell, 1985).

There are transitional and end states to these adaptability functions. These are first, the necessity to initiate specific compensation against the onset of either a novel or intrusive input stress. This is the limit to the normative state. The failure of comfort signifies magnification of this perturbation, which in terms of psychological adaptability is most probably recognised as a conscious state. With the progressive depletion of attentional resources, the performer maintains efficienty through the strategic manipulation of these resources which remain. This attentional narrowing to cues of perceived task salience (Easterbrook 1959; Hancock & Dirkin, 1983) reflects one mode of adaptive behaviour that permits continuing activity in the face of a driving input stress. However, the combination of exposure time and input severity may act eventually to perturb the performer bdyond the limits of adaptability and, even with strategic change in attention allocation as reflected in the narrowing phenomenon, progressive performance deterioration will be observed.

The complete failure of psychological adaptability may be taken as the draining of attentional resources or an unconscious state and it may be preceeded by the cessation of purposive behavioural response with respect to the task at hand. The latter condition most probably represents the implicit realisation that continuation on tasks that do not counteract input stress and therefore promote direct survival, no longer serve any vital purpose. There are examples of such behaviour. In terms of exposure to extreme heat, it has been noted that voluntary withdrawl from a heated location is highly correlated with an individual's physiological heat storage capacity. Finally, the subsequent failure of physiological adaptability quite simply threatens the continued functioning of vital life support functions.

Levels of Adaptive Response

The theme running through this paper is the notion of adaptability - that is, an overall readiness to respond to a multivariate array of input stress. Inputs at any level have both specific and distributed effects. The specific effects relate to the "system" they impact most directly; eg noise impacts the auditory system. However, the distributed effects impact the individual not only at the level at which they occur but also at alternate macro and micro- levels. It has been argued that input stress acts to reduce adaptability, where such reduction is dependent upon the time and severity of the input stress and governs the rate of change in the adaptability function. Adaptability is proposed as a ubiquitous property of the responding individual and although, as a first approximation, it is equated with attentional capacity at a psychological level, it is envisaged as a somewhat broader concept in toto (Hancock & Chignell, 1986). Although physiological and psychological adaptability are not synonymous, it is proposed that there is a direct relationship as expressed in Figure 2. This overall picture may serve as a gross isomorphism which acts to delineate coincident general tendencies. Specific isomorphisms may only be observed in particular instances, although the demonstration of a particular instance has yet to be shown unequivocally (See Barlow, 1972; Marr, 1982).

In the attempt to derive a more complete definition and potential theory for the overall action of stress, it is important to draw links between levels of investigation in both a general and more specific manner. Definite and distinct "levels" of analysis are largely chimeric and represent an artificality rather than actuality of division. However, in reality investigators do employ differing techniques and terminology to examine essentially common phenomena. Two major efforts to bestride such levels (see Coles & Gratton, and Robbins, this volume) are indicative of beneficial approaches. In common these works explicitly express the necessity to map neurophysiological function with overt behaviour. It has been suggested that various phenomena at differing levels of analysis may be "mapped" to one another in fairly strict fashion. A less sanguine view, proposed here, is that a mapping of all phenomena on a plane to that of a second in a 1:1 manner is unrealistic, especially with respect to human functioning. Rather, it may be the case that specific phenomenon may map to each other and are represented as either points of singularity or occasions where the mapping is few to one. Superceeding such specifics must be a general structure within which to frame such important connections. It is toward an understanding of such an overall framework that this paper is directed.

CONCLUSION

In presenting a three part view of stress, this paper has focused upon the adaptive ability of the human performer as a key element in an overall understanding. Although input stress has been identified as important in relation to adaptive response a general description of such input is not fully expanded in the paper. Also, due to space limitations, an output view of stress is presented only briefly here. A full understanding of the action of stress upon capability requires a more detailed analysis of these two elements. However, the need to link adaptive capability at differing levels is explored and the limits to adaptability act to frame the brief picture presented. It is suggested that this approach may be used as a descriptive structure for a general theory of stress and human activity.

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