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Ergonomics as a foundation for a science of purpose

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The argument here is at once simple and profound. The first premise is that technology is the most powerful 'shaping' force on the planet today. The second premise is that individual impact on this force is most evident at the human–machine interface. A corollary of the second premise is that unity in intention is to be found in the aggregate of individual actions. Ergonomics, as the pursuit that mediates between operator and technology, is, therefore, the first step along the path to a science of intention as expressed in 'world' changes. Some initial observations on the integration of existing behavioural theories represent the first step along this royal road.

1. Introduction

For ergonomics to become more than an 'appliance science' which solely attaches heuristic patches to flawed initial designs, it has to generate and validate a utilitarian theory of human–technology interaction. With very rare exceptions, such as the conception of symvatology (Karwowski 2000), there are essentially no theories of ergonomics (see Meister 1999). Given that there promises always to be more individuals generating unhealthy technology than there are ergonomists to cure it, theory is our only viable method to power ahead of the development curve. However, what form should such a theory take and what differentiates it from any other theory of contextual behaviour? We need not be apologetic that we have no present answer, since ergonomic theorizing is in its infant stages. After all, despite one or two notable historical exceptions (Jastrzębowski 1857), ours is a small and still growing branch of knowledge and, here, we do not erect a full theory of intention as mediated by ergonomics. However, we do advance some ideas that might be used as foundation-stones for the base of such an edifice.

2. Theories in ergonomics

As evidenced by the Journal you are holding in your hand, there is a growing interest in the role of theory in ergonomics. Many scientists have recently commented either indirectly or explicitly on the unsatisfactory situation in respect to ergonomic theory (Hendrick 2000, Rasmussen 2000). In the past, ergonomics has traditionally 'borrowed' or assumed theories from foundational disciplines such as physiology and psychology (Meister 2000, Jaksholt 2000), while extrapolating methods from engineering and mathematics in order to implement the ideas and notions that have emerged from the inter-disciplinary vigour associated with the linkage between

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humans and technology. Now, we are engaged in a search for our own theoretical basis, contingent upon but separated from the constructs of contributory disciplines. One clear instance of this search is evident in the idea of human-centred design. It is through this concept that we have sought to derive quantitative descriptions for the 'goodness of fit' between any one individual and the proximal technology of their use. Karwowski's notion of 'ergonomic entropy' is central to such a conception and we applaud his insight. However, the designation of entropic state specifies a disparity between *what is*, and *what could be*. We believe that the supraordinate and differentiating issue is the difference between *what is* and *what should be*. This denotes an explicit need for an explanation of purpose. As we have previously noted (Hancock 1997), human-centred design and, thus, 'ergonomic entropy' can well apply whether the purpose of the technology itself is suicide, genocide or terracide. Thus, for example, implementation of principles in human-centred design can obviously help terrorists achieve their aim of covert attack. It is in this manner that Moray (1993) and others have observed that science itself is a neutral pursuit with respect to the aims toward which it is directed. In contrast to this neutral posture, our primary aim here is to advance the contention that purpose itself is the critical central component of any fundamental ergonomic theory. Indeed it is, in its very essence, this concern with ethics and purpose that sets ergonomic theory apart from all other theories of behaviour in context (Hancock 1998). That this places a higher burden upon us in ergonomics to seek and specify what are ethical directions for technological purpose is a philosophical challenge, but one which elevates us beyond our foundational disciplines and helps codify our uniqueness. For, as Moray (1993: 34) has observed:

> The ultimate purpose of our discipline is not only to improve productivity or the efficiency of systems used for killing people but, rather, to better the human condition. The time has come to seriously consider what role human factors can play in the coming century. The problems are global ones, and if human factors does not play its role, we will be guilty of the *trahaison des clercs* (treason by the intellectuals) as it applies to our discipline. We have a moral duty to find our role.

We are not prepared, as yet, nor arguably is anyone else, to present a fully developed theory which features intention and purpose. We readily acknowledge that we are as yet only in the early formative stages of any such encompassing perspective. Thus, the present work is simply a first step in which we seek to show linkages between extant behavioural theories which have traditionally underpinned ergonomics. Founded on this beginning, we endeavour to show what the outlines of a theory of ergonomics purpose may be. By illuminating this one bridge between two behavioural theories, the present paper aims to serve as a catalyst for further theoretical discourse and development.

3. Purpose predicates process

In his 1857 treatise 'The Science of Work', Jastrzębowski related the potential societal, spiritual, and technological benefits attained through striving to create environments where humans can work 'at the least expenditure of toil'. Subsequent to his derivation of the name 'ergonomics', Jastrzębowski delineated many concerns fundamental to ergonomics which remain applicable today. Of especial interest is that, while Jastrzębowski outlined what a science of ergonomics *can* do, he made a specific point of describing what a science of ergonomics *should* do. He

addressed the dichotomy that would be brought by the development of a science of ergonomics: that harmful acts are facilitated to the same or to a greater degree than are beneficial acts. As evident in definitional data presented by Dempsey *et al.* (2000), the notion of purpose has all but been lost in subsequent definitions of ergonomics since Jastrzębowski's seminal work.

Having recognized the supposed neutrality of intellectual pursuits, why should we not let ethics be that field principally directed toward the designation of right and wrong? Our answer lies in the central character of ergonomics in bridging from ideas, goals, conceptions, and aspirations to their associated consequences in environmental and behavioural change. Ethics serves to study moral judgements and is concerned with *ex post facto* generation of statements about prior behaviours. Ethics as a voice is predominantly passive. In contrast, ergonomics selects and facilitates behaviours and, thereby, represents an active endeavour. While the ethicist can shed light on moralistic decisions, the ergonomist is actively capable of shaping the outcome of future behaviour. However, before aspiring to a world as we hope it could be, it is important to understand the world as it is.

4. The practical problem: ergonomics amongst rapid technological development

In our contemporary society, change is the only constant. Were this all, we might be able to cope, but unfortunately its derivative, the rate of such change, is itself in flux—a situation that renders crystallized knowledge concerning specific technical systems rapidly obsolete. Who today, other than an antique collector, needs someone to repair an eight-track tape-recorder or generate punched cards for data analysis? As software innovations replace hardware capacities, individuals become 'de-skilled' even more rapidly and, in capitalist societies, such job instability generates significant social stress. In competitive economies, there is then constant focus on the new. The customer, to consume, must be persuaded that what is on offer is better than that which they currently possess. While this is often not the case, vast amounts of resources are spent on advertising to persuade enough individuals of the exact opposite, so they are induced to perceive that they now *need* what is on offer—this being an intentional manipulation of behaviour. Those who cannot fill megabytes are sold gigabytes, and suburban drivers possess vehicles that are able to go 150 mph—but never do. In this cavalcade of novelty, manufacturers have now discovered how important human–machine interfaces are and have adjusted their marketing strategies accordingly. Workstations are touted as 'ergonomic' and epithets such as 'fahrvegnugen' surface periodically to reinforce this putative advantage. None the less, especially in the field of high technology, it remains too often the case that the financial anxiety over product release overwhelms the concern for user facility. As the number of professional ergonomists is eclipsed by the exponential growth of these new technologies, it is clear that *post hoc* strategies are not a plausible means to implement the ergonomic ethos.

5. Toward an integrative theory

If collective ergonomic fingers cannot plug the flooding dyke of technological dreck, how can we ensure that any ergonomic integrity is injected into new products? As we note, purely *post hoc* means of regulation such as litigation are clearly not feasible change agents when considering the scale and the dynamics of the problem. Thus, we have to engage a more viable solution in an *a priori* approach where theory guides the design process. A caveat to this proposition is that, in the realm of the ergonomic

sciences, no theory currently exists with a wide enough breadth to account for sufficient environmental circumstances, capability requirements, design variations, and user characteristics that distinguish one innovation from another (but see Karwowski 2000). The first step toward a resolution of this problem is to coalesce fundamental contemporary theories relevant to ergonomic science in order to attain the basis for a more universally applicable theory. Theoretical convergences have been and continue to be sought (e.g. Chignell *et al.* 1999, Hancock 1996, and see also Wilson 1998). Examples can be found in general theories of interactivity of organisms with their environment and in answers to enduring questions regarding the mind–brain relationship, as well as the conceptualization of consciousness (e.g. Gomes 1995). Ergonomics would benefit greatly from an acceptable general theory; and steps toward this gain can perhaps be achieved by first reconciling two dominant approaches already used in the field of behaviour, the ecological perspective and the information processing perspective.

6.   Comprehensive perspectives

Ecological psychology, at its heart, deals with the relationship between the properties of an organism and the properties of its environment. It is often viewed in stark contrast with the Cartesian vision, which separates the activities of the mind from the external world. Gibson's ecological account of perception focused primarily on vision and presented a broad theoretical framework in which response is motivated and constrained by features of the surrounding environment—for a comprehensive description, see Gibson (1954, 1966, 1979) and Greeno (1994). From a Human Factors standpoint, the ecological approach is in accord with the basic tenet of compatibility, in which minimal cognitive effort is necessarily demanded in order to successfully interact with a system (see Flach *et al.* 1995, Hancock *et al.* 1995). In contrast, the information-processing approach proposes that stimulation and cues present in the environment enter the cognitive process via the senses for subsequent transformation and processing. Thus, the ecological view focuses on what information is present in the environment, while information processing focuses on how internal representations of the environment are constructed from elementary sense data (Rosch 1996). While Gibson's theory remains phenomenological in nature and difficult to test (Blake 1994), many information-processing theories seek corroboration with neurophysiological evidence, in order to more completely explain the actual cognitive activities that mediate perception and response (see Marr 1982). Aside from their levels of specificity, the duality of mind and environment is the primary source of conflict between these two theories. Rather than representing irrevocable differences, the disparity between these two approaches may be reconcilable, so to suggest a more robust foundation upon which to erect a purpose-specific ergonomic theory.

7.   Bridging existing theories

The first step to be taken in bridging any two apparently disparate theories is to search for and identify any commonalties (Hancock and Parasuraman 2002). In the present case, we take one concept derived from the very earliest foundation of ecological theory and show how, in its essence, it is synonymous with one of the most recent concepts in the energetic facet of information processing. The concept from ecological psychology is the notion of the 'field of safe travel' derived from one

of Gibson's earliest published works. The energetic concept is situation awareness (SA) (Endsley 1995).

Even before his crucial work for the US military during World War II, and well before his later articulations of ecological theory (e.g. Gibson 1966, 1979), Gibson examined the real-world problem of automobile control. In typical Gibsonian fashion, he went to the very heart of the problem and, together with his colleague Crooks, produced what still remains today one of the most influential works on driving ever published (Gibson and Crooks 1938). Clearly influenced by Lewin's *Topological Psychology* (1936), Gibson and Crooks strived to articulate two fundamental concepts that dictated vehicle control. The first, the 'minimum stopping zone' represented a purely physical value derived from the kinematics and kinetics of the vehicle involved. Given sufficient knowledge of the physical environment, the minimum stopping zone of any vehicle can always be specified. However, Gibson and Crooks also articulated the notion of the 'Field of Safe Travel', and it is this conception that dominates our attention here. It is best to explain this concept in precisely the terms given by Gibson and Crooks (1938: 454). They indicated:

> Within the boundaries of the road lies, according to our hypothesis, an indefinitely bounded field which we shall name the field of safe travel. It consists, at any given moment, of the field of possible paths which the car may take unimpeded. Phenomenally, it is a sort of tongue protruding forward along the road. Its boundaries are chiefly determined by objects or features of the terrain with a negative 'valence' in perception.

This concept, that specifies a relation between the capabilities of driver and vehicle (a human–machine system) and the opportunities intrinsic to the environment, is clearly a forerunner of the later notion of affordance that represents the central pillar of the (Gibsonian) ecological position (see Nakayama 1994, Treffner 1999). The fact that, in this example, the minimum stopping zone represents the constraints on the driver–vehicle dyad, rather than the constraints on the motor response system of the unaided individual alone is immaterial to the argument. For, as Gibson and Crooks noted, driving, like flying, skating, wind-surfing etc, is only a form of aided locomotion. Thus, the 'field of safe travel' (FST) is a concept that applies in virtually any dynamic motion situation, whether the carriage of concern is that of a single human limb or a multi-passenger airliner. Our present argument uses the concept in these general terms rather than its specific driving case. We consider the general case of the 'field of safe travel' as synonymous with 'situation awareness,' a provocative but supportable assertion.

Situation awareness is a conception that has received much recent attention and has been the subject of considerable dispute (see Flach 1995, Smith and Hancock 1995). The leading figure and proponent of situation awareness is Endsley, and it is thus fair to define the concept in her terms. She indicates that:

> Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future (Endsley 1995: 36, after Endsley 1987, 1988).

Situation awareness (SA) has been a pragmatically useful construct and has followed up on a number of comparable notions such as cognitive workload, in trying to capture the energetic state of the individual. Fortunately, there have been numerous efforts to tie the notion of situation awareness to traditional

information processing components, and those efforts are likely to loom large in importance if our theoretical bridge is solid.

First and foremost, both SA and FST are identified with perceptions and interpretations from these perceptions. Both definitions present the external environment as a source where information is contained and also exerting two types of influence. The first is that ambient environments provide distinct characteristics which stand out from the rest of the surround to motivate response and generate intent; this is denoted as 'objects or features' in FST and as 'elements' in SA. Secondly, it provides a more general level of information about the actor's surrounding in terms of space and time, which is characterized in FST as 'an indefinitely bounded fielded . . . at any given moment' and as 'a volume of time and space' in the definition of SA. The two definitions are also consistent in their idea that an actor responds to the environment based upon the consequences that are expected to follow. This notion is manifest in FST as 'a negative valance' and as 'comprehension of [the] meaning [of environmental elements]' in SA. This indicates that a response to a specific feature present in the environment occurs due to both the actor's own intent drawn from hedonistic decision-making, past experience, and also due to intent conveyed through the environment for which certain types of features intrinsically enact appetitive or repelling influence. Lastly, both definitions describe anticipative reasoning or strategizing; this is indicated by the idea in FST of use of the term 'protruding forward' and by Endsley's notion of SA as applicable to 'the near future'. This notion is driven by influences from the environment and through reasoning on the part of the actor, as well as the synergy from when the parts of the actor are compatible with parts of the environment.

Thus, when we unpack each of the critical components of the definitions of FST and SA, we can see that they are essentially co-incident and this must set critiques of SA in a different light (see Flach 1995). Further, since, after these comparisons, no additional critical terms are left in either definition, these concepts, in their general expression, are essentially synonymous. If the precursor to Gibson's affordances is synonymous with SA, some might say this is merely re-discovery. However, we believe it represents something much more important than this. It is our contention that this link represents a first step along a road to a comprehensive theory of ergonomics and intention.

8.   A science of intention

Looking carefully at the definitions of each concept, we can see that they each seek to specify answers to the questions who, what, when, and where. By inference, they each address the how question through reference to any proximal technology under consideration. What each definition defaults on is 'why'. It is evident that the implied answer to the why question is linked to some general statement of intent such as the desire to get from origin to destination, but for what purpose? If the purpose is antithetical to the general good, should ergonomics support such intent? What is the compatibility between individual and collective intent using convivial and/or monopolistic tools (Illich 1973)? In essence, since purpose predicates process, process independent of purpose is mindless and, currently, our world is dominated by mindless technology. Our appeal is for a mindful technology and an integrated theory of behaviour that brings intent to the forefront. Before asking who, what, when, where, or how, the ergonomist must be the scientist who asks 'why?'

Some have analogized our relationship to burgeoning technology as a novice rides on an out-of-control mustang. If ergonomics is simply a handmaid of rampant consumerism, our greatest aspiration is akin to making sure the spurs are shiny and sharp. We are asking ergonomists not merely to evaluate the interface between man and horse but to raise its sights to consider the nature and purpose of the journey. At present, we are so taken up by simply hanging on, there are few to peruse where we are going and an even smaller number to ask why we are going in that direction. Since we believe ergonomics is the nascent form of science of intention—asking why is our primary purpose.

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