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Putting mind and body back together: A human-systems approach to the integration of the physical and cognitive dimensions of task design and operations

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ABSTRACT

As human factors and ergonomics professionals we should be considering the total context within which the person must operate when performing a task, providing a service, or using a product. We have traditionally thought of the person as having a cognitive system and a physical system and much of our scientific literature has been myopically focused on one or the other of these systems while, in general, totally ignoring the other. However, contemporary efforts have begun to recognize the rich interactions occurring between these systems that can have a profound influence on performance and dictate overall system output. In addition, modern efforts are beginning to appreciate the many interactions between the various elements of the environment that can influence the components of the human systems. The next level of sophistication in the practice of human factors and ergonomics must begin to consider the totality of the human-system behavior and performance and must consider systems design interactions which result from these collective effects. Only then will we be able to truly optimize systems for human use.

1. Introduction

What makes a human factors specialist or ergonomist different from say a physiologist, psychologist, bioengineer, kinesiologist, physical therapist, industrial engineer, product designer, or sociologist? After all, each of these respective disciplines consider the human being relative to some aspect of their environment; yet human factors and ergonomists (HF/E) professionals are different and identify themselves as unique relative to these other groups of professionals. Special professional organizational structures and scientific societies have evolved across the globe to support the intellectual pursuits of the HF/E community. Obviously they feel their needs and their focus are unique compared to each of the other cited groups and professions, although it is also clear that there is much overlap between each of these respective pursuits. Yet we still need to identify what specifically distinguishes the HF/E professional from members of these other disciplines? What special or unique services are offered by the HF/E professional that can't be provided by any of the others? What aspects of science and research are truly unique to HF/E? For example, do we still need to clarify whether we are a foundational discipline or a hybrid science? Answers to such questions are essential as we continue to further establish and justify our role in an ever-changing technical world.

One could argue that the answer to these questions is centered on the ability of the ergonomist or human factors professional to analyze and consider the human situation in context. According to the Merriam-Webster online dictionary, context is defined as the *interrelated* conditions in which something exists or occurs (environment, setting). Furthermore, the Merriam-Webster Learner's Dictionary defines context as *the situation in which something happens: the group of conditions that exist where and when something happens*. In other words HF/E professionals consider the system within which the human must operate when performing some task, whether that task is performing a mentally or physically demanding task or interacting with a new product or design. The two key concepts associated with these definitions of context are "interrelated conditions" and "situation" in which something happens. A lay element of this interaction, as we shall see is the integration of the physical and cognitive aspects of human response (see also Hancock and Diaz, 2001).

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However, as a group of professionals do we ever really consider the full complexity of all relevant interrelated conditions or more colloquially the entire situation? From the origins of our field one could argue we have not. Human Factors evolved primarily from the United States aviation efforts during World War II (Chapanis, 1999). The original focus of these efforts was related to human error in military aviation where the cognitive behavior of the pilot was the major motivation for these efforts (see, e.g., Fitts and Jones, 1947). While these efforts were eventually expanded to include dimensions such as anthropometry and strength concerns (physical ergonomics), the majority of the efforts within the U.S. have traditionally revolved around cognitive issues.

In contrast, HF/E work outside of the U.S. and particularly within Europe has evolved from physical ergonomics and especially the bases in biomechanics (Grandjean, 1980) and exercise psychology (Astrand and Rodahl, 1970). Physical work effects on the human body formed the basis for much of this effort and go back to the vey origin of Ergonomics in its earliest conceptual and implementation phase (see British Industrial Fatigue Research Board, 1922; Jastrzebowski, 1857). These efforts have also expanded over time to now embrace cognitive concerns, but here again, the majority of the HF/E efforts are still thought of as physical in nature. Around the world, this still remains the majority perspective, on Ergonomics at least (IEA, 2012), although the precise profile is evolving differentially in varying countries across the globe.

Given these continuing biases in the orientation and practice of HF/E around the globe, do we really consider the human in full context with the world around them? The systems perspective protests that human considerations must include the essential and necessary interconnection between cognition and body (see e.g., Carayon et al., 1999; Clark, 1998). Yet, the practice of our science, until perhaps the most recent decade has typically considered almost exclusively the interplay between the operator cognition and the environment or the person's physical abilities and their environment. Two sides of this quintessential triangle are ubiquitously featured but the way in which the body affects cognition and cognition itself is embodied by its very nature are patently missing from our present approach. Given the contextual distinction in the definition of our uniqueness it is then highly problematic that we consider the human in context to the situation at hand but still separate out mind (brain) and body as if they were discrete elements. In short, why do we still split our consideration of the human at the neck?

As a result of the forgoing observations we believe it is now essential that we consider the entire human system and not just individual subsystems at play. If we do not, we will always be suboptimizing our understanding. Therefore, this paper issues a specific call for our profession to move toward an integrated consideration of the entire human being in the context of the entire environmental system. In pursuit of this goal, we present a high level overview of the types of systems that must be considered in order for the HF/E community to fulfill its stated obligation and fulfill its unique attributional debt in considering the entire human-system in context.

2. The systems framework

The advantage of considering a situation via a systems framework is that one can consider, in a principled and organized manner, how all the components and subsystems of the system behave and interact (Dul et al., 2012; Vincent et al., 2012). It is only through an analysis of the systems behaviors that we can identify all the potentially significant parts and understand how these each interact to influence the system performance. It is important and gratifying to note that a more general tide toward the overall systems approach has reached and begun to impact our collective science; a trend that has been championed by a number of researchers and groups (see e.g., Carayon et al., 2013; Dul et al., 2012; Hendrick and Kleiner, 2002; Wilson et al., 2007, among others).

While we advocate for and applaud this macro-level strategy, we still have to consider manageable boundaries for effective analysis. In the human-systems context that we focus on here, we therefore consider three major components (see Fig. 1). First, the environmental context in which the person must operate should be evaluated and considered in terms of its potential influence on the human. Such environmental properties themselves range from physical sources of stress and their influences (e.g., Hancock et al., 2007; Hancock and Vasmatzidis, 1998; Szalma and Hancock, 2011) to specified physical task demands (Granata et al., 1996) to social considerations of the work environment (Leplat, 1991; Rasmussen et al., 1987). Given the origins and current foci of HF/E, the second major component involves the cognitive behavior of the human in the system. Third, is the physical behavior of the human within the system which thus comprises the final major component to be considered.

The long term goal of considering the human-system interaction should be to understand, describe and/or model the behavior of each of these interactive components and their combined effects on human perception of the environment and associated workload. We do not believe, of course, that this triad represents an exhaustive description of the wider socio-technical systems in which action occurs, since such even broader conceptions have already been articulated (see e.g., Carayon et al., 2013; Hancock, 2012) However, as our purpose here is to weld a much closer association between the physical and the cognitive dimensions of human performance in context, we are content to focus on these specific levels of description.

3. The task environment subsystem

The task environment consists of all the elements within that environment that play a role in the response of the human within that particular context. Typically, such an environmental context is formed by the profile of physical parameters but more and more it is seen as being contingent upon the cognitive appraisal of work. Humans respond according to how they interpret the conditions under which they must labor. Therefore, it is important to consider the influence of any and all environmental conditions that may

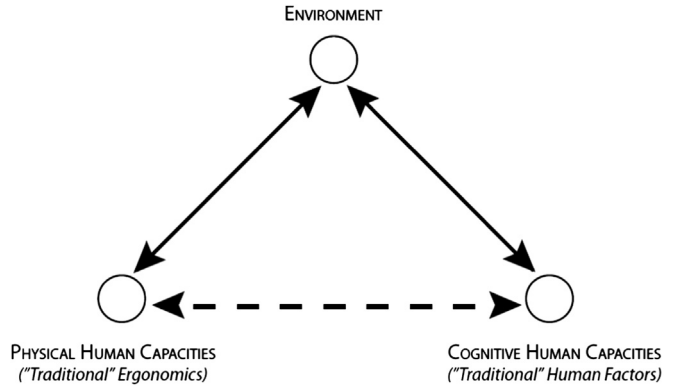

Fig. 1. Simple triadic representation of the present system linkages of concern – the strong links between physical capacities and the environment ("traditional" ergonomics) and cognitive capacities and the environment ("traditional" human factors) are contracted with the weak link (dotted line) between bodily effects on cognition and cognitive influences on physical capacities.