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What's in a name? Using terms from definitions to examine the fundamental foundation of human factors and ergonomics science

PATRICK G. DEMPSEY†*, MICHAEL S. WOGALTER‡ and PETER A. HANCOCK§

† Liberty Mutual Research Center for Safety & Health, 71 Frankland Road, Hopkinton, MA 01748, USA

‡ Department of Psychology, North Carolina State University, 640 Poe Hall, Raleigh, NC 27695-7801, USA

§ Human Factors Research Laboratory, University of Minnesota, 141 Mariucci Arena-Ops, 1901 Fourth Street SE, Minneapolis, MN 55414, USA

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A collection of words extracted from definitions of human factors/ergonomics (HF/E) were analysed to examine the foundational basis of the field. The collected terms provide a descriptive taxonomy supporting the belief that HF/E is a multi-disciplinary endeavour that involves the design and engineering of systems for human use. The importance of an inclusive definition with respect to communicating work to others is discussed, including the need for a single name capable of capturing the essence of this dynamic and human-centred field.

1. Introduction

Prior to the industrial revolution, the relationship between workers and their tools was not a fundamental concern, given the nature of craft production. Workers often used many tools and engaged in numerous and varied work tasks during the course of a day. In some cases, workers created or modified their own tools, which allowed them to adapt specific instruments to their particular needs. One example, described by Singleton (1969), is the hand scythe. The handle was adapted to fit the human requirements for performance. This is just one of many possible illustrations of tool individualization or customization that characterized the early cottage-based industry.

The industrial revolution marked the beginning of the widespread implementation of Adam Smith's principles of the division of labour. This new production philosophy changed the human relationship to tools. One profound outcome was that the worker was no longer responsible for producing an entire product with a selection of tools. Rather, tasks were divided into compound elements often requiring the use of a single tool, or a very limited selection of tools. The economic environment fostered an atmosphere that sought to drive up efficiency, thereby creating broader markets through the cost reduction benefits possible through large-scale production. Initial productivity gains were realized primarily through technological advances, especially mechanization. In the face of this overwhelming revolution, workers were forced to serve and adapt to 'new' tools and machines.

* Author for correspondence. e-mail: patrick.dempsey@libertymutual.com

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Either by training, necessity, or compulsion, individuals were subjugated to their machine tools, particularly in heavy industrial environments. Thus, there was a strong impetus to select workers to fit jobs, rather than to design jobs to fit workers.

Change in political and social perspectives and ever increasing technical complexity has slowly changed the focus of work from the machine to the human-machine interface. Whether through the recognition of medical damage to coal miners or productivity failures in cotton mills, industry began to understand the importance of worker safety and health. The notion that human performance was a key factor in further productivity gains led researchers and practitioners to focus their attention on the role of human capabilities and limitations in the production process. Jules Amar and Etienne-Jules Marey in France (Amar 1920), Hugo Münsterburg in Germany and, later, at Harvard in the US (Münsterburg 1913), the Industrial Fatigue Research Board in Great Britain, Frederick Taylor (Taylor 1911) and Frank and Lillian Gilbreth (Gilbreth 1911), as well as many others, began to lay the foundation of the fundamental principles of human performance relevant to the design and evaluation of industrial systems.

Professional societies were established, partly contingent upon the accelerated experiences of the World War II, in which cadres of individuals had served their country in mediating between military personnel and the ever more complex weapons systems. The knowledge gained during the analysis of work following the industrial revolution would form the basis of task-analytic methods for defining training requirements. There was little doubt that linkage and mediation between people and technology was of crucial import. This field took on different names such as human engineering, engineering psychology, human factors, and ergonomics. What was initially at issue were the boundaries and contents of this enterprise and, equally as important, who would it be that researched, taught, and implemented it.

In Europe, K. F. H. Murrell struggled with etymology to produce the term Ergonomics, which represented the rebirth of the term from its earlier usage in the Polish language (Jastrzebowski 1857). The Ergonomics Research Society in the UK was formed, and is the oldest professional ergonomics society. In the US, the Human Factors Society was formed (now the Human Factors and Ergonomics Society). In turn, there was a further evolution of ergonomics practice as the application venues spread to the design of items such as consumer products, as well as less tangible elements such as auditory interfaces. Future applications will undoubtedly expand the field to include new horizons as it has with digital developments including web-based entities and other innovations of the digital revolution. The growth of the field is further evidenced by the International Ergonomics Association, a federation of ergonomics societies from around the globe.

This brief introduction is not presented as a formal history of the field. Such essays have been presented in more detail elsewhere (see Meister 1999, Nickerson 1999). Rather, the authors remain concerned with the content and nomenclature of definitions as a basis for establishing the name, content, and future of the enterprise of human factors/ergonomics. Thus, this introduction provides a brief overview of how ergonomics has evolved and, potentially, the future lines along which evolution might occur. Through the elaboration and explications of a unified definition, one may be able to bring this enterprise ('ergonomics' or whatever alternative term might be chosen) to the level of recognition the authors believe it deserves.

Table 1. Example definitions of ergonomics/human factors.

Murrell (1965)
... the scientific study of the relationship between man and his working environment. In this sense, the term environment is taken to cover not only the ambient environment in which he may work but also his tools and materials, his methods of work and the organization of his work, either as an individual or within a working group. All these are related to the nature of the man himself; to his abilities, capacities and limitations. (p. xiii)

Grandjean (1980)
... is a study of man's behaviour in relation to his work. The object of this research is man at work in relation to his spatial environment ... the most important principle of ergonomics: Fitting the task to the man. Ergonomics is interdisciplinarian: it bases its theories on physiology, psychology, anthropometry, and various aspects of engineering. (p. ix)

Meister (1989)
... is the study of how humans accomplish work-related tasks in the context of human–machine system operation and how behavioural and non-behavioural variables affect that accomplishment.

Sanders and McCormick (1993)
... discovers and applies information about human behaviour, abilities, limitations, and other characteristics to the design of tools, machines, systems, task, jobs, and environments for productive, safe, comfortable, and effective human use.

Hancock (1997)
... is that branch of science which seeks to turn human–machine antagonism into human–machine synergy.

2. Methodology

In previous work (Wogalter *et al.* 1998), the authors used definitions of human factors and ergonomics that were taken from a set of definitions (from 78 sources) compiled initially by Licht *et al.* (1990). To these, definitions from another set of 56 different sources including HF/E textbooks and brochures, World Wide Web sites, and introductory psychology, industrial/organizational psychology and safety engineering textbooks were added. Definitions selected were intended to describe the field circumscribed by one or more of the following names: ergonomics, human factors, human factors engineering, or engineering psychology. Some were short, dictionary type definitions (e.g. 'the study of work' and 'human–machine interface'); others were much longer accounts giving the contents and goals of the field. Examples of such definitions are given in table 1.

A series of procedures was applied to the collective set of definitions to produce a final list of content words most frequently employed. First, the names designating the field (cited above) were deleted from the definition text, e.g. the term 'ergonomics' was deleted if it appeared as part of the definition. The terms 'human factors', 'human factors engineering', and 'engineering psychology' were also deleted when they co-occurred in these specific sequences, but the terms themselves were retained if they occurred in other word contexts and sequences (e.g. human was included in cases such as 'designing for human ...'). The definitions were further refined through removal of terms unlikely to reveal meaningful interpretation from their content or meaning. Most of these were common connector type words (e.g. and, in, the).

The purpose of the current work was to extend the work of Wogalter *et al.* (1998) by further analysis of the word list compiled. Using the remaining set of words and their frequencies extracted previously, they were grouped to permit easier extraction

of summary information. Following this, a much more concise set of terms defining the 'who', 'what', 'when/where', 'how' and 'goal' was derived from the content and frequency information. Finally, a set of sequential statements was derived from the most frequently appearing terms. These short statements can be considered concise definitions. A short empirical definition was also developed that reflected the collection of definitions studied.

3. Taxonomy

The most frequently used definition words reported by Wogalter *et al.* (1998) were grouped according to semantic similarity. In several cases, a single word category was formed from the assemblage of words with a common root word. For example, machines includes machine and machinery. The resulting semantic groupings are presented in table 2. Rather than selecting an elaborate taxonomic foundation, table 3 presents the short list of terms in categories that describe the structure of human factors/ergonomics. Finally, table 4 presents short example statements formed from some of the most frequently used terms. This was a fairly subjective process, with no particular methodology used. The statements provide examples of viable descriptions of the field. The word list can be used to tailor these or other statements to particular situations.

4. Discussion

Advancing ergonomics to a higher level of societal recognition will certainly require communication of these functions and goals to non-ergonomists. Examining the fundamental basis of the field may provide useful reference information for describing the field and the activities of its member. The goal in examining the content of a large set of definitions was undertaken as a first step towards characterizing the fundamental basis. Ultimately, this may enhance ones ability to communicate the field in a manner that leads to increased appreciation and recognition of ones work.

Although examples of ergonomics can serve a useful purpose in some situations, examples do not provide a description of ergonomics *per se*, but rather a limited view of the many potential applications. Just as explaining the effect of positive reinforcement on behaviour does not convey the whole of psychology, explaining the performance benefits of a correctly designed workstation does not convey the whole of ergonomics. Clearly, language that would unify this enterprise would serve this study well.

The current exercise provides a retrospective view of what ergonomics is, from the literature that has been created thus far. While a comprehensive view is not claimed, the number of definitions used and the frequency analysis helps to guide one towards a consensus view of the ergonomics literature. Although some will justifiably argue that other words need to be added, this particular exercise leads one to conclude that ergonomics involves the design and engineering of human–machine systems. A limitation of this statement is that it does not convey ergonomics, since clearly the goal of the design is not included. However, optimizing human performance presents a unifying goal. There are many determinants of human performance, including safety, health and productivity, among others. Defining human performance in a manner that is inclusive of the work of the members of the field provides the possibility of a definition with sufficient scope. Therefore, the definition that ergonomics is the *design and engineering of human-machine systems for the purpose of enhancing human performance* is put forth.

Table 2. Groupings of content words from definitions of human factors/ergonomics.

human	*180*	*machines*	*69*	*work*	*68*
people	*45*	*equipment*	*55*	*job*	*37*
man	*32*	*products*	*25*	*tasks*	*23*
users	*23*	technology	13	life	17
operators	11	tools	15	procedures	12
personnel	11	things	8	activities	11
beings	8	components	5	problems	8
persons	7	parts	5	aspects	6
individuals	7	devices	4	play	4
workers	7				
		limitations	*34*	*systems*	*104*
Man–machine	14	*capabilities*	*31*	groups	7
interaction	12	*characteristics*	*29*	organizations	6
integrating	8	abilities	11		
combining	4			goal	13
		using	*52*	objectives	9
environment	*58*	*performing*	*48*	aims	7
workplace	11	*operating*	*32*	accomplishment	5
industrial	9	*behaving*	*24*	purpose	5
facilities	7	used	7	intent	4
conditions	5				
places	4	*designing*	114	*efficiency*	*30*
		engineering	64	*effective*	*25*
factors	11	*psychology*	25	productivity	11
variables	8	*physical*	20	results	6
		physiology	18	effects	4
relations	25	biology	11		
relate	7	engineers	11	*science*	48
		anatomy	8	research	16
applying	*57*	medical	7	data	15
operating	*32*	anthropology	6	methods	10
improving	*20*	health	5		
developing	12	cognitive	4	*studying*	*31*
maintaining	10	designers	4	*discipline*	*28*
training	9	interdisciplinary	4	*knowledge*	*22*
requiring	9	psychosocial	4	principles	17
controlling	8			considering	16
specifying	8	errors	7	information	14
minimizing	8	accuracy	5	evaluation	12
enhancing	7			field	12
helps	6	comfort	13	measuring	8
reducing	6	satisfy	7	area	8
maximizing	4	stress	7	profession	9
selecting	5			branch	8
exploiting	4	***fitting***	*23*	focusing	8
creating	4	matching	4	experimental	7
serving	4			seeks	5
supporting	4	suitable	6	analysing	5
processing	4	acceptable	5	approach	4
				systematic	4
adapting	6			understanding	4
accommodating	5				

Terms with a frequency greater than 20 are italicized. The above list contains the entire set of content words with frequencies of 4 or greater except: new(er), 8; senses, 8; taking, 6; emphasis, 7; better, best, 5; following, 5; possible, 5; speed, 5; various, 5; attempts, 4; basis, 4; ensure, 4; only, 4; and synonymous, 4.

Table 3. Terms assigned to a simple category structure describing human factors/ergonomics.

Who	What	How	When/where	Goal
Human	system	engineering	environment	safety
people	machine	designing	work	comfort
users	equipment	applying	life	efficiency
person	product	studying		
	technology	optimizing		

Table 4. Moderate-length statements describing ergonomics formed from the most frequent terms.

(a) Designing and engineering human–machine systems.
(b) Applying science to people performing in working environments.
(c) Studying workers' limited capabilities related to safe job operation.
(d) Improving knowledge on the fit between users and tasks.
(e) The interface between people and machines in systems.

While understanding that some will not agree with this definition, it is hoped that any disagreement will encourage collegial discussions that will lead to more critical insight into just what ergonomics (or whatever it is called) is and will become. Fundamentalists may argue that ergonomics has always and should always deal with the problems of humans at work; others will insist that this view is antiquated. Some say ergonomics involves an interface with technology; others will inquire about the technological aspects of workers unloading boxes from a truck. These and other arguments may cause debates that all should be willing to contribute to.

It is also necessary to consider the importance of a single name for the field. Clearly, at this point in time, ergonomics is the most prominent and well-recognized name for the field. This does not necessarily imply that unilateral adoption of ergonomics is imminent, but it would be the most practical solution. Unfortunately, those that strongly believe that ergonomics goes beyond work may be uneasy with the 'ergo' in ergonomics. However, a less literal translation of work to include expending energy for non-employment activities is a solution. In any case, one must be clear in ones communication of what ergonomics is, and clear in ones communication when conveying what ergonomics is not or when the word is used incorrectly. An example of abuse is the term 'ergonomic injury.' What injury enhances human performance? The advantage of a nice definition is that the response could convey that ergonomics influences design in order to enhance human performance and, therefore, the use of ergonomic injury is not correct.

In a journal dedicated to the theoretical issues of ergonomics, it is important to engage in discussion of precisely what ergonomics is. It has always been found useful to consider the reverse question of what ergonomics is not. Technology is a pervasive influence in current society and technology at some level is, supposedly, directed to the betterment of humankind. The fact that people are involved in the design, the operation, or the maintenance of technologies implies ergonomics becomes a very large enterprise with ever-increasing applicational possibilities. As new technologies are developed (e.g. nanotechnology), new interfaces, new operational procedures and new maintenance processes are required and ergonomic input should be of value. As much of science and education relies on equipment and communication tools,

ergonomics has a role to play in both the discovery and transmission of knowledge. It may very well be this broad-based potential that attracts many diverse students and professionals to its study. However, as indicated, such breadth does not support the idea of definition by example, i.e. ergonomics is what ergonomists do. Thus, ergonomics needs to represent a dynamic process, not a static product. Further, as a highly interdisciplinary exercise, the definition cannot rely solely on typical content area definitions, as traditional disciplines do. In actuality, ergonomics needs to be representative of a new way of thinking of and structuring knowledge which emphasizes the dynamic and human-centred nature of such activity. Although little professional time is devoted to discussions of just what ergonomics is and is not, it is believed that there is considerable value to the field in such exercises and one hopes to foster further discussion based upon these initial ideas.

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About the authors

Patrick G. Dempsey is a Researcher at the Liberty Mutual Research Center for Safety & Health. After receiving a B.S. degree in Industrial Engineering from the State University of New York at Buffalo, he completed his M.S. and PhD degrees in Industrial Engineering at Texas Tech University. He is a member of the American Society of Biomechanics, the Ergonomics Society, the Human Factors and Ergonomics Society, and the Institute for Industrial Engineers. His current research work is focused on work-related low-back disorders and manual materials handling with an emphasis on measurement of exposure and statistical modelling of risk, and performance and biomechanical aspects of hand-tool use. His applied interests include the application of time and motion studies to industrial tasks, measuring

demands of upper-extremity intensive work, and assessing the usefulness and applicability of manual materials handling criteria in the workplace.

Michael S. Wogalter is an Associate Professor of Psychology at North Carolina State University. Before joining the faculty at NCSU, he held appointments at Rensselaer Polytechnic Institute and the University of Richmond. He has a PhD in human factors from Rice University, an M.A. in human experimental psychology from the University of South Florida and a B.A. in psychology from the University of Virginia. Most of his research focuses on hazard and risk perception, warnings, information design, complex visual and auditory displays, and applied cognitive psychology. At NCSU, he teaches courses in research methods, statistics, ergonomics, warnings and risk communication, human–computer interaction, and advanced human factors methods. He holds memberships in several professional organizations including the Human Factors and Ergonomics Society, the Ergonomics Society, Sigma Xi, APA, and APS. He is also on the editorial boards of several journals including *Human Factors*, *Ergonomics*, *Psychology and Marketing*, and *TIES*.

Peter Hancock is Professor and Director of the Human Factors Research Laboratory at the University of Minnesota. He received a Bachelors and a Masters Degree from Loughborough University in England, and a PhD from the University of Illinois at Urbana-Champaign. He is the President of the Human Factors and Ergonomics Society for the year 2000. His research interests span a broad area of human performance with a particular focus on capability in the face of extreme levels of stress. He can be reached at: peter@hfrl.umn.edu

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