Human Factors/Ergonomics

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Introduction

The convergent scientific disciplines of human factors and ergonomics (HF/E) are primarily concerned with how human beings interact with technological systems in all their various forms. HF/E has focused particularly on ways of improving the quality and safety of human work. Contemporary HF/E encompasses the imagination, design, fabrication, operation, maintenance, and decommissioning of all technical systems. To accomplish these goals, HF/E draws heavily on the theoretical and empirical bases of experimental psychology and, more recently, the neurosciences. It combines these theoretical perspectives on human behavior with the practical tenets and principles of engineering. The aim of this fusion is to optimize the conjoint abilities of humans and technological systems. HF/E is also involved with the creative processes of design as well as the affective nature of user experience. In seeking to accomplish such aims, HF/E professionals draw information from a wide variety of allied areas, ranging from ethnology and sociology through engineering, modeling and simulation, to anatomy and physiology. While HF/E has been, since its inception, a pursuit directed to the practical improvement of human life, it is important that its future should be much more central in articulating and achieving the more fundamental purposes of humankind. This article begins with a brief perusal of the history of HF/E: for, to see clearly into the future, we have to look well into the past.

A Brief History of HF/E

One can argue that, in their essence, HF/E have been around since the very inception of human tool use. When humans first shaped tools, concern about finding ways to work more efficiently was born. However, the modern scientific foundations of these areas of study began much later. 'Ergonomics' was a term first coined by the Polish scientist Jastremboswki in his treatise of 1857 entitled "*An Outline of Ergonomics or the Science of Work Based Upon the Truths Drawn from the Science of Nature*." Later, the term ergonomics would be reinvented by the English scientist Murrell, as part of the gestation of the Ergonomics Society of Great Britain, one of the oldest such scientific societies in the world. Traditionally, ergonomics as a science and practice has been associated predominantly with human interaction with physical work. Growing out of the social concerns for industrial worker safety and productivity around the turn of the twentieth century, studies in time-and-motion research and in industrial fatigue represent the earliest expressions of ergonomic concern. Today, ergonomic practitioners collaborate directly with professionals in systems safety, industrial engineering, industrial hygiene, and occupational medicine to prevent damage and injury on the job. They mutually collaborate to eliminate or reduce the adverse effects of hazardous occupational environments and poor physical work designs. Physical ergonomists work on issues such as manual handling of materials, slips and falls, and repetitive strain trauma which are the concern of agencies such as the National Institute for Occupational Safety and Health (NIOSH) in the United States, the Health and Safety Executive (HSE) in Britain, and the International Labour Organization (ILO) which is based in Switzerland. The historical antecedents of ergonomics lie largely within the countries that have emphasized the importance of safe working conditions. It is therefore no surprise that ergonomics has traditionally been considered to be of European origin. One of the classic texts '*Fitting the Task to the Man*,' for example, was produced by the Swiss scientist Etienne Grandjean. The name 'ergonomics' is retained in the title of many major scientific and professional organizations of Europe. Indeed, the name ergonomics is incorporated in many research societies worldwide, including the overall global organization, the International Ergonomics Association (IEA).

In contrast to ergonomics, the science of human factors can be considered the North American face of the same fundamental enterprise. Largely emanating from the technical difficulties that challenged the US military in the Second World War, especially the US Army Air Corps, human factors was motivated by a search for efficient and error-free operations. With its origins stemming from concerns about piloting aircraft, human factors was originally much more focused on elements of cognition than its European counterpart. Thus, a classic 1947 paper by Fitts and Jones on the origin, etiology and prevention of pilot error is emblematic of the earlier human factors' type studies in the United States. It should, however, be noted that the war had exerted the same pressures in England, and the 'Cambridge Cockpit' represents an expression of comparable concerns about cognitive performance in similarly complex military environments. This example illustrates how various aspects of the two disciplines have been inextricably interwoven over the years. A number of events and trends that followed the cessation of the hostilities of World War II conspired to initiate the emergence of human factors science. In particular, the promulgation and wide dissemination of Shannon's '*information theory*' provided a common language through which the more experimentally oriented behavioral psychologists could now interact with the more mathematically oriented engineering community. It was the presence of this *lingua franca*, as well as the tenets of emerging 'control theory,' that permitted some of the first fruitful forms of interaction at the base of human factors. Founded subsequently on the basis of advances in information theory and servomechanism theory, Norbert Weiner's invention of 'cybernetics' served to provide further valuable conceptual and quantitative basis for the generation of models of early human–machine interaction. However, the most important development along the path of convergence of HF/E was, arguably, the rise of the 'computer.' When the computational medium became the setting of activity in most modern workplaces, it represented the collapse of the most important barrier between the cognitive and the physical nature of work that had previously separated HF/E. As the byte rather than the erg became the currency of work in most 'postindustrial' circumstances, many HF/E pursuits coalesced. However, there remain many circumstances in which physical labor is still very much the dominant element of human work. In such circumstances, traditional ergonomic concerns about manual handling of materials, repetitive strain trauma, and physical workplace injuries still predominate. This is especially true in parts of Europe and indeed a number of regions across the globe, including the emerging powers of China, India, and Brazil. Overall, the increasing unity of HF/E in the developed world is now reflected in the names of the respective scientific societies, which most often use both terms in their title. Nevertheless, even in the purportedly 'developed' nations, there remain segments of the economy, both in the manufacturing and service industries, in which the physical demands of work still predominate.

The Rise of Computer Influence in HF/E

In this article, it is not possible to deal with all of the various facets of HF/E, such as workplace safety and physical ergonomics. Such issues are fully explored in several of the handbooks cited for further reading. Here, I have chosen to emphasize one major facet of HF/E evolution that deals with human interaction with automated and semiautomated systems. Indeed, the central theme that has dominated computer-mediated work in recent decades has been the removal of the human operator from the inner loop of control. Perhaps the best example of this has occurred in aviation, which was perhaps the first setting for human factors research. Aircraft control of the early years, including the World War II era, featured hands-on piloting. Indeed, the competence of an individual pilot was judged by his or her so-called 'stick and rudder' skills. Even into the era of the Apollo space flights, most advanced systems still relied upon the manual flying skills of pilots as a critical backup capacity, as the first ever moon-landing so clearly illustrated.

In HF/E, this phase of development was reflected by a strong emphasis on the motor control aspects of system operators' responses. The landmark work of Kenneth Craik, who, sadly, died in a road traffic accident, very much reflected the notion of human-in-the-loop actions. A major series of conferences that focused on these issues was even nicknamed 'Annual Manual.' It featured energetic discussions of various engineering models of operator movement responses, typified by the 'transfer function model' and the 'optimal control model.' Such research led to helpful insights, which were incorporated into the later models of operator response capacity. These are still being used by various agencies and military organizations. Despite the progress made in understanding such manual response capacities, it was not too long before the advent of computer-mediated control enabled the human operator to reduce the need for hands-on response. In commercial aviation, this development took the form of the 'automatic pilot.' Similar forms of automation were developed for many other dynamic control situations, including, for example, industrial process control. This evolution saw the human operator transition from an active, momentary controller of the system to a relatively passive supervisor, his or her requirement to interfere with the on-going processes becoming increasingly sporadic. Researchers such as Sheridan, Moray, and their colleagues revealed a hidden, but growing, problem in semiautomated control systems. That is, when systems rarely require people to respond, people will rarely respond when required. People are not good at passively monitoring systems that fail rarely. This shortcoming is reflected in the inherent problem of human vigilance or sustained attention.

Since the pioneering work of the English scientist Norman Mackworth in the late 1940s and early 1950s, we have known that human beings, in general, are rather poor at vigilance tasks. Asking individuals to monitor the repetitive actions of the more reliable automated systems is not an advisable strategy. Humans quickly get tired, bored, and fatigued in such circumstances. They end up failing to respond. This has been referred to as being 'awake at the switch,' but might be more realistically thought of as being 'asleep at the switch.' Despite this understanding, many systems are designed to take as much advantage of automation as possible. However, because all functions cannot always be automated, we see the human being employed as 'the subsystem of last resort.' Thus, vigilance tasks persist in many occupations and we see them everywhere, modern airport screening being a good example. Vigilance decrements are also very evident in the spectacular failures of many large scale semiautomated systems.

Sadly, it is a true observation that nothing has served to provide an impetus for the HF/E profession as much as the spectacular failures of large scale technical systems. Disasters that are commonly recalled today, such as the '*Chernobyl disaster*' and 'the *Bhopal gas tragedy*,' present evidence of HF/E related failures, and calls for improved HF/E applications quickly followed their occurrence. Perhaps the most famous of such events in the U.S. was the '*Three Mile Island*' accident. In March 1979, events at a nuclear power station in the Susquehanna River near Harrisburg, Pennsylvania, threatened to lead to the nightmare scenario of a nuclear explosion adjacent to a large urban area. Because of safety concerns associated with this incident, construction of nuclear power plants essentially ceased in the United States. However, with the current energy policies now favoring a return of investment in nuclear power generation, and the circulating fear of three decades ago now dissipated, HF/E has again emerged as a critical issue in the prospective safety of any new nuclear facilities. After the threat of immediate disaster had been averted at Three Mile Island, it became very clear that the critical situation had been created by a number of HF/E related failures. These included the poor design of the control room that prevented a clear representation of the state of the plant to the operators who were in charge of the plant and its complex control loops. In its essence, this was a human–machine interface problem made worse by the poorly designed rules of the operation. The impact of Three Mile Island on HF/E was crucial not only in terms of interest and the promotion of science, but also in terms of the many insightful conceptual advances that were made. One of the most profound of these was that of Perrow, whose text '*Normal Accidents*,' became an HF/E classic. The questions for HF/E were many: How should displays be created to best represent system status to the operators? How should displays be grouped so that the closely related functions appear in appropriate proximity? How do we combat the vigilance decrement? How much cognitive load should each operator be asked to sustain and for how long? What balance is needed between hard rules and spontaneity in operating procedures? These questions provided a major impetus to areas of research such as sustained attention and mental workload evaluation. Also, it created fields of study, such as ecological interface design, that form the centers of discussion in the discipline even today, as do also studies of the social dynamics of teams and the design of operating procedures.

We are still developing our understanding of human interaction with increasingly automated technology. The selfsame questions of vigilance and interface design are still being asked in more modern contexts, such as the control of multiple unmanned aerial vehicles (UAVs). Here, we see the next stage of removal from the direct control loop. The nominal 'pilot' is now not even inside the vehicle itself. In the military context, remote piloting means that the 'operator,' 'controller,' 'supervisor,' and 'pilot' (the roles begin to blur with this progressive remoteness of control) can be, and is indeed on occasion, half a world away. As some UAVs are also armed now, this individual can potentially rain down death and destruction via remote control virtually anywhere on the planet. More than HF/E design questions, this 'remoteness' from the site of action raises moral questions about the technology that we are creating and the way in which it is being used. HF/E cannot divorce itself from such ethical issues.

The most recent trends in HF/E have seen expansions and elaborations into areas of interest beyond the central core discipline. Perhaps the first of such expansions of note concerns the area of sociotechnical systems or 'macroergonomics,' as it has sometimes been called. Traditional HF/E was mainly concerned with one operator acting in conjunction with one single system, just like a single person sitting at a Personal Computer (PC). This limited identification presents useful boundary conditions for scientific study. For example, one can focus on individual cognition, one single interface (i.e., keyboard, mouse, and screen) and one overall response loop. These immediate constraints mean that the problem is bounded and, therefore, somewhat amenable to immediate problem resolution. Unfortunately, people rarely work in isolation. PCs themselves are embedded in both a physical and social context. All too often, supposed 'solutions' that can be derived in the experimental laboratory prove to be unreliable, and even irrelevant, when used in the 'real' world. The importance of the operational context was emphasized in classic works such as Ed Hutchins's '*Cognition in the Wild*' and a series of HF/E related conferences on Organizational Design and Management (ODAM). It has become clear in the decades of the eighties and nineties that the context of work (e.g., its social and environmental setting), is at least as, if not more, important as the design of interfaces or the memory capacities of a particular operational system. It may well be that this emphasis was derived from earlier European concerns for the overall work environment. In Europe, the standards bodies have had particular influence on such working conditions since the earliest days of the Industrial Fatigue Board that operated in Britain in the early years of the twentieth century. In many countries, legislation compels the use of ergonomic principles in workplace design.

In addition to the environmental context of work, there has been an increasing emphasis on the social conditions of work settings. Often, people work in teams, and the productivity of a team is contingent upon more than simply the action of each of its individual members. These emergent social properties add another layer of complexity to an already difficult study. Now it was insufficient to simply specify how, for example, the vigilance decrement might influence an operator. It became imperative to specify whether that individual was working alone or in a team setting, such as military special forces or typical industrial operators, where a team-mate might make up for any lapse. Examples such as these have led us to realize the importance of the much more complex evaluation of sociotechnical systems.

One approach to these increasing complexities was to build overall system models. Early models of this type focused on the performance of a single operator. They were often created as an assembly of modules related to the psychological dimensions of response capacity, for example, memory. The development of these models (e.g., SAINT, IMPRINT) were often funded by the military, which needs to predict the performance of servicemen and women. Such selection tools go all the way back to the very earliest efforts at intelligence testing. Other agencies such as NASA pursued their own version of these modeling efforts (e.g., MIDAS) because their particular context of performance had to be modeled in its own special detail. Although large scale sociotechnical models often have certain basic assumptions in common, in detail they tend to vary according to the particular needs of those who had the resources and the capacity to support their creation. Some HF/E modeling efforts have also derived impetus from painful system failures. Today, there are a number of such models, which are integrated with more 'micro' level models of cognition and they are used for the design, selection, and training of large numbers of individuals and systems. They continue to be refined as the empirical basis of understanding itself evolves. The degree to which they accurately portray reality continues to be strongly debated, and their application in real-world situations remains somewhat limited. However, their very formalization gives a solid basis to such disputes, a basis that is sometimes missing in other dimensions of HF/E.

In addition to reaching out to the social sciences, such as organizational design, ethnology, and sociology, one recent effort in HF/E has tried to combine the significant advances in the neurosciences with the control of technology. In HF/E, this effort has been termed neuroergonomics, which is a name first proposed by Parasuraman, a leading researcher in both realms. He defined neuroergonomics as "*the study of brain and behaviour at work*." Largely as a result of the tremendous innovations in noninvasive brain imaging techniques, we are now able to get a much more detailed and dynamic representation of the brain in action. This view provides diagnostic information that can be used as control inputs for technical systems. Perhaps the most obvious example of this type of brain–machine interface derives from the clinical efforts to provide opportunities for the handicapped, especially those who suffer from what is termed as 'locked-in' syndrome. Such individuals may have unimpaired cognitive capacities but are unable to express such acts of cognition through their own muscular system. Through the use of technologies such as EEG and imaging approaches, the electrical activity of the brain can be collected, analyzed, subjected to a degree of interpretation and then used as technology control inputs. These enable the individuals with very little or even no voluntary muscle control capacity to activate and operate mostly computer-mediated systems. It is true that at present these systems are often slow and unwieldy. However, these are communication bandwidth and interface issues. Such barriers to efficient interaction should be diminished in the near future. Similar augmented feedback designs can work equally well for unimpaired individuals. This promises an exciting avenue through which to conceive developing HF/E applications.

In these conceptions of mind–machine interfaces, the human operator is the source of intention and generates the command for action. This is then communicated to the computer, which acts as the intermediary and carries out the intended human desire by communicating that command to some other remote entity. However, this feedback loop can be run in a somewhat different fashion. If instead of a simple sequence of momentary events, that is, command, communication, interpretation, and response, we consider this channel as a more general flow of behavior and the operator as commanding the computer, those selfsame neurophysiologic signals can be used by the computer to monitor the state of the operators themselves. Let us hark back to an earlier concern about vigilance failures for an example of how this could work. Suppose that some of the brain signals being monitored by the computer could diagnose an incipient vigilance failure? The computer could then warn the individual of the failing state. Indeed, in extreme emergencies, the computer could take over the function of the operator to ensure that the overall system performed safely. It is this conception that lies at the heart of a program supported by the Defense Advanced Research Project Agency (DARPA) named AUGCOG (for Augmented Cognition). AUGCOG, a very successful program, was initially based on the principle of adaptive systems. To speculate on the future of such adaptive systems, we must delve briefly into their antecedents as human–machine symbiosis is one of the identified directions for future HF/E efforts.

The notion of mutual adaptation between human and machine runs as a general theme through the whole history of HF/E. In the earliest days, of course, the adaptation was slow and episodic. A craftsman may have made a tool to fit his own hand, but it may have been very poorly adapted to any other individual who tried to use it. In the age of mass production, standard sized tools were produced to try to accommodate as much of the population as possible. With later developments, greater ranges of users were catered to, which included the progressive inclusion of women as they entered the workforce and became an increasingly important segment of consumers. Thus, tools in general were fabricated to fit a sufficient number of individuals but for the most part, during the last century and a half, it was the human that did the adapting. This continued into modern times when early PCs were relatively slow, and both hardware and software difficult to use. The idea of static adaptation came with the notion of individualized design, and we can see bespoke products as early indicators of this form of customization. However, computational systems are much more agile and dynamic in their capacities, and so, moment to moment task adaptation was proposed by Rouse. The extension of this idea by using dynamic physiological indicators, such as heart rate and EEG to perform adaptive, on-line changes in task demand and task structure was introduced by Hancock and Chignell in the early 1980s; from these origins, the notion of dynamic, adaptive systems has developed. It was in these notions and earlier observations of augmentation in the robotic realm of the early 1960s that the idea of going beyond adaptation to human augmentation was also born. Today's opportunities found in web-based applications and hand-held portable technologies, which can access such sources of augmented support, are examples leading toward an eventual state of human–machine symbiosis. However, before I turn to a brief examination of possible future trends for HF/E, I wish to look briefly at some current issues and also at what qualifications it takes to become an HF/E professional.

Contemporary Issues in HF/E

Given that HF/E professionals are looking to improving all forms of interaction with technical systems, it is unsurprising that they are often involved with the most pressing issues of the day. One of the more recent of such concerns has centered around the problems of medical error. Unlike errors in commercial sectors such as aviation, medical error has remained largely hidden. Traditionally, the medical profession has not been associated with extensive public scrutiny of medical failures. Such failures often resulted in the injury or death of only a single individual and as road safety professionals are very aware, such events are not as newsworthy as large scale failures, such as the crash of a commercial aircraft. This relative insulation has also served to inhibit the identification of systemic failures. Each particular incident tended to be seen as the failure of an individual and not the failure of some other element, such as inadequate equipment design or procedural shortcomings. Fortunately, the recent social emphasis on understanding medical error has begun to expose these various forms of failure and now the medical profession has begun to embrace disciplines, such as HF/E, that have now served to significantly improve the record of safety. This is a solid success story, not simply for HF/E, but for the medical profession in general. Although there remains much to be accomplished, the groundswell of effort has set medicine firmly on the track of systematic improvement here.

Another issue that has experienced strong and persistent social interest is sustainability. Care for the environment, in terms of pollution reduction and recycling have begun to have impact. Whether this expression of collective social conscience can be effective within the limited time available, is an inevitable source of concern. However, here the HF/E professional can make a profound contribution. Many incidents of major pollution, for example, *Exxon Valdez*, derive from operator (human) errors expressed in error-intolerant systems. HF/E contributions to improve system safety and reliability can help address these man-made ecologic disasters. As one HF/E luminary, Nickerson, has pointed out, there are in fact very few major social issues where HF/E cannot make a significant impact. From the simple improvements of design for filtering potable water to the most complex industrial and manufacturing systems, HF/E can contribute not only to improved safety but also to enhanced productivity. One epithet used by many HF/E professionals is that "*good ergonomics is good economics*." Whether good economics is itself good, is a larger ethical issue that HF/E professionals have now begun to wrestle with. From the way in which we elect our representatives to the way we conduct war or provide aid and relief to those in need, HF/E can have a pivotal role in improving the quality of all aspects of life. It is an important and burgeoning profession.

On Being an HF/E Professional

One question that might then come to mind is where those in HF/E come from and how one might join such a profession. The answer to this question is that HF/E professionals come from a wide variety of backgrounds. This fact is evident as one looks through the membership roles of many of the professional societies. The majority of professionals in HF/E possess a background in either experimental/applied psychology or in industrial engineering. Formal programs of study are usually found in such departments in the major universities that teach HF/E in the United States. In Europe, Australia, and Japan also, this is often the case, but around the world, the parent Departments in which HF/E can be found tend to be more diverse. Although any professional can graduate in HF/E or some formally related discipline, there are always a significant proportion of people in HF/E, who have followed programs of study beyond these traditional core disciplines. For example, many from the medical sciences are involved, especially in ergonomics. The formal study of kinesiology also frequently provides a strong base from which to begin a professional career in HF/E. Thus, students of biomechanics can easily apply their knowledge and skills in the field of occupational ergonomics, and graduates in motor control have much of the foundational knowledge of skill development and operator performance assessment. More recently, those studying computer science with a particular focus on interface design and development have entered the field, through concern for usability and specific interest in related fields, such as serious games design. Also, many modeling and simulation graduates specialize in aspects of applied HF/E. Consequently, although there are a number of accepted paths, many diverse avenues of interest can eventually lead to a career in HF/E. Finally, HF/E has a strong and persisting link with Industrial Design. The diversity in the backgrounds of HF/E professionals has led to many debates about the core competencies and professional accreditation of those in HF/E. Indeed, there are a number of such accrediting bodies in existence. However, contentions over the inclusion of diversity while retaining the basic professional standards are issues that have still to be fully resolved in HF/E.

Future Concerns of HF/E

Kenneth Oakley's wonderful text of the mid-twentieth century '*Man the Tool-Maker*' emphasized the crucial relationship between early humans and their tools. Today, we might extend this vision to suggest that, perhaps, it was not humans who created tools, but rather the tools themselves that served as one of the crucial factors that helped differentiate the human species from all others. However, the idea of tools cannot be confined to their physical representation alone. Indeed, nonphysical tools such as language and mathematics have been just as influential in human progress, if not more so. Alongside the progressive evolution of all forms of tools, there has been a comparable evolution in interfaces. Interfaces provide the link between human and tool. Interfaces have also evolved across the ages. Interface evolution represents the growth in the level of intimacy between humans and technology.

For many millennia, we have lived in an active and progressively more symbiotic relationship with our tools. Now, in our own times, the tools are starting to invade our physical being. As we go about our daily activities, we carry many of our essential technologies in our pockets. One can scare people by threatening to take their 'Blackberry' from them. (For those who are reading this in the future, a Blackberry was a form of portable wireless device, which no doubt will soon seem dated, but descriptions of it, will be able to be accessed by existing computer database search engines.) Our current support tools are portable because of the development of microelectronics and the now almost ubiquitous wireless access across the globe. Much of the present size of portable technologies is actually dictated by the need for an interface to have a visible and usable screen, as well as an input device such as a mouse or a keyboard. These interface elements are still at the 'slow and clunky' stage compared to the actual information processing capacities of the devices themselves. But we are starting to do more than simply transport our technologies in our pockets. For example, with devices such as cochlear implants and heart pacemakers, technology is slowly becoming indwelling, within the body itself.

Internal devices, such as pacemakers, act as medical support technologies to help those suffering from disease and injury, or to compensate for inherent problems. Recently, there has been a significant increase in the number of implanted devices for damage mitigation and the amelioration of disease effects. While these are used as forms of function restoration, there is no barrier to their being employed as forms of functional enhancement. My automobile contains a device to provide an automated alarm, if there is an attempt to steal it. My dog has an implanted device to identify his owner, in case he is lost. It will not be long before we have technologies introduced into normal human beings to provide similar capacity enhancement. Devices will literally become a part of us. The future promises a much more radical increase in this form of physical and indeed cognitive intimacy. As the symbiosis between humans and tools is perfected, therefore, interfaces will become not merely transparent but, eventually, like the smile of the Cheshire Cat, they will disappear altogether. We shall have reached true symbiosis when our interfaces with our technology have become completely invisible. These are the optimistic upsides of technological innovation. However, there is a potential downside. For example, greater technological sophistication can mean greater vulnerability. Thus, if we lose the capability to manufacture such devices or the ability to produce energy dense power supplies, either through large scale natural disasters or even man-made global disasters, our highly interdependent technical world could collapse easily, so much so that we would then envy even the ancient artisan and his 'primitive' survival capacities.

Such developments concerning our ineradicable intimacy with technology will be the subject of much social discussion about issues of privacy, personhood, etc. However, the current state of technology certainly permits such innovation, and there are very few examples of situations in which a technology once invented is intentionally not implemented somewhere in the world. These types of development will begin to force us to ask questions about what it is to be human. For example, where does an individual end? For instance, in education, we test individuals on their memory of learned material, but when memory can be extended by many orders of magnitude by access to distal storage facilities, why are we testing the individual's unaided capacities? Presently, we do not let students use web-access laptops into standardized test examinations. However, will we be able to prevent such access when the individual has an indwelling chip? Indeed, would we want to? This is just one simple example of the possibility of physical extensions of individual human capacities with the bodily insertion of technological support. But the next stage of evolution promises to go well beyond this.

As the physical and cognitive barriers between humans and technologies begin to crumble, we begin to reach what Kurzweil has called the '*singularity*' or in De Chardin's prior conceptualization – the '*omega point*.' Here, the very nature of consciousness promises to evolve to a following stage of development. When and how those barriers are overcome will have a direct effect upon the nature of this emergent consciousness, and so a direct influence on who and what human beings will turn into. Thus, the purpose of the process will dictate the process of the purpose. The science at the heart of that transition is HF/E.

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Relevant Websites

www.hfes.org – Human Factors and Ergonomics Society.
http://www.ergonomics.org.uk/ – Institute of Ergonomics and Human Factors.
http://www.iea.cc/ – International Ergonomics Association.
http://www.bcpe.org/ – Board of Certification in Professional Ergonomics.
http://www.ergonomics.jp/e_index.html – Japan Ergonomics Society (English version).
http://www.ergonomics.com.au/pages/200_sitemap.htm – Ergonomics in Australia.
http://www.fees-network.org/ – Federation of European Ergonomics Societies.
http://www.ergonomia-polska.com/ – Polish Ergonomics Society.
http://www.apa.org/about/division/div21.aspx – American Psychological Society – Division 21: Applied Experimental and Engineering Psychology.